LOUGHBOROUGH DESIGN SCHOOL

Exploring the Use of a Virtual Reality Learning Environment to Support Innovation Education in Iceland

by

GISLI THORSTEINSSON

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Exploring the Use of a Virtual Reality Learning Environment to Support Innovation Education in Iceland.

Abstract

Innovation Education (IE) in Iceland aims to train students to identify needs and problems in their environment and to find solutions: this is referred to as the process of ideation. The thesis explores the contexts of teaching and learning, incorporating the VRLE with IE to support the students' work. There is a focus on blended learning, as the VRLE is used in conjunction with conventional classroom-based activity.

The work employed the grounded theory (Glaser and Strauss, 1967) perspective, in order to observe the complex social/educational activity relating to this real-life learning context. It was intended to build understanding (grounded theory), rather than an attempt to establish cause and effect. The author intended to observe, describe and interpret settings as sources of data and the main aim was to gain a greater understanding of the use of the VRLE in supporting students work in conventional Innovation Education classes within Icelandic schools.

The overall research question was: 'How does the use of the VRLE affect teacher's pedagogy and the students' work, in conventional Innovation Education in Iceland?'

Research tools and multiple data sources were selected, in order to gather triangulated data. Specifically, a series of case studies were employed in an Icelandic elementary school, featuring groups of volunteers from the seventh class (age 12).

The main findings highlighted the significant categories and issues relating to the impact of the VRLE on the contexts of teaching and learning, which were:

1. The teacher and his approach to his work;
2. The use of homework;
3. Use of the VRLE;
4. Innovation Education and idea generation;
5. Drawing;
6. Values.

The findings indicated that a teacher's approach to his work is significant; he must be able to alternate between various roles during lessons. Such roles include computer administrator, instructor and a facilitator, in encouraging students to become self-sufficient and autonomous. The students' homework enabled them to generate the content of the course and make meaning of their work, while the VRLE facilitated students' collaboration and co-operation during ideation work. Training students in the use of the CAD programme, drawing and the VRLE appeared to be important in enabling their ideation work. However, the students also learned through their own practice.

The research's main contribution to knowledge is the understanding of the contexts of teaching and learning, in terms of the use of the VRLE in developing students' ideation in IE. Furthermore, it contributes to the knowledge of the practical use of IE in education. The work is an exemplar of a qualitative approach based on case study methodology and grounded theory, within an Innovation Educational context.

Key words: Innovation Education, Virtual Reality Learning Environment, grounded theory, ideation, ideation process, teacher's pedagogy, students' learning.

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List of Publications Relating to the Research

Thorsteinsson, G. (2002) Innovation and Practical Use of Knowledge. In: (Ed.) Norman, E.W.L. (Ed) DATA International Research and UK Education Conference book, 2002, pp. 171-177. Wellesbourne: *The Design and Technology Association*.

Thorsteinsson, G. & Denton, H. (2003) The Development of Innovation Education in Iceland: a Pathway to Modern Pedagogy and Potential Value in the UK. *The Journal of Design and Technology Education*, Vol. 8, No. 3, pp. 172-179.

Thorsteinsson, G., Lehtonen, M., Page, T. & Ruokamo, H. (2005) A Virtual Learning Environment for the Support of Teaching, Studying and Learning in Technology Education (Winner of best paper prize). Proceedings of Fourth IASTED International Conference on Web-based Education. Dr Vladimir Uskov (Ed), *ACTA Press,* WBE 2005, Grindelwald, Switzerland, February, pp 109-118, ISBN: 0-88968-480-2.

Thorsteinsson, G. & Denton, H.G. (2006) Ideation in a Virtual Learning Environment: A Pilot Project in Innovation Education from Iceland. In Norman, E.W.L., Spendlove, D. & Owen-Jackson, G. (Eds). The Design and Technology Association International Research Conference Book 2006*.* Telford, July 2006, pp.155-164, Wellesbourne: *The Design and Technology Association.*

Thorsteinsson, G. & Denton, H. (2007) A Discussion of Constructivist Learning in Relation to the.Development of Ideation Using a Virtual Reality Learning Environment for Innovation Education in Iceland. In Denton, H. & Twidle, J. (Eds). IDATER 07: International Conference on Design and Technology Educational Research and Curriculum Development, *Loughborough University.*

Thorsteinsson, G. & Denton, H.G. (2008) Developing an Understanding of the Pedagogy of Using a Virtual Reality Learning Environment (VRLE) to support Innovation Education (IE) in Iceland: a Literature Survey. *Design and Technology Education: an International Journal*, Vol. 13, No. 2, pp.15-26, ISBN 1360-1431.

Thorsteinsson, G. (2009) Co-operative Learning in a Virtual Reality Environment (VRE), Through Idea Generation: A Pilot Study from Iceland. In Norman, E.W.L. & Spendlove, D. (Eds). The Design and Technology Association Education and International Conference Book, 2009, The D&T - A Platform for Success*,* Loughborough University, p.115, Wellesbourne: *The Design and Technology Association.*

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Chapter 1. Prologue and Background

1.0 Chapter Summary

This chapter presents the rationale of the thesis, explaining the origin, purpose and nature of the research, and introduces the background and basic terms of the research. The study originates from the Icelandic school subject Innovation Education (IE), a new Virtual Reality Learning Environment (VRLE) designed to support student ideation (see section 2.10.4) and the pedagogy relating to these. The purpose of the research is the need to explore and understand this new learning and teaching context and the author's expectations are presented, with regards to his contribution to knowledge and theory. The limits of the research are explained and, finally, the research and thesis structure are outlined.

1.1 Introduction

Innovation Education (IE) originated in Iceland in 1991 (see section 2.4.2). It was developed within design and craft lessons and was closely linked to the principles of Nordic Sloyd (see section 2.4), in that it also aimed to educate children holistically, via a carefully structured system (see section 2.4.1). In the case of Sloyd, such a carefully structured system was handicraft and, with regards to IE, the system refers to ideation skills (see section 2.3.3) within the context of innovation (see section 2.3.2). IE focused on the conceptual work of students, searching for needs and problems in their own environments, generating appropriate solutions or applying and developing known solutions (Thorsteinsson & Denton, 2003; Gunnarsdottir, 2001a). While IE had its roots in design and craft, it was aimed at general education and, in 1999, IE was developed into a new subject within the Icelandic National Curriculum (1999). In 2006, it became a cross-curricular element of the National Curriculum (2006).

At this time, the author was a teacher in Icelandic schools and became a member of the steering committee for IE (see section 2.4.2). In 1996, he joined the Iceland University of Education and continued to work in IE, on projects such as the three-year EU funded *Practical use of Information Technology (IT)* and *Open and Distance Learning (ODL) in Innovation Education* (InnoEd, 2011). These projects combined computer-based technologies and ODL with original IE concepts, in order to develop new ways of supporting student ideation work in IE classes. A major output of the *InnoEd* project was the development of a specific 'Virtual Reality Learning

Environment' (VRLE), in which students could communicate, interact, develop and host their Innovation Education work within a rolling virtual exhibition/competition.

As the relationship between the VRLE and the IE process was new and potentially complex (see section 2.5.3), the author identified the need to research student work and teaching approaches (pedagogy)[1] relating to this context and existing learning theories (see chapters 2.0 and 10.0). The curriculum development work moved into the research phase, as the author registered for a higher degree by research. He began to read around the context and identified research strategies and methodologies appropriate for exploring and describing the issues relating to the new learning and teaching context. This built on the work of Gunnarsdottir (2001a & section 2.6.1), who outlined the pedagogy for early IE work, prior to the introduction of the VRLE (Gunnarsdottir, 2001a; Thorsteinsson, 1998).

1.2 Ideation and its Role in Building Innovativeness through General Education

The main emphasis of the pedagogy of IE is to make students better equipped to deal with their world and take an active part in society through innovation (Gunnarsdottir, 2001a; Thorsteinsson & Denton, 2003). The ideational skills developed during IE aim to encourage this aspect of students' development and thus strengthen the ability of future societies, in terms of innovation and development (The Ministry of Education, 1999).

In IE, students are introduced to a process of innovation that focuses on the 'front-end' of the design process; i.e., problem and need identification, initial concept generation, the development of basic solutions using simple models (see section 2.5.3) and descriptions with images or multimedia content (Thorsteinsson & Denton, 2003) (ideation skills are central to the formation of ideas in this process). The Icelandic National Curriculum takes the position that everyone can be innovative and that it is possible to introduce classroom activities that develop ideation. Innovation Education is integrated into regular ordinary schoolwork and taught by non-specialist teachers, who aim to:

[1] Pedagogy: Is the art and science of how something is taught and how students learn it. Pedagogy includes how teaching occurs, the approach to teaching and learning, how content is delivered and what the students learn as a result of the process. In some cases, pedagogy is applied to children and andragogy to adults; however, pedagogy is commonly used in reference to any aspect of teaching and learning in any classroom (SLO terminology glossary, 2010). The term is used in the thesis in accordance with normal usage in Scandinavian/Nordic educational contexts, as the science, art, theory and practice of teaching and learning.

1. Stimulate and develop innovativeness in students and teach them certain approaches and processes, from concept through to realisation;
2. Teach individuals to be innovative in daily life, so that they become better equipped to adapt their environment;
3. Encourage and develop students' initiative and strengthen their self-image;
4. Make students aware of the ethical values of 'objects', while teaching ways in which to improve their environment (Thorsteinsson, 1998:143).

1.3 Using a VRLE to Support Innovation Education

The original idea behind the VRLE was to find a new way of supporting students' ideation work, using information and computer technology (Thorsteinsson et al., 2005, section 2.10.4). The specific VRLE was designed to enhance ideation via collaborative learning support and thus offers individual and social educational opportunities. The main output of the project was an online VRLE, linked to a database: this VRLE was developed as a combination of the managed learning environment (MLE) and the virtual reality environment (VRE). The MLE provided the framework for teachers to manage student learning, while the VRE provided a simple virtual environment that enabled students to meet and communicate through a number of means, such as voice, text, drawings, photographs and presentations. The database enabled these ideas to be shared and recorded and these, as a whole, represented the VRLE.

The VRLE is potentially a tool for experiential learning, as it provides various dynamic and rapid ways to see, experience and generate ideas and information. The VRLE can be used as a tool for problem solving and communicating ideas and includes the possibility of promoting a high degree of interactivity and immersion (Ogle, 2002; Bricken, 1991; Johnson et al., 2002; Jonassen, 1999; McLellan, 1995; Winn, Windschiti & Thomson-Bulldis, 1999; Osberg, 1993). The VRLE is interactive in two ways: firstly, a user interacts with data in the database within the VRLE and also beyond; for example, via the World Wide Web (www). Secondly, it allows the interaction of a number of students and staff within the VRLE, using a range of modes including speech, drawing and writing. Students could be from the same class or in other schools or countries, accessing the VRLE via the www.

Using the VRLE within the classroom context offers multi-modal communication through the Internet to the world outside and this would be expected to influence students' learning experiences (see figure 1.1).

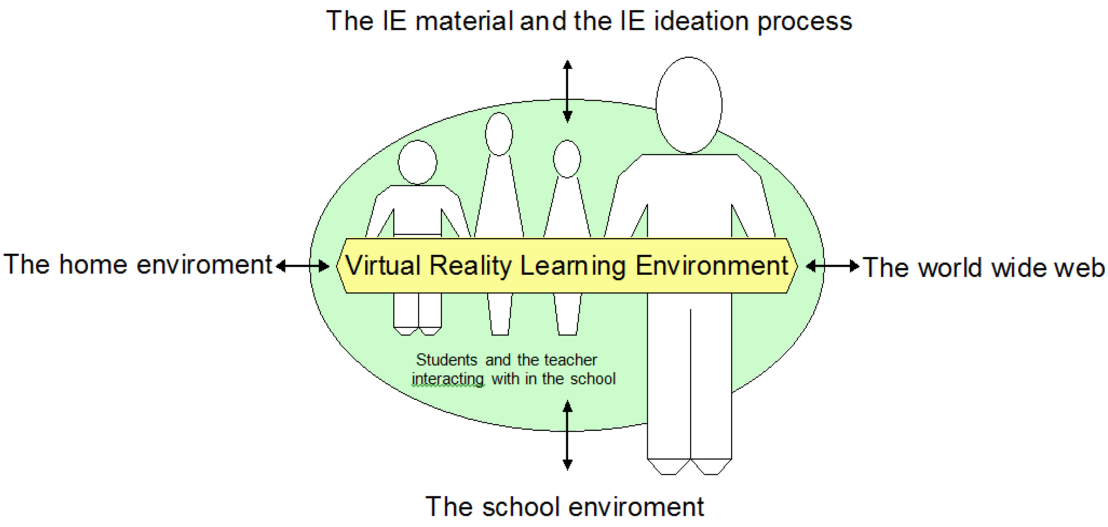

Figure 1.1: The VRLE offers different dimensions of communication.

1.4 Virtual Reality Learning Environment Opportunities

The VRLE was based on issues demonstrated in Gunnardottir's model (see section 1.5) and the author's initial model for ideation within IE (Thorsteinsson & Denton, 2003). Gunnarsdottir's model employed conventional classroom methods of learning, but the author's model (1.6) demonstrates the way in which IE students work through the innovation process, using both conventional modes of interaction (IE as classroom based) and modes supported by the VRLE, including idea recording and development.

Extraneous interruptions while using the VRLE are avoided by the use of a user name and password (it is important to prevent anyone interfering with the scaffolding of the lesson for malicious reasons). As before, the student brings needs and problems (see section 2.5.3) identified at home into the school and works there, supported by the VRLE. They can also take part in the Icelandic Young Inventors Competition by sending their ideas directly from the VRLE to the competition.

The main reasons for students using the VRLE in IE classes were:

- To offer another mode of working together, in terms of ideas, sharing problems, solving such problems and developing solutions;
- To enable students to meet each other and their teacher online;

- To facilitate easy communication inside virtual 3D spaces, where students and teachers could meet in real time, share information and work together with ideas;
- To provide the opportunity to develop certain skills within the innovation process (i.e., brainstorming, drawing and discussion);
- To allow students the opportunity to give online presentations;
- To set up virtual exhibitions;
- To enable virtual meetings between participants.

1.5 Gunnardottir's Pedagogical Model for IE

Gunnarsdottir (2001a) gained an understanding of how students learnt in IE classes prior to the introduction of the VRLE. She looked at how students learned through their social activities during ideation in IE and put forward a pedagogical model of teaching and learning in *Innovation Education* (Gunnarsdottir, 2001a).

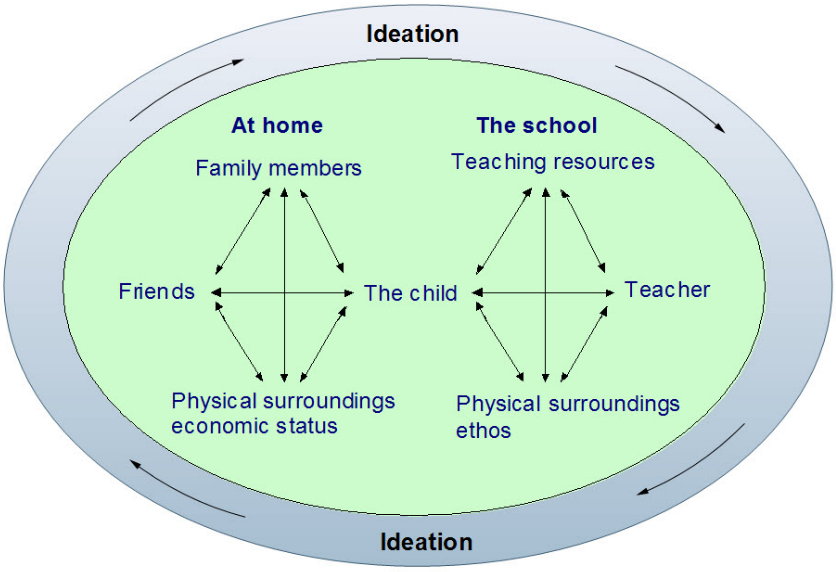

Figure 1.2: Gunnarsdottir's model shows the interaction between a student's home life and ideation during IE classes and illustrates the relationship between the two.

Gunnarsdottir's research concluded that the IE paradigm is related to social constructivism (Edwards, 2001), and this is supported by the work of Dewey, Piaget and Vygotsky (see section 2.13.1). The research is based upon the theory that new knowledge is an active product of the learner integrating prior knowledge with new information and perceptions. Social constructivists study how people use social activities to change their conditions of existence and their self-image (Shotter, 1993:111; section 2.13.1.3) and Gunnarsdottir uses social constructivist theories to explain how individuals become active participants in the culture that surrounds them, both inside and outside school (Edwards, 2001). She demonstrates the extent to which a high degree of learner autonomy and limited direct instruction by the teacher can be indicative of *Vygotsky's Zone of Proximal Development* (Vygotsky, 1978 and defined in section 2.13.1.2).

Gunnarsdottir (2001a) informed how, through the IE process, students employ ideation skills and prior knowledge to suggest solutions and build their self-image as innovators. In IE lessons, students have access to support from others and this significantly moulds the contents and working methods of IE learning. They also employ their teachers as one of several types of resource and develop the capacity to produce new knowledge (Edwards, 2001). The role of the IE teacher is to create circumstances that support or scaffold students' learning and to be one of a number of sources of information that facilitate the activity of students (Gunnarsdottir, 2001a).

1.6 The Author's Initial Pedagogical Model for IE

Based on Gunnardottir's work (2001a) and the author's description of the innovation process in IE, the author put forward an initial model for IE (Thorsteinsson & Denton, 2003; also see chapter 2.0 and figure 1.3). This illustrates the way students work through the innovation process in Innovation Education classes and is based on a series of steps, iterations and relationships, with the overlying direction leading from 'finding needs' to 'presentation of solutions'. Students employ ideational skills at all stages and learn through the innovation process within the overall IE pedagogical framework (The Ministry of Education, 1999 and 2006). In the model, students learn through the innovation process within the overall IE pedagogical framework, which is managed by the teacher. The process is as follows (see more details in section 2.5.3):

1. Finding needs;
2. Brainstorming;
3. Creating and choosing initial solutions;
4. Concept drawing or modelling, in order to develop the technical solution;
5. Creating a description of the solution, in addition to the drawing;
6. Presentation.

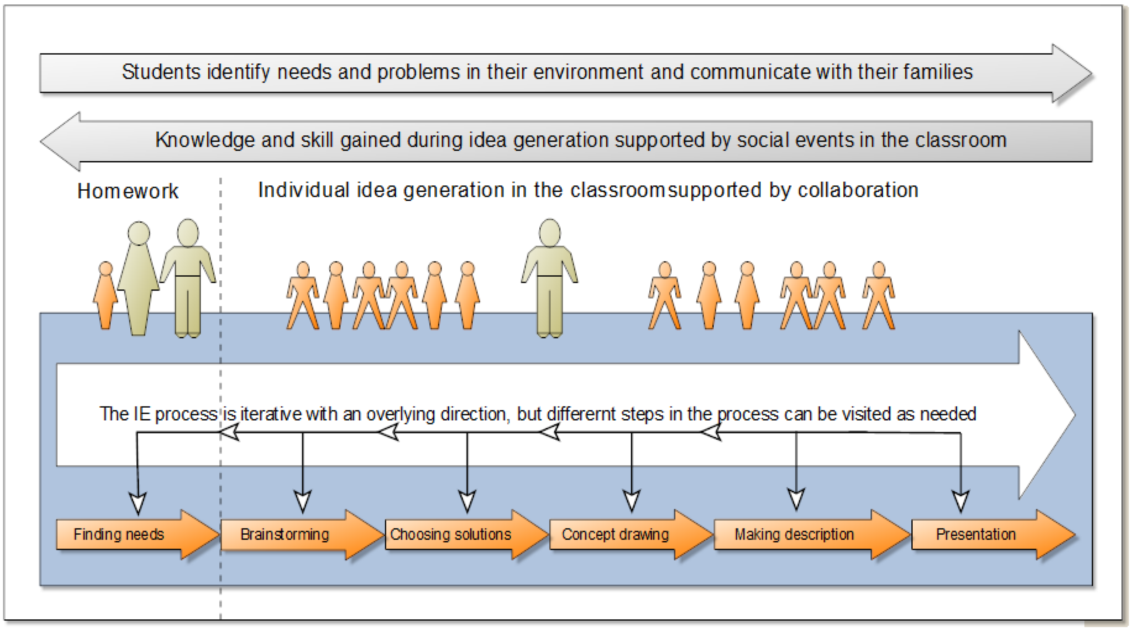

Figure 1.3: The basic pedagogical model of the IE innovation process. The model illustrates innovation as a 'process', with appropriate feedback loops and options.

1.7 Innovation and Practical Use of Knowledge

The pedagogical framework for IE is now part of the Icelandic National Curriculum, under the term '*Innovation and Practical Use of Knowledge*' (The Ministry of Education, 1999). This is a set of broad principles (not classroom actions) that guide plans and actions implemented by teachers.

IE is intended to be a framework for the teaching of ideation skills and thus aims to increase students' innovativeness (see also section 1.2). In Innovation Education, students seek solutions to real world problems: they propose solutions at a conceptual level and research the knowledge that is needed to develop the solution. As the students engage in the process of innovation, gaps in their knowledge emerge and they find it necessary to research and gain appropriate knowledge, in terms of the particular innovation process they are involved in. This process is paramount, as subject knowledge develops accordingly. As students acquire increased knowledge and experience of ideation work, they can employ this in new contexts (The Icelandic National Curriculum, 1999). The resulting effort can be seen across the curriculum, as individuals rely on critical knowledge and information from different sources in searching for viable solutions, and the emphasis is to train students to produce valuable and practical results of their knowledge through innovative work (The Icelandic National Curriculum, 1999). Innovation work can take place within all school courses and can be seen as the formation and development of human knowledge at all levels of education (Thorsteinsson, 2002).

Innovation Education is intended to strengthen an individual's innovative and independent thinking, together with the ability to respond to a new situation. As the Ministry of Education asserted: 'In today's ever-changing environment, what individuals need is the ability to respond to new situations, rise to challenges and exploit innovations and advances in all areas' (2011:19).

1.8 The Focus and Aims of the Research Project

Computer technologies and the Internet are now an everyday part of students' lives and are arguably becoming the preferred mode of both communication and the collection of information (Hennessey & Deaney, 2004; Passey et al., 2004). As the use of the VRLE for IE was new and the learning and teaching context complex and dynamic, the focus became the exploration of the use of the VRLE to support student ideation work and the pedagogy developed within the context of IE in Iceland (see section 2.5). The intention was to identify the issues involved, to use literature and fieldwork to understand how these issues were related and, eventually, to be able to prepare a map of directions for further research.

While the VRLE has the potential to enable open and distance learning in IE work, in terms of co-operation between students and teachers across continents, it was decided that this would be too large a dimension for this research. Thus, the focus is on the use of the VRLE within the conventional classroom context, as a logical precursor to future work and looking at ODL work.

The main aim of the project is:
To explicate the pedagogy of using the Virtual Reality Learning Environment (VRLE) to support conventional Innovation Education within Icelandic schools.

The main objectives of the research are:

a) *Identifying the required pedagogy, in terms of using the VRLE within the specified context.*
b) *Demonstrating an IE pedagogical model, in terms of supporting the VRLE.*
c) *Describing students' ideation when using the VRLE.*
d) *Evaluating the students' ability to draw inside the VRLE.*

e) *Recognising the value of using the VRLE in IE.*
f) *The provision of indications that may enable further research.*

The following overall research question was thus formed to guide the research: *‘How does the use of the VRLE affect teacher’s pedagogy and student work in conventional Innovation Education in Iceland?’*

1.9 Contribution to Knowledge

The author expects to contribute to academic knowledge, in terms of the understanding of the use of the VRLE within Innovation Education (specifically, the development of student ideation skills and teachers’ pedagogy).

1.10 Theoretical Input

The research is based on the principles of grounded theory (Glaser & Strauss, 1967). In terms of this, the author acknowledges the weaknesses of the project (see chapter 3.0), due to the limited time and resources available. However, following Glaser’s work, this thesis places the work in the public domain, where it can contribute to the development of grounded theory within this area. The project contributes to the academic discussion of the pedagogy of using ICT in school education. Furthermore, it contributes to the field of using a new teaching and learning technology within this specific context. The thesis also contributes to the ongoing pedagogical discussions of Innovation Education and Entrepreneurship Education.

1.11 Limits of the Research

The most significant limit of the research is the specific context: it only applies to the Icelandic educational system and, necessarily, to small fieldwork samples in unique, complex and dynamic contexts. Nevertheless, if handled effectively, such approaches can add to knowledge and have been used in many research projects; for example, Thomas (2008), Bricken & Byrne (1993) and Heinze (2008).

The research focused on building up a general understanding of the teaching and learning strategies appropriate for use in the VRLE, in terms of students’ ideation work in IE. Furthermore, the research looked at IE within a conventional classroom context, rather than at open and distance learning; this would be a logical continuity of such research.

A significant problem in researching this area is the use of different terms such as *creativity, pedagogy, innovation* and *ideation*, as these terms are used in different contexts. The majority of research studies relating to ideation have been based on controlled laboratory experiments that measure or improve ideation (Hender et al., 2001; Shah et al., 2003; Malaga, 1999; Dormann & Lindgaard, 2004; Bakki & Pinsonneault, 2001; Sosik et al., 1998; Kramer et al., 1997; Tatcher, 2001; Bostrom & Nagasunarum, 1998). In this research, no attempt is made to specifically measure the levels of ideation based on the approaches described in the literature: this is because this would be a very significant task, beyond what could be achieved within the context of this work.

The InnoEd project began in Iceland but has since extended into several European countries and thus the educational context has become multinational and multicultural (Innoed, 2011). Nevertheless, it was necessary to limit the cultural context of this project and so the author decided to focus on the Icelandic element and a fairly limited student age range. An exploration of the IE model in other countries would be a natural development of this project. Further research may focus on the VRLE used for collaborative learning within open and distance education.

The specific software used in this project is a low-cost, desktop-based VRLE. This makes it easy for schools and students to use their computers, as it has minimal hardware requirements. The specific VRE element of the VRLE gives both students and teachers the opportunity to communicate ideas using avatars (see section 2.10.4). However, the level of the students' immersion is limited, compared with using an immersive 3D interface based on body-mounted devices (Ogle, 2002). The InnoEd VRLE is not used with interface devices, such as head-mounted displays, fibre-optic wired gloves, position-tracking devices or audio systems providing three-dimensional sound.

In the VRE, students use a combination of keyboard and mouse. With the desktop-based VRLE, the user 'sees' with the VRE element through the 'window' of the computer screen and they can navigate through the 3D world, using the mouse as the control device (see section 2.10.4). However, a user does not have to be entirely immersed in a virtual world to travel through it and a desktop-based interface can provide an enriching personal experience. By using simple interface technologies, the VRLE is more broadly available to users in schools and at home and is generally well understood by these users via their knowledge of computer games, which employ similar control devices. It may even enable the user to learn more through the computer screen than in the real world (Taubes, 1994b).

1.12 Developing the Use of the Research Methodology

As the research took place in a complex social/educational context, grounded theory (Glaser and Strauss, 1967) principles were used as a way of observing, describing and interpreting settings as sources of data (grounded theory is a principle based on the systematic building of theory, using qualitative or/and quantitative data). The key points in the data are marked with a series of codes, which are then grouped into emerging conceptual categories. These categories are related to each other as a theoretical explanation of the action(s) that continually resolve the main concerns of the participants within a substantive area (Denzin & Lincoln, 1994; chapter 3.0).

Grounded theory focuses on obtaining an abstract analytical schema of a phenomenon that relates to a particular situation (Creswell, 1998). However, Strauss & Corbin (1998) explicitly pointed out that the value of grounded theory lies in its ability not only to generate the theory, but also to ground that theory in data. This inductive method is particularly helpful in identifying patterns of behaviour or thought in a particular group of people, as in this study.

Further reading on the principles of grounded theory and specific research methods appropriate to this educational context (Glaser & Strauss, 1967; Cohen et al., 2005) lead to the design of a programme of case studies intended to explore the research question. Three case studies were undertaken, each based on a programme of lessons, and these were used iteratively, in that a period of analysis and reflection followed each case study and led into the next. An action research phase was used to aid the teacher and the students. Issues were identified and tested, in terms of the use of the VRLE within IE.

Specific techniques used for data collection included interviewing, observations and document analysis. The use of different data sources helped the researcher to 'validate and crosscheck findings' (Patton, 1990:244). In the case study series, different types of qualitative data were collected in the form of interviews with the participating teacher and students; classroom observations; video recordings of students' activity when using the VRLE; screen video recordings; student work samples and the teacher's and researcher's logbooks (see chapter 3.0). These multiple perspectives offered a good degree of triangulation (Denzin, 1984; Cohen et al., 2005; chapter 3.0).

The three case study series took place in an Icelandic elementary school in west Iceland that was running classes for six to sixteen-year-old students (various groups of volunteers, from the seventh class onwards, took part in the research). The case study series were independent but interrelated through an iterative process and therefore were reported sequentially. They demonstrate how understanding is built up throughout the research and how the use of the methodology is developed.

Case study series	Time	School	Teacher	Students
One	Autumn 2002	Grundarskoli	Teacher	Age 12 /mixed gender
Two	Spring 2003	Grundarskoli	Same teacher	Age 12/ mixed gender
Three	Summer 2004	Grundarskoli	Same teacher	Age 12 / mixed gender

Table 1.1: Case study series

1.12.1 A Pre-Pilot Study (see chapter 4.0)

A pre-pilot and background survey helped to formulate the subsequent pilot study. This enabled the author to establish a research direction that grew into a series of scoping case studies.

1.12.2 A Pilot Study (see chapter 5.0)

The case study series consisted of three related case studies. The aim was to identify issues relating to the use of the VRLE within an IE context in the classroom and to test data collection methods. The study piloted and developed the use of the VRLE in IE classes. The pilot study also explored a research methodology and provided evidence to enable further development of the VRLE software.

The research questions for the pilot study were:

1. How could the VRLE be used with IE material within a conventional classroom?
2. What teaching and learning strategies influence the IE activities when the VRLE is used in the classroom?

1.12.3 Case Study Series Two (see chapter 6.0)

The second case study series consisted of three related case studies, incorporating an action research element. The aim was to develop a further understanding of issues relating to the context of teaching and learning identified in the pilot study. The contrast between the innovation process undertaken in the VRLE and in the classroom was highlighted and the differences described.

The research questions for this series were:

1. What characterises the role of the teacher when the VRLE is used and how does this differ from the earlier IE model (i.e., pre-VRLE)? How can its effectiveness be improved?
2. Is students' work supported by computer collaboration within the VRLE?
3. What elements of the IE course support the students' ideas generation?
4. How may the students' ability to draw inside of the VRLE be improved?

1.12.4 Case Study Series Three (see chapter 7.0)

Case study series three consisted of two lesson case studies. The aim was to gain further experience and understanding of the teaching and learning strategies of using the VRE and MLE inside the VRLE, within an IE context in school. The study focused on communications between teacher and students when designing together inside the VRE part of the VRLE. It also examined further the teacher's role, in terms of the conventional IE pedagogical context, using the VRLE to support students' ideation skills.

The research questions were:

1. How can the VRE be used for idea generation inside the VRLE?
2. How does collaboration relate to teaching and learning within lessons?
3. How does communication during the lesson support students' work?
4. What is the value of using the VRLE for IE within the context of the school?

1.12.5 Follow-up Interviews with the Teacher (see chapter 8.0)

Two semi-structured interviews were undertaken with the teacher, with regards to issues identified during the research. The purpose was to clarify various issues that had emerged during the fieldwork, concerning students' work and the teacher's pedagogy (see definition in chapter 2.0). Analysis of the data enabled further development, clarification and extension of the categories emerging from previous chapters and the findings were put forward, in order to enrich the overall discussion in chapter 10.0 and to strengthen triangulation.

1.13 Outline of the Thesis

Chapter 1.0 (i.e., this chapter) is an introduction to the thesis: the rationale, purpose and nature of the research are explained. The background of the study is examined and the basic pedagogy of the earlier, classroom-based Innovation Education is described. The limits set for the research project are clarified and justified. Finally, the thesis is outlined.

Chapter 2.0 is a literature survey of the four central categories: Innovation Education (IE), ideation, the Virtual Reality Learning Environment and pedagogical theories on the use of VRLEs in Education. The various terms are defined.

Chapter 3.0 outlines the research design and specific methodologies used, along with their limitations. The data collection and analysis are explained and ethical and legal issues discussed.

Chapter 4.0 reports a short pre-pilot study, including a background survey. This enabled the author to establish a research direction that grew into a series of scoping case studies (5.0).

In chapters 5.0, 6.0 and 7.0, summaries of the data gained from the case studies are presented, which form the basis of the project. The detailed data from these case studies can be found in the appendices.

Chapter 8.0 follow-up interviews with the teacher are reported.

Chapter 9.0 explains the overall findings of the case studies.

Chapter 10.0 discusses the data, in view of the literature.

Chapter 11.0 presents conclusions and suggestions for further research are put forward.

Chapter 2. The Literature Review

2.0 Chapter Summary

This chapter defines the terminology relating to the research. The IE pedagogy is described, in relation to the background of design and craft education in Iceland, using the available, limited literature: this includes a brief review of the pedagogical methods for developing ideation skills. The literature covering the fields of ideation and the use of VRLEs in education are discussed and contrasted and the pedagogical models pertaining to the use of virtual reality learning environments within school education are outlined. The chapter then provides a discussion of this body of literature and establishes how it was used to inform the subsequent empirical research.

2.1 Introduction to the Literature

The enquiry starts with the proposition that a *Virtual Reality Learning Environment (VRLE) can be used to support the pedagogy of developing ideation skills within the innovation process in Innovation Education*. The first step in testing this statement was to examine the related literature.

The framework of the enquiry is the development of the Icelandic Innovation Education (IE) pedagogy and the supporting VRLE. Earlier pedagogical models prior to the introduction of the VRLE had already been established (Gunnarsdottir, 2001a; also see sections 1.5 and 1.6). This was used to support the development of the understanding of an appropriate pedagogy relating to this context during the research.

The literature search was designed to answer the following questions relating to the effectiveness of the use of the VRLE in supporting teachers’ pedagogy and students’ work during conventional Innovation Education in Iceland (see overall question in chapter 1.0):

1. How are different terms used in these fields defined and how are they related?
2. Is there any relationship(s) between IE and the pedagogical background of Icelandic craft education?
3. What research projects have been undertaken that focus on ideation and/or VRLE in school education?

4. What are the most relevant pedagogical methods for developing ideation within school education?
5. Which pedagogical theories are most suitable for understanding the dynamic social interaction when the VRLE is used for ideation within a conventional classroom?
6. How can the identified pedagogical theories be used to understand, evaluate and demonstrate the values of using the VRLE for IE?

A strategy for the literature review was established, beginning by defining the topic and its fields: key words were identified, explored and used for searching for appropriate literature within the field. Online catalogues were used, together with search engines such as *Metalib* (2011), *Ultraseek* (2011), *Scholar* (2011) and the Icelandic web portal *hvar.is* (where.is). Data was also found in books; reference materials; journals; conference papers; dissertations; indexes; printed abstracts; electronic databases; government publications and theses. Keywords employed included: *ideation*; *idea generation*; *innovation*; *innovation education*; *inventions*; *design*; *information and computer technology*; *virtual learning environment*; *virtual reality* and *creativity* and *problem solving*. In addition, keywords were generated as a result of 'snowballing' while reviewing the literature.

2.2 What is Pedagogy?

The word *pedagogy* is derived from the Greek '*to lead the child*' (Etymology Site, on-line, 2011). The Oxford Dictionaries online (2011) defines *pedagogy* as 'the profession, science or theory of teaching': it is the study of the methods and activities of teaching and how teachers manage their classroom instruction in ways that help students to learn subject matter. Watkins and Mortimer (1999) simply define *pedagogy* as 'any conscious activity by one person designed to enhance the learning of another' (p3). The *Encyclopaedia Britannica* (2011) further defines pedagogy as 'the study of teaching methods, including the aims of education and the ways in which such goals may be achieved. The field relies heavily on educational psychology, or theories concerning the way in which learning takes place'.

Many authors (McNamara, 1991; Brown & McIntyre, 1993; Black & William, 1998; Ireson et al., 1999; Bruner, 1999; Loveless, 2002; Beetham & Sharpe, 2007) acknowledge that the variables that help understand 'teachers' pedagogy' are multifaceted and suggest there are various issues that affect practice. Teachers bring much more than just the latest government guidelines on how they ought to teach inside the classroom; for example, the school environment, a teacher's position in the school, former teaching experience, teacher training and a teacher's own experience of learning may influence their practice.

Alexander (2003) suggests that pedagogy requires discourse, stating: 'pedagogy is the act of teaching, together with its attendant discourse. It is what one needs to know and the skills one needs to command, in order to make and justify the many different kinds of decisions of which teaching is constituted' (p3). Leach and Moon (1999) develop this understanding further by defining a pedagogical setting as 'the practice that a teacher, together with a particular group of learners, creates, enacts and experiences' (p267). This implies that pedagogy is a collaborative activity in which the learner has an active role; it also offers an alternative perspective by drawing on the social communication between teachers and learners.

In relation to more open views on pedagogy, it is important to take children's learning into account. Bruner (1999) considers that the way in which teachers adopt an understanding of children's thinking is a precondition to any progress in pedagogical practice. He outlines four dominant models of learners' minds (children as imitative learners, children as learning from didactic exposure, viewing children as thinkers and children as managers of their own knowledge) and it is important that these are considered.

Educational scientists have contributed to our understanding of how the learning process occurs and how it can differ from one learner to another. They have also demonstrated the impact of social and cultural contexts on students' engagement with learning. Many authors have criticised the traditional definitions of pedagogy, viewing learning as the central concern of pedagogy rather than teaching (Beetham & Sharpe, 2007). Malcolm Knowles (1990) states how the original Greek meaning of the term regarding the slave who led children to school, makes it inappropriate for the modern concept of lifelong learning, in which learners gain self-direction and self-reliance. According to Beetham and Sharpe (2007), the common definition of pedagogy as the 'art or science of teaching' is limited for educators that place emphasis on the activity of learning. In a truly learner-centred environment, teaching should not be the focus of concern. Learners can no longer be seen as passive recipients of knowledge and skills; rather, they are active participants in the learning process.

The term *pedagogy* is used in this thesis in accordance with normal usage in the practice of teaching and learning within the Scandinavian/Nordic educational contexts. It has as broad a meaning as the approach adopted by the teacher in a series of case studies in the research (chapters 5-7) and incorporates the holistic context of his different roles and responsibilities, the social interaction between teachers and learners and interaction between the learners themselves.

To enable the teacher's progress during the research, it was important to take children's learning into account. Pedagogy is thus seen as the art and science of how something is taught and how students learn it: this includes how learners generate the course content in their environment, the approach to teaching and learning, how teaching occurs, how content is delivered and what the students learn as a result of the process. Accordingly, the term *pedagogy* is a dialogue between teaching and learning and the term *teaching i*s seen as possible threat to the active nature of learning and to individuals' unique capacity to learn. How students learn and how they can best be guided to learn is no longer a concern that merely belongs within the confines of educational establishments.

2.3 Terminology within the Areas of Innovation and Ideation

Literature relating to this work showed researchers used different terms for similar phenomena, within the context of their own working areas. This demonstrated the importance of the requirement for clear terminology within the research. In the following sections, the basic terms used in the enquiry are defined and figure 2.1 below is an attempt to establish a simple framework of terms relating to ideation skills, in order to gain a better understanding of the terminology relating to this enquiry.

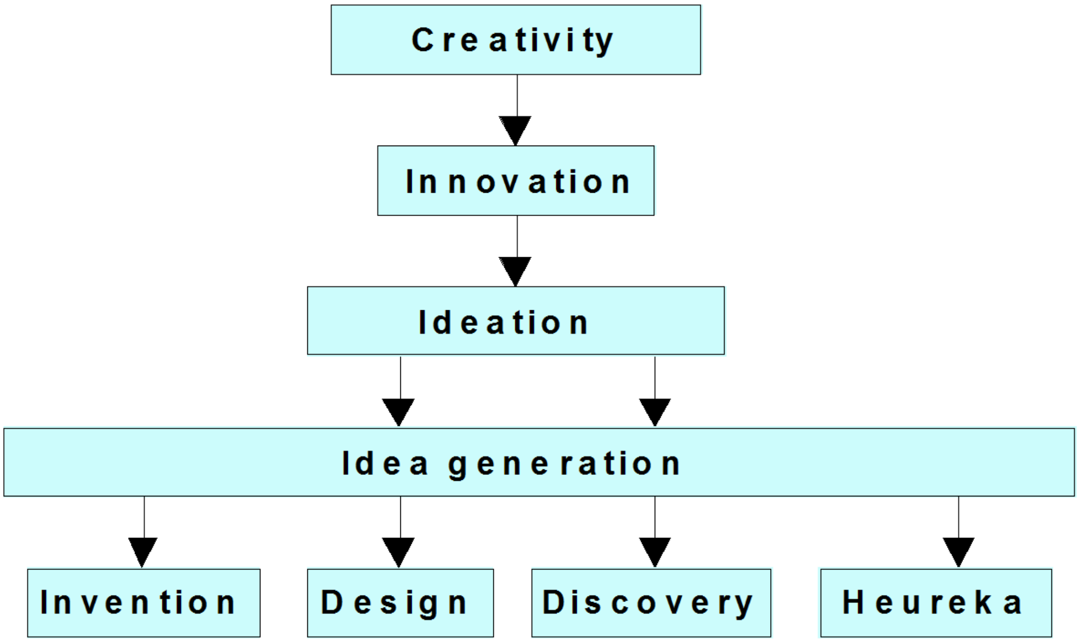

Figure 2.1: Shows the suggested working hierarchy used in this thesis and the relationships between the different terms employed in the research project, as reported in the chapter.

2.3.1 Creativity

Creativity has a long history in educational research, with a focus on individual differences, cognitive abilities and problem solving (Britannica, 2011). Many researchers have explored the area of creativity and have set out different positions (Kraft, 2005; Amabile et al., 2005; Csikszentmihalyi and Csikszentmihalyi, 1988; Drazin et al., 1999; Heap, 1989). *Creativity* is a broad term and in this work the focus is on innovation and ideation rather than creativity *per se*. Nevertheless, there are relationships between the terms and these are acknowledged.

Some researchers see creativity as a process that ebbs and flows over time, in response to problems that unpredictably arise (Gabora, 2002; Drazin et al., 1999). In this view, creativity is connected to sense making, problem finding and the interpretation of events and situations. Sternberg (1996) defines creativity as the ability to produce work that is both novel (i.e., original or unexpected) and appropriate (i.e., useful or meets task constraints). Heap suggests that *creativity* is the ‘synthesis of new ideas and concepts by the radical restructuring and re-association of existing ones', whereas *innovation* 'is the implementation of the results of creativity' (1989:81). This definition is consistent with that of Majaro (1988) and Zhuang et al. (1999), in that creativity is seen as over-arching innovation. Titus (2000) has defined *creativity* as 'the birth of imaginative new ideas' (p266) and Gurteen (1998) similarly defines the term as the generation of ideas, whilst *innovation* is defined as putting these into action by sifting, refining and implementing. Gurteen believes that creativity is concerned with divergent thinking, while innovation requires convergent thinking (see section 2.7.1): this approach highlights how idea generation (see section 2.3.4) is a key component of creativity.

Recent theoretical and empirical work (i.e., Simonton (2000) considers creativity as something the brain does naturally: it is an adaptive feature of normal cognitive functioning that has evolved to aid problem solving under conditions of uncertainty. This perspective asserts that all human beings have the potential for creativity, as they share common neural processes (Clapman, 2003). However, whether creativity is expressed or suppressed depends on the socio-cultural context, personality differences and specific personal experiences, such as knowledge and skills. Under such circumstances, novel approaches and invention (see section 2.3.7) are highly advantageous (Simonton, 2000; Findlay & Lumsden, 1988).

Whether creativity is considered a process or an output, it is often linked to social processes (Csikszentmihalyi and Csikszentmihalyi, 1988). The systems perspective views the individual as the source of variation and change (new ideas). These are presented to others, who then select and retain creative ideas that are used to elaborate the larger domain. The results of this elaboration are fed back to the individual and the process continues (see section 2.7.2, group ideation).

Creativity is the basis for innovation (see section 2.3.2) and Innovation Education in Iceland was intended to be a creative activity. It was an attempt to bring out the creative talent in students (Gunnarsdottir, 2001a) by training them to identify needs in their environment and devise solutions, in the form of a product.

2.3.2 Innovation

According to the Oxford Dictionaries Online (2011), *innovation* is the action of innovating; the introduction of novelties and the alteration of what is established by the introduction of new elements or forms. The terms *creativity* and *innovation* are strongly connected, but have been largely studied in isolation by researchers using different methodologies and pedagogical models. *Innovation* is generally defined as useful novelty; not novelty for its own sake, but novelty that can be applied and add value (Oldham & Cummings, 1996). The term *innovative* comes from the Latin word *innovare*, meaning '*to renew'* or 'to make new' (The Webster Dictionary*,* 2005) and innovation includes the generation of ideas, alternatives and possibilities (Smith*,* 1998). *Innovation* is a form of problem solving that begins with the feeling that change is needed and ends with the successful implementation of an idea (Smith, 2003).

Amabile et al. (1996) differentiates between creativity and innovation as follows: 'Like other researchers, we define creativity as the production of novel and useful ideas in any domain. We define innovation as the successful implementation of creative ideas within an organization' (p2). Rogers (2003) states that:

> 'Innovation is an idea, practice or object that is perceived as new by an individual or other unit of adoption. It matters little whether the idea is objectively new, as measured by the lapse of time since its first use or discovery. The perceived newness of the idea for the individual determines his or her reaction to it: if the idea seems new to the individual, it is an innovation' (p11).

The novelty in a student's work has an individual meaning that is concerned with the individual's ability to deal with their world by calling upon their creative talents on a daily basis (Gunnarsdottir, 2001).

Thus, innovation is different from creativity, although both share elements of meaning. Innovation is the application of new ideas (Rogers, 2003), whereas creativity, in contrast, is the generation and articulation of new ideas. It follows that people can be creative without being innovative; for example, if they have ideas but do not implement them. Similarly, individuals can be innovative without being creative: if they apply or implement ideas from elsewhere, then they are innovative, even though the ideas were not their own. The creativity is in the putting together of others' ideas in an innovative way; for instance, the technology behind the Sony Walkman (a personal cassette player) existed, yet innovation came in the miniaturisation of the player and thus a new context of use. A term often associated with innovation is *problem solving*. For example, Bessant et al. (2004) state how innovation is fundamentally about creative problem solving. However, it is also necessary to recognise that innovation is largely associated with responding to opportunities rather than simply addressing 'problems'.

Ideation and ideation skills are important parts of the IE pedagogy, as they enable students to go through the innovation process (see section 2.5.3). Divergent thinking (see section 2.7.1) is a cognitive process that focuses on developing multiple possibilities rather than finding a single solution, thus promoting greater ideation. Ideation is important during several phases of innovative problem solving, including the development of ideas, in terms of solving problems, and the development of solutions to such problems (Clapman, 2003; Doolittle, 1995).

2.3.3 Ideation

Ideation is a concept derived from Guilford (1950) and is used to describe the pattern of interactions that arise when a person works on and produces an idea. As the Oxford Dictionaries Online (2011) states, ideation is the formation of ideas or mental images of things not present to the senses. According to The Webster's Dictionary (2005), ideation is described as 'the faculty or capacity of the mind for forming ideas; the exercise of this capacity; the act of the mind by which objects of sense are apprehended and retained as objects of thought' (p725).

Santanen et al. (2004) state that 'ideation activities are fundamental to the process of creativity' (p23), yet reflection on the definitions in the previous paragraphs shows that the process of innovation clearly requires ideation skills (see section 2.5.3). During an ideation session, one or more people work together, in order to generate solutions to a problem or opportunity and this is intended to generate solutions that might otherwise go unnoticed (Santanen et al., 2004).

In early Innovation Education work (Gunnarsdottir, 2001a), the term *creativity* was used relatively loosely and evolved into the concept of ideation. This was described as 'facilitating creativity for ideation' (FCI) (a pedagogical definition of creativity) and was first used in an attempt to explain what happens when children learn or engage in Innovation Education (Gunnarsdottir, 2001a).

While this version of FCI was forming, the authors were attempting to observe and understand what happens through Innovation Education, from the viewpoint of a child. FCI also illustrated how an individual can influence their environment and build up their self-image through creative activities. The following model was thus proposed:

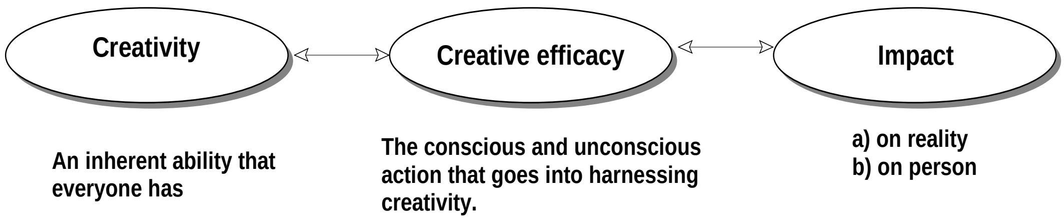

Figure 2.2: The 1996 version of the term 'Facilitating Creativity for Ideation' (FCI) (Gunnarsdottir, 2001a:18).

However, Gunnarsdottir's statement in figure 2.2, that creativity is an inherent ability that everyone has, is arguable. This is also likely to be a variable amenable to development.

2.3.4 Idea Generation

Idea generation is the generation of possibilities, performed at various points in problem solving and innovation episodes (Smith, 2003). Lying at the heart of both invention (see definition in 2.3.7) and design (see further in 2.3.8), it is a widely acknowledged key part of the innovation process (Van de Ven, Angle & Poole, 2000). Innovation is closely related to idea generation, as the innovation process invariably includes problem-need identification and solving, since the idea generation and implementation of ideas for change (Smith, 2003).

Osborn (1967) recommended that idea generation be seen as a separate activity to idea evaluation. This resulted in an increased emphasis on idea generation, which formerly tended to be in the shadow of idea evaluation (Smith, 2003). Maier (1963) concluded that this segregation and increased focus would ultimately improve the quality of problem solving and such an approach is consistent with Demerest's (1997) knowledge-management approach, where knowledge creation is recognised as a key separate activity supportive of idea generation. These events occur prior to the phase of knowledge embodiment in organisational groups, where filtering rules are applied, similar to that of idea evaluation. Furthermore, Morris (1999) argues that idea generation, based on an expansive view of knowledge creation, is essentially the grouping and integration of ideas from many sources of accepted knowledge, prior to the viewing of those ideas.

Rickards and Freedman (1978) suggest that an additional time separation or deferment of judgement should occur in the idea generation phase, as this time factor allows ideation to develop before idea evaluation takes place. Titus (2000) speaks of periods of idea generation rather than separated events, suggesting the need for reflection and further development. Similarly, Henry (1991) considers the need for a period of incubation in idea generation: this period is referred to as deferred judgement and is distinct from dormancy. Rather, it should be a period of knowledge creation through dialogue, debates, scanning, etc. Accordingly, ideas are generated and shaped, prior to idea evaluation.

2.3.5 Heureka

Sometimes, students in IE classes get a sudden idea that just ‘pops into their mind’. Many researchers call this *eureka* and, according to the Oxford Dictionaries Online (2011), this English term comes from the Greek *heureka.* This derives from the expression ‘I have found it’, said to have been uttered by Archimedes when he suddenly found a method for determining the purity of gold. *Eureka* means ‘exclamation, a cry of joy or satisfaction when one finds or discovers something’.

Heuristics is a term often associated with *heureka*; it may be described as ‘a set of rules or procedures applied in problem solving’. Thus, ‘means-end’ analysis or attempts to solve a problem by working backwards from a goal is commonly considered heuristic (Mumford & Norris, 1999). An example of a ‘heureka’ moment would be when Dyson was cleaning his house and he realised the vacuum cleaner could work without a bag. This then became a goal when Dyson developed the first bagless vacuum cleaner (The Independent, 4th October, 2006). Edison's light bulb could also probably be considered an example of heureka. Edison had to search for lots of information and this was partly gained from observing possibilities in a systematic way.

To solve such novel problems requires a systematic, principle-based association of disconnected information: both a declarative and procedural knowledge is needed. Heuristics can be viewed as a form of procedural knowledge if one reflects on the rules, procedures or strategies for applying a declarative knowledge, when solving certain types of problems. A declarative knowledge reflects on the content, characteristics and association of relevant objects or key exemplars (Mumford & Norris, 1999).

2.3.6 Discovery

Discovery, as an educational term and learning method, is defined as 'finding out or making known something which was previously unknown' (The Oxford Dictionaries Online, 2011). Bruner is considered the founder of discovery learning, but his ideas are actually similar to those of scholars such as Dewey (Martin, 2003). Bruner (1961) asserts that 'practice in discovering is considered '*learn by doing'* (p26) and thus discovery learning is a method through which students interact with their environment by exploring and manipulating objects, asking questions and doing experiments.

Pedagogical theories, such as constructivist learning and social constructivism, look upon discovery as the nature of the learning process and this is supported by the work of Jean Piaget (1950), Jerome Bruner (1996) and Seymour Papert (1998).

Social constructivists (see section 2.13.1.3) also view learning and discovery as an active social process. However, some academics have found evidence that direct instruction is more important for novices (Tuovinen & Sweller, 1999): these learners need direct instruction first and then need time later to apply what they have learned (Kapla and Owings, 2000).

IE is not based on discovery as a method, as such. However, discoveries sometimes emerge and help students in the innovation process.

2.3.7 Invention

The Oxford Dictionaries Online (2011) defines the verb *invent* as 'to find out in the way of original contrivance; to create, produce or construct by original thought or ingenuity; to devise first and originate…It is the faculty of inventing or devising; the power of mental creation or construction'. The term *invention* is typically applied if ideas can be patented (Smith, 2003) and the invention involves problem-solving activity (Dasgupta, 1996). Not all ideas are invention, with the latter having a higher standard of originality rather than design (Dasgupta, 1996). However, many fields of design may generate highly original and creative output that cannot be patented, such as sculpture.

The relationship between innovation and invention is important. Invention, as the creation of new tools or the novel compilation of existing tools, is often confused with innovation and so a distinction between the two terms is useful. As Fagerberg informs: 'Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice' (2004:4). *Change* and *creativity* are other terms often substituted for innovation, with much of the current business literature interchanging the concept of *innovation* with *value creation*. In this view, an innovation does not take place until someone successfully implements an idea. One use of the term is to constitute innovation as an action. As Fagerberg further informs: 'Innovation occurs when someone uses an invention or uses existing tools in a new way to change how the world works, how people organise themselves and how they conduct their lives' (Fagerberg, 2004:4).

The front-end of the IE innovation process (see sections 1.6 and 2.5.3) focuses on idea generation and the development of novel ideas and this helps students use their experiences to form meaning from their IE studies. However, innovation is perhaps a more important aspect of the IE pedagogy, as the students usually come up with older ideas or further development of already existing ideas. Innovation takes place throughout the innovation process: the students implement and manipulate their ideas, before bringing them into realisation.

A person's idea-generation ability and performance depends on their ideation skills. Smith's (2003) model, demonstrating the relationship between the innovation process and idea generation, shows invention and design as the general outputs (see figure 2.1). Invention and design are established through problem solving and during idea generation; idea generation is the mental production of possibilities or alternatives and must be performed at various points in most problem-solving episodes. Idea generation, at the heart of both invention and design, is widely acknowledged to be a key part of the innovation process (Van de Ven, Angle & Poole, 2000; Weber & Perkins, 1992).

2.3.8 Design

The term *design* is usually considered within the context of the applied arts, engineering and architecture. The Oxford Dictionaries Online (2011) defines *design* as 'a mental plan or scheme conceived in the mind and intended for subsequent execution; the preliminary conception of an idea that is to be carried into effect by action'.

According to Simon (1981), 'Everyone designs who devises courses of action aimed at changing existing situations into preferred ones' (p130): to design is to plan for the making of something new. Designing entails generating, transforming and refining descriptions and specifications of different aspects of a still non-existent artefact and making representations of it that enable communication and examination of the ideas involved, which ultimately enables the production or construction of the artefact. Goldschmidt (1999) considers design to be closely associated with ideation because new artefacts are expected to be innovative and original: two hallmarks of creative products. Thus, designers are expected to be innovative persons who exercise innovative processes.

The term *design* implies a conscious effort to create something that is both functional and aesthetically pleasing (Goldschmidt, 1999). The creation of artefacts is readily associated with technology and their appearance naturally related to the visual arts. Design is therefore seen as a merger between the two, with a possible dominance of either an artistic tendency or a technological bent. However, both the appearance and the function of designed artefacts are usually expected to meet standards of excellence, based on state-of-the-art technologies and artistic norms.

A design process may include a series of steps, depending on the product or service. Typical stages of the process (Ullman, 2009) include:

1. Pre-production design:
    a) Design brief, a statement of design goals.
    b) Analysis of current design goals.
    c) Research investigating similar design solutions in the field or related topics.
    d) Specification, specifying requirements of a design solution.
    e) Problem solving, conceptualising and documenting design solutions.
    f) Presentation, presenting design solutions.
2. Design during production*:*
    a) Development, continuation and improvement of a designed solution.
    b) Testing a designed solution in a real situation.
3. Post-production design feedback for future designs:
    a) Implementation, introducing the designed solution into the environment.
    b) Evaluation and conclusion, summary of process and results, including constructive criticism and suggestions for future improvements.
4. Redesign any or all stages in the design process repeated (with corrections made) at any time before, during or after production.

Innovation Education, however, focuses on the ‘front-end’ of the design process: the identification of needs/problems, initial concept generation and the development of basic solutions using simple models (1.6).

2.4 Developing Innovation Education inside Craft Classes

Innovation Education started as a curriculum development project within craft classes in the Icelandic elementary school (The Icelandic Ministry of Education, 1994). Thus, IE was influenced by the pedagogical background for craft education. To put this research into context, it is therefore necessary to give a brief description of the historical and pedagogical background of craft education in Iceland, now named design and craft (The Icelandic Ministry of Education, 2007).

Icelandic craft was established as a subject in 1900, under influences from the Scandinavian Sloyd pedagogy (see section 2.4.1). At this time, Iceland was a Danish colony and Icelandic scholars were therefore influenced by the Danish culture. The new Icelandic subject was first based on a system for Danish School Sloyd, developed by Axel Mikkelsen in his handicraft school in Copenhagen. Mikkelsen established Sloyd as a general subject in Danish public schools in 1883, under influence from the originators of the Sloyd pedagogy in Finland, the Swedish educationalists Salomon and Cygneus (Borg, 2006).

The term *Sloyd* is related to the old Icelandic word *slægur,* with the original meaning being connected etymologically with the English word *sleight* (as in ‘sleight of hand’), meaning cunning, artful, smart, crafty and clever (Nudansk Ordbog, 1990; Den Danske Ordbog, 2003-2005; Borg, 2006). Sloyd comprises of school activities that use craft to produce useful and decorative objects: it is a pedagogical system of manual training that seeks to aid the general development of the child through the learning of technical skills in woodworking, sewing and knitting and making useful objects by hand (Borg, 2006 & Salomon, 1893:63).

The Danish Sloyd model was focused on bringing physical work into harmony with spiritual aspects (Thane, 1914), with the development of the potential of the whole child being the central focus. The curriculum was designed for students to acquire basic knowledge and skills in their early years, which later enabled more advanced stages in their individual development as good citizens (Moreno, 1998).

Different curricula focusing on craft were developed in Iceland until 1999, when craft was re-established as a new technological subject under the name design and craft. Design and craft is based on a rationale for craft education, technological literacy, innovation and design and the main aim is to develop technological literacy and ideation skills in students. The infrastructure of design and craft was also influenced by the IE project: ideation became part of its foundation, along with technological based craft (The Ministry of Education, 2009).

2.4.1 Sloyd Pedagogy

Uno Cygnaeus (Finland) and Otto Salomon (Sweden) were the leaders in the development of a systematic Sloyd model for school education: they emphasised the usefulness of constructing objects through a formal educational methodology (Kantola et al., 1999; Borg, 2006). Sloyd was disseminated by Salomon, through thousands of teachers from all over the world who attended his classes. Sloyd had a noted impact on the early development of manual training, manual arts, industrial education and technical education in many countries, including craft in the UK (Bennet, 1926; Kantola et al., 1999).

Salomon was focused on the analysis of processes and their use in educational instruction. There were three key elements in his system: (1) making useful objects; (2) analysis of processes and (3) the educational method (Moreno & Yokoyama, 2001; Bennett, 1926:64).

Salomon's system for educational Sloyd aimed to educate children holistically, via a carefully structured system for teaching craft (Borg, 2006; Bennett, 1926; figure 2.3). The child became the centre of the educational activities and the development of the capabilities of the whole person. Salomon underlined the importance of teaching basic knowledge and skill in the beginning, in order to enable more advanced stages in the development of the individual as a good citizen (Moreno, 1999 (see figure 2.3.).

Salomon's didactical system for Sloyd (see figure 2.3) had a humanistic character and its principles were guidelines for the whole activity in the subject. Individual development and self-realisation were at the centre of the subject, rather than just technical knowledge and skill taught by the teacher. The system aimed to fulfil the demands of a holistic education by fostering the entire human being's capabilities. At the same time, it prepared the individual for the future working life, in accordance with the needs of an industrial society.

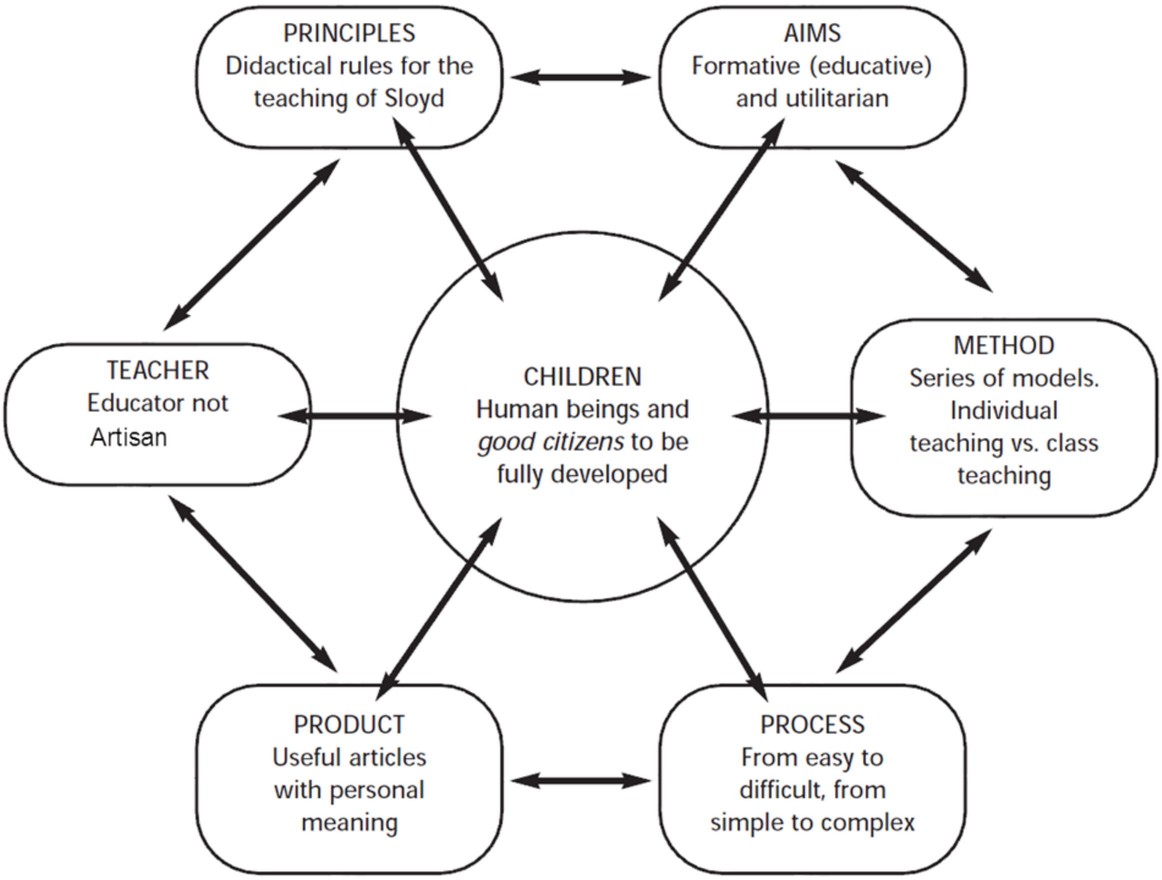

Figure 2.3: The didactic system of Salomon for Sloyd education (Moreno & Yokoyama, 2001).

The system character for teaching and learning was to guarantee an initial level of knowledge and skill, in order to transit to more advanced stages in the development of the individual. The teacher had to be educated as an educator rather than an artisan, in order to ensure a clear distinction from vocational training, and Sloyd was aimed at general education (Moreno & Yokoyama, 2001).

2.4.2 The Development of Innovation Education in Iceland

The Innovation Education project was developed in Icelandic schools from 1991 (Jonsdottir, 2005). This began with a meeting of individuals from schools, industry and the technical college that wished to encourage young innovators. A working group was established, whose primary goal was to connect the schools and the work place through innovation.

IE began inside craft classes and as an after-school activity and it quickly became apparent that the content of these sessions could be integrated into ordinary schoolwork (The Icelandic Ministry of Education, 1999). Regular classes in IE began in several schools in Reykjavik, with the work based on the premise that everyone is innovative and that it was possible to base regular classroom teaching on the concept of ideation. The decision was also made to set up an innovation competition and the group established the following aims:

a. To stimulate and develop innovativeness in students and teach them certain approaches and processes, from own concept to realisation
b. To teach individuals to be innovative in daily life, so that they would become better equipped to adapt to their environment and re-creating it
c. To encourage and develop the students' initiative and strengthen their self-image
d. To make students aware of the ethical values of 'objects', while teaching them ways to improve their environment (Jonsdottir, 2004).

The group first established a course for pupils in a school in Reykjavik and, in response to this initiative several schools outside of the capital requested assistance in establishing innovation courses. The 'Young Inventors Competition' became an annual event from 1991 and the IE project was supported by several developmental funds administered by the Ministry of Education, Science and Culture, The Reykjavik Local Educational Authority and The Teachers Association (Jonsdottir, 2009).

The author wrote course materials for 'Innovation Education' with Gunnarsdottir (Gunnarsdottir, 2001a). IE was primarily taught to students between the ages of 9-12 years and, later, to students up to the age of 20. The project developed into a new subject in the Icelandic National Curriculum in 1999. In 2006, IE became a cross-curricular element of the National Curriculum.

The main component of the course is student ideation within the context of innovation, based on any needs they identify in their environment: this requires a basic knowledge of the ideation and innovation processes (see section 2.5.3). The content includes sections on:

- *Initiative-creativity*: students explore and solve any needs they identify in their environment.
- *Creativity-technology:* how to use technical solutions to solve needs.
- *Ideas-Ingenuity*: regarding the production, marketing and selling of products.
- *Environment-Design*: regarding the solving of environmental problems through innovation.

2.5 The Pedagogy of Innovation Education

Ideation is at the core of the IE pedagogical framework and the emphasis is to develop students' ideation skills through the innovation process (Gunnarsdottir, 2001a). IE is based on conceptual work that involves searching for needs and problems in students' environments and finding appropriate solutions, or applying and developing known solutions (see 1.6). The aim is to develop students' innovativeness and make them better equipped to deal with their world and take an active part in society.

Students work through the IE innovation process iteratively (see sections 1.6 and 2.5.3), with the overlying direction leading from 'finding needs' to 'presentation of solutions'. Innovation relates to the usefulness of ideas and/or how they can be implemented as solutions to the many problems encountered in daily life. In Innovation Education, students use appropriate knowledge and information from different sources to find solutions to the problems or opportunities identified: this mirrors Vygotsky's (1978) zone of proximal development (see section 2.13.1.2). Students work with their own concepts, but learn to work through the innovation process to bring their ideas into being and gain what is now known as *Creative Relevant Skills* (Gunnarsdottir, 2001b).

2.5.1 Practical Use of Knowledge

As students undertake the process of innovation, gaps in their knowledge emerge and they find it necessary to research and gain appropriate knowledge that suits the particular innovation process they are involved in. This process is paramount, as subject knowledge develops as appropriate and in context. As the student acquires increased knowledge and experience of ideation, they can employ it in new contexts (The Icelandic National Curriculum, 1999).

2.5.2 Ideation and Practical Use of Knowledge

The role of knowledge in IE is different from traditional craft and design education in Iceland and, to some extent, other countries. In the Icelandic subject *Design and Craft* (The Icelandic National Curriculum, 2009), the student is provided with a brief by the teacher and is asked to follow a sequence of rules and activities associated with a relatively prescriptive view of the design process, when developing their work. Thus, the student depends primarily on the application of prior knowledge in an area prescribed by the teacher, via a specific 'brief'. In Innovation Education, however, students seek solutions to real world problems they have identified in their environment. They propose solutions at a conceptual level and research the knowledge that is needed to develop the solution.

2.5.3 A Model of the IE Process (see also 1.6)

IE is intended to be a simple way to teach ideation skills within the context of innovation activity and such skills are incorporated at all stages. The process is as follows:

1. Finding needs
2. Brainstorming
3. Finding the initial concept
4. Ideation drawings or modelling, in order to develop the technical solution
5. Making a description of the solution, in addition to the drawing
6. Presentation

The IE innovation process is a simple model to support ideation. Ideation is at the core of the IE pedagogical framework: students develop skills in ideation through the innovation process within the overall IE pedagogical framework, which is managed by the teacher (see 1.6).

IE uses a project approach and the content has to be researched as it becomes apparent it is needed. This is student-centred, due to the process of identifying needs within the students' own home environments. The IE process is iterative, with an overlying direction leading from 'finding needs' to 'presentation of solutions'.

2.5.3.1 Identifying the Needs

Students explore their environment beyond the school and identify needs or problems (see section 2.8.1). In this, they often use a notebook. Students are encouraged to speak to people, read newspapers, watch the TV, look inside school, go to shops or use the Internet, in search of these needs/problems. In most cases, students will bring back initial solutions in their notebooks and this provides teachers with the opportunity to explore the need or problem, rather than developing concepts without understanding their origin (Gunnarsdottir, 2001b).

2.5.3.2 Brainstorming

The teacher writes the needs on the blackboard and students brainstorm possible solutions together (see section 2.8.2). In this way, co-operative brainstorming techniques are used to expand their knowledge and understanding (Buzan, 1985).

'Brainstorming' is a tool for ideation and is frequently used in IE classes for training students. It helps them to become skilled in idea generation on an individual basis, in addition to the support given by fellow students. In brainstorming sessions, students generate new ideas, identify how these ideas are associated and then develop them further. The students usually bring the problems and needs (PN) they have identified at home to the session (see chapter 5). The teachers then register the PNs as a source in the brainstorming sessions and the students use the list of PNs in their individual work. The teacher also uses brainstorming sessions to help the students understand the values of idea generation and group support. Rather than focusing on one initial solution, they are asked to find associated ideas on their own, sometimes through communication with co-students and the teacher. One of the teacher's roles is to respect all ideas the students come up with: if the teacher passes judgment, the stream of ideas may stop (Gunnarsdottir, 2001a).

2.5.3.3 Finding the Initial Concept

The students choose the solution they want to adopt after discussion with their teacher and colleagues.

2.5.3.4 Ideation Drawings or Modelling to Develop the Technical Solution

Sketching, 2D and 3D modelling and discussion facilitate understanding and the development of the concept towards the solution: this includes self-communication (reflection) and advice from the teacher (Gardner, 1993). Freehand sketching can be used to explore ideas quickly; such sketches are usually rough and incomplete, typically not following the conventions of more finished drawings (McGraw-Hill Higher Education, 2002).

2.5.3.5 Making a Description of the Solution as an Addition to the Drawing

Students provide a description of their innovation work, both for display and as a basis for a presentation. Making a poster can be a good way to understand a solution and the poster should include illustrations, drawings showing how the solution works, who will use it, where it could be used and the materials it could be made from (Gunnarsdottir, 2001b).

2.5.3.6 Presentation

Developing a spoken presentation based on a poster can be a good way of deepening a student’s understanding of their solution (concept), its relationship with the environment and the original need/problem identified; this process also develops communication skills. Discussion of the presentation offers valuable feedback to students. In seeking to understand, communicate and solve problems, students improve their own practice (Murphy, Lunn & Davidson, 2002).

2.6 Prior IE Research Projects in Iceland

Two academic projects have been undertaken on Innovation Education since its inception. The earlier project (Gunnarsdottir, 2001a) was conducted to increase the understanding of how students learnt in the IE classes prior to the introduction of the VRLE, whilst the latter (Jonsdottir, 2005) looked for factors that influenced the implementation of the Innovation Education curriculum in Iceland.

2.6.1 Defining Innovation Education (also see section 1.5)

Gunnarsdottir (2001a) defines Innovation Education in the Icelandic context. She tries to understand how students learn through their social activities in IE and puts forward a pedagogical model (see section 1.5) on teaching and learning in Innovation Education. Gunnarsdottir's model shows the interaction between a student's life and IE classes and explains how this affects the way that students learn in IE. These two processes need to be in balance as, through the IE process, students use ideation skills and prior knowledge to suggest solutions and build their self-image as innovators. Gunnarsdottir (2001a) also suggests that, if the teacher's role is overwhelming, then the students tend to stop using their experience and little IE work will ensue. In addition, it appears that an important factor is that the students interact with each other, in order to stimulate the evolution of skills and knowledge within the lessons.

2.6.2 The Dissemination of Innovation Education in Iceland

Jonsdottir's (2005) research focused on how Innovation Education emerged in Iceland and how the subject has developed, what makes the subject different and the internal and external factors that have influenced its dissemination. Jonsdottir states*:* 'In Innovation Education, it is assumed that everyone can be creative and the emphasis is on enhancing the creative activities of students through direct connections to everyday life. Educational innovations based on this kind of approach have struggled against the strong underlying factors inherent in the institutional culture of education' (2005:3). Jonsdottir found several factors influenced the implementation of the Innovation Education curriculum in Iceland and these were: the role of teachers and their professional philosophies; school culture; the role of the head teacher; assessment; emphasis on academic learning and access to information and teaching materials.

This research further indicates that curriculum formulation and implementation is a complex interplay of the above and is not completely predictable. It appears preferable to view changes within the education system as an organic rather than a linear progression, more comparable to biological evolution than to the production process of a factory.

2.7 Developing Ideation Skills

Ideation skills refer to 'the expertise to form ideas or mental images of things not present to the senses' (The Oxford Dictionary, 2005) or 'the knowledge to exercise the capacity of the mind for forming ideas' (The Webster Dictionary, 2005). Individuals develop ideation skills by implementing some method for ideation (see definition in section 2.3.3), and, in IE, this is done by practising the IE pedagogy (see further in section 2.5.3), in order to improve the students' ideation within the IE process. Both individual and group support for ideation perspectives are considered before additional idea generation methods are presented (these include checklists, forced relationships and imagery). Training may also include methods for the removal of obstacles and this may include deferring judgment; relaxation; enhancing self-confidence or self-efficacy; increasing appreciation for creativity; allowing oneself time and space to let the ideas flow and providing the necessary resources to facilitate the flow of ideas (Clapman, 2003).

Improvement of ideation occurs when new associations are made between already existing pieces of information (Parnes, 1999). Parnes uses a comparison to illustrate the essential ingredients required for this process to take place: ideation requires energy to make it run and the removal of obstacles to allow it to run. The energy consists of sensory impressions from any source, including books, environments and experience, whilst the blocks consist of any constraints, internal or external, which limit our mental exploration. Using this model, we can loosely categorise the techniques used in ideation training programmes as being designed to either 'add something' or 'subtract something'.

2.7.1 Individual Ideation

The model of IE used prior to the introduction of the VRLE was/is an activity based on ideation and the individual student (Gunnarsdottir, 2001a, see also section 1.6). Nevertheless, IE school activities also include collaboration, intended to support the individual's ideation.

The IE process begins in the student's home environment, in seeking needs and problems as a basis for idea generation in the school. The notebook (A2.0.2) is an important source of information for the student and enables the teacher to see the student's ideas and directions. The teacher's role is to develop and maintain students' innovative spirit, helping them to search for solutions and ways of bringing their ideas to realisation (e.g. as drawings or descriptions) (Gunnarsdottir, 2001b). This part of the IE process personalises the process and connects the activity to prior knowledge and experience (see section 2.5.1).

Nevertheless, the students often register solutions in the notebook instead of needs and problems (see chapter 5 and section A2.0.2). Runco and Dow (1999) observe that an innovative solution to a problem may depend on how the problem has been identified and found; problem solving may also depend on problem definition. In its original or conventional form, the problem may have been exceedingly difficult, but a redefinition can make that same problem easier to solve. The specific processes under 'problem finding' include problem identification, problem construction, problem expression and problem posing and definition (Runco, 2007; Runco & Dow, 1999).

Ideation requires individuals to look for many new approaches to problems. This is often called a divergent style (Vidal, 2006), including both unique and typical responses, which may require the random association of different areas, sets of knowledge or ideas.

During his research, Guilford (1954) discovered that most individuals display a preference for either convergent or divergent thinking (Cropley, 2009). Convergence is the deductive generation of the best single answer to a set problem. Vidal's (2006) research also indicated that, in both individual and group ideation, it is more effective to start with divergent thinking, in order to produce as many ideas or solutions as possible and, thereafter, to switch to convergent thinking, in order to select the most promising ideas.

Today, various computer programmes give support to individual ideation (Dugosh et al., 2000). For example, such programmes can help individuals with divergent thinking through electronic brainstorming, in order to increase the amount of generated ideas. Some software solutions also help individuals to generate extraordinary word associations (Brown et al., 1997). In this project, individual students stated how the VRLE helped them to generate further ideas when they were working in the school (see in chapter 5.0). Some programmes exist that guide individuals through brainstorming or the different stages of problem solving (Isaksen et al., 2011; Markas & Elam, 1997; Rickards et al., 1978). Others consist of interactive games (Reeves, 2011; Prensky, 2007; Doolitle, 1995).

2.7.2 Group Ideation

There is evidence that working in groups/teams can improve the quality of ideation (Smith, 2003). Traditional brainstorming philosophy states that, by drawing on people from diverse backgrounds and at different levels of expertise, brainstorming may generate a greater number of creative ideas: if brainstorming involves multiple people, ideas can evolve through group input. However, group brainstorming may produce fewer ideas, due to face-to-face process loss.

Osborn (1942) regarded group brainstorming (see section 2.8.2) as more effective than individual brainstorming, while Peacock (1989) stated that there was evidence that team performance is ‘infinitely higher’ than individual performance. Salomon and Globerson (1989) asserted that group work ‘could induce a greater mindfulness, as well as helping groups to perform more elaboration, rehearsal, planning, summary and the internalisation of peer provided meta-cognitions’ (p89). A group of individuals working together are able to develop better conceptual combinations then individuals working alone (Smith, 2003). Individuals with diverse knowledge and skills working together in a group can also combine different inputs in unique ways: this is referred to as *synergy* and is a term often used within the context of group interaction. Hampden-Turner (1970) defines synergy as ‘an affective and intellectual synthesis which is more than the sum of the parts, so that each party to the interaction can win a return on investment that is greater than the competence risked’ (p55). In IE classes, collaboration usually takes the form of brainstorming sessions (see section 2.5.3.2), which incorporate synergy as one of the principles; the students work together to generate ideas. However, IE aims for individual output, with group work used in a supportive, synergetic role.

It is important to note that the literature on group working does not reflect a uniformly positive effect, as indicated above. Several researchers have identified negative aspects, such as the potential for negative synergy (Witte, 2007; McDonagh-Philp & Denton, 2000; Denton, 1992; Larey & Paulus, 1999).

The value of a group's synergy may be negative, positive or neutral, in terms of its performance (Witte, 2007; McDonagh-Philp & Denton, 2000; Denton et al., 1999). Shaw (1971) used the term *group syntality* for a group's personality and the entire effect of a group performance. He also used the term *effective synergy,* with regards to a group dropping its energy level as a result of interpersonal relations. Like Shaw (1981), Denton (1992), Larey & Paulus (1999) and Hackman (1987) used the term *group process loss* for a drop in performance due to the communication time required and for personality effects within a group. Techniques such as *Delphi* (Weaver, 1971) and *Nominal Group Technique* (Lomax & McLeman, 1984; O`Neil & Jackson, 1983) aim to minimise group process loss and maximise effective synergy (Lecher & Witte, 2002; Denton et al., 1999).

Larey and Paulus (1999) refer to groups as having the tendency of conformity or looking for agreement. Individuals who move away from a group agreement or norm often receive negative reactions from others in the group. However, strongly motivated individuals who continue promoting their novel ideas may eventually gain group acceptance. Research on the impact of minority opinions in groups (Dugosh et al., 2000; Larey & Paulus, 1999; Clapman, 2003) indicates that persistent minorities can have an impact on the beliefs of those holding the majority perspective. New generations that are not as committed to older paradigms are also likely to accept novel perspectives and exposure to minority perspectives can increase divergent thinking (Dugosh et al., 2000; Larey & Paulus, 1999; Clapman, 2003). The persistent effort by a creator to promote his or her ideas is thus a critical factor in innovation.

2.8 Pedagogical Methods for Improving Ideation

There are many educational programmes or methods that claim to improve ideation and innovation skills (Smith, 2003). Some of these focus on the stages of the innovation process and can be taught individually or in combination with other cognitive processes. These training programmes/methods aim to promote specific ways of generating ideas or teach the various stages in solving problems, from problem finding to solution implementation. They may also teach how to manage cognitive processes, in order to effectively alternate between the generation of ideas and the evaluation of ideas, and this section provides a summary of such methods. Some approaches/methods are designed for children whilst others focus on adults in educational or business settings. A few techniques focus on enhancing individual ideation whilst others teach people to work in groups: these include the popular techniques of idea writing, Delphi and nominal groups (Shavinina, 2003; Moore, 1987).

Some innovation training programmes place an emphasis on divergent thinking (see section 2.7.1) and one example of this is *Purdue Creative Thinking* (Shavinina, 2003; Callahan, 1973). In this programme, the teacher stimulates creativity by telling stories about famous people, offering techniques and exercises to enhance inventiveness: this is done to build up creative problem solving skills (see section 2.8.4) and self-confidence. Course content often includes 'mysteries' or 'detective' problems that require both convergent and divergent thinking, in order to be solved (Sikka, 1991).

The numbers of computer-based programmes supporting innovative thinking have increased and the VRLE is an example of such a programme. Some of these programmes consist of interactive games (Clapman, 2003; Doolitle, 1995): software guides individuals through brainstorming or the stages of problem solving (Shavinina, 2003; Markas & Elam, 1997; Rickards et al., 1978; Small, 1992). Other programmes generate extraordinary word associations (Clapman, 2003; Brown et al., 1997).

2.8.1 Problem-Need (PN) Identification

PN identifications are often included in techniques for innovative thinking (Hiley et al., 2007) and are also an important part of the IE process. Students are taught to use their inventor's notebook for recording and defining identified PNs (Jonsdottir, 2004, 2002). Guilford referred to PN as *sensitivity to problems,* which may imply an affective tendency rather than a cognitive skill (Clapman, 2003). PN identification can be defined, in general terms, as the process or processes that precede PN solving (Runco & Dow, 1999) and the specific processes of this include PN discovery; construction; expression; posing; definition and identification. PN finding is a process of discovery and is the initial part of the IE process: this involves the application of innovative thinking, which requires intellectual vision and insight (Hiley et al., 2007; Jay & Perkins, 1997).

*Many techniques for improving ideation reflect PN definition, rather than PN solvin*g, and an innovative solution may firstly depend on defining a PN innovatively (Jay & Perkins, 1997). PN identification plays an important role in IE, as the process starts in the students' own environment: they identify needs and problems at home. Part of IE depends on PN identification in strengthening the individual's ability to solve PNs in daily life (Gunnarsdottir, 2001). PN identification and definition is an important part of the innovation process: in its original or conventional form, a PN may have been exceedingly difficult (2.8.1). However, the solution to a PN may be obvious, once it has been properly defined and represented (Hiley et al., 2007).

2.8.2 Brainstorming

The brainstorming method was first proposed by Osborn (1967) and was developed by others (Davies, 2004). Osborn introduced this as a tool to support idea generation and used it in creative problem solving (CPS). Brainstorming should not be confused with the process of idea generation itself, nor that of creative problem solving (Nijstad et al., 2003).

Brainstorming is a technique for idea generation that has been incorporated into many creativity-training programmes (Nijstad et al., 2003; Rickards, 1999). Osborne's approach to improving ideation is based on the premise that the production of many different ideas increases the likelihood of formulating a high-quality idea; with this approach, idea generation is separated from idea evaluation. Proponents believe that the early evaluation of ideas restricts the process of idea generation and thus participants are taught to defer judgment until the idea generation stage has concluded.

Research has found that initial ideas are frequently overlooked as the most preferred (Santanen et al., 2004; Basadur & Thompson, 1986), supporting the contention that the effort in developing more ideas is beneficial. Brainstorming can be done either alone or in a group and in group brainstorming sessions the participants are encouraged to share their ideas with one another as quickly as they are generated.

The key to brainstorming is not to disrupt the flow of ideas by a reflection/analysis process: as ideas come to mind, they must be captured quickly and used to inspire the development of more ideas. Brainstorming may enhance creativity, as the generation of a broad range of ideas may lead to a unique and improved concept.

There is a strong case for group collaboration when brainstorming complex problems (Morgan & Davies, 2004; Osborn, 1967). Indeed, Osborn defines brainstorming as ‘a meeting technique through which a group attempts to find a solution for a particular problem by amassing all the ideas spontaneously by its members’ (1967:299). He also describes it as a means of group problem-solving that considerably increases the quality and quantity of ideas produced by groups (1967:300). He emphasis of brainstorming is on the presentation of as many deliberately extraordinary solutions as possible and on pushing the ideas as far as possible. Crucially, it was only ever seen by Osborn as an addition to individual ideation (see section 2.7.1) and was never considered a replacement. He was keen to emphasise the meaning of individual ideation, both before a brainstorming session and after, in achieving maximum creativity (Morgan & Davies, 2004).

According to Morgan and Davies (2004), a traditional brainstorming session typically comprises a group of four to fifteen people, working together in a room and suggesting ideas that are noted down, usually on a flipchart or blackboard, for analysis at a later stage. A facilitator should be present to introduce and organise the session and to ensure that the brainstorming rules are followed; the opening should involve detailing the purpose of that particular session and should include an outline of the rules of brainstorming.

Osborn (1967:300-302) defined four basic rules of brainstorming: all aim to support flexibility and fluency by overcoming motivational and social factors that can inhibit idea generation. The four rules are:

1. Criticism is ruled out; this includes self-criticism as well as the criticism of others. The judgement of ideas should be deferred until a later stage. The premise is that even a seemingly foolish idea can lead to better ideas.

2. 'Freewheeling' is welcome: the wilder the ideas, the better. Wild and exaggerated ideas are encouraged, as these may, in turn, introduce ideas that are more valid.

3. Quantity is required. The more ideas, the better, as this will increase the likelihood of a good idea and the chance of generating new ideas in others.

4. The combination and improvement of ideas is sought. The aim is to elaborate on and enlarge the suggestions and ideas of others and to use the ideas of others as inspiration for your own. At the same time, combinations of existing ideas can allow the exploration of new possibilities.

Brainstorming is an important tool in getting an IE class started or refreshed when students get tired in their individual work (see in chapter 5.0) and humour is sometimes considered as a form of inventiveness (Cayirdag and Acar, 2010; Howrigan & MacDonald, 2008; Kaufman et al., 2008; O'Quin & Derks, 1997). Very often students contribute to a brainstorming session in a humorous way: this makes them relax and facilitates the idea generation process (Cayirdag and Acar, 2010). Koestler (1964) noted the relationship between humour and creativity, stating that the structural pattern is the same in art, science and humour or 'the discovery of hidden similarities'. He characterised the outcome of that discovery as the *aah* of art, the *aha* of science and the *haha* of humour. A sudden change in the angle of vision on reality is the key to a humorous way of thinking, in addition to the type of thinking that supports ideation within the scientific and artistic fields (Kaufman et al., 2008; O'Quin & Derks, 1997).

Many research projects have focused on brainstorming (see section 2.8.2) and a good number of these indicate that individuals or nominal groups perform (in terms of number of ideas generated) better than verbally interactive groups (Rietzschel et al., 2006; Taylor et al., 1958; Paulus et al., 1995). The major reasons for this are blocking, social loafing and evaluation apprehension (Gallupe et al., 1992; Szymanski & Harkins, 1992). However, some of these projects indicate that participants believe they perform better in verbally interactive groups (Paulus et al., 1993; Stroebe et al., 1992). Within the context of the IE VRLE, students can brainstorm verbally inside of the classroom or alone through the computer screen and this is one of the important issues that may affect the new context of the IE pedagogy.

2.8.3 Computer Software Supporting Ideation

The number of computer-based programmes intended to support innovative thinking has grown and the VRLE is an example of this (see 1.3). Some support collaborative ideation, whilst others are individual based.

Electronic brainstorming is a technique: computers are networked and so the ideas of the group members can be entered from one participant's computer and shown on the screens of the other group members. Various brainstorming software is now available to facilitate the idea-exchange process and, at the end of brainstorming sessions, ideas are often summarised and evaluated by means of computer voting.

When groups use a computer-based exchange process, their performance may significantly improve (Valacich et al., 2006; Barki & Pinsonneault, 2001; Larey & Paulus, 1999). Research incorporating electronic brainstorming techniques indicates that electronic brainstorming (EBS) groups outperform (in terms of number of ideas generated) verbal groups and the performance difference grows as the group size grows (de Vreede et al., 2010; de Vreede & Dickson, 2000; Fjermestad & Hiltz, 2001; Briggs, 2006; Shepherd et al., 1996; Aiken & Riggs, 1993; Dennis et al., 1993; Gallupe et al., 1994; Valacich et al., 1994; Gallupe et al., 1994). However, the ability to enter ideas anonymously with electronic brainstorming may remove evaluation apprehension and production blocking: two suspected reasons for decreased idea generation in face-to-face, verbally interactive brainstorming.

Earlier research work (Connolly, Jessup & Valacich, 1990; Dennis et al., 1996; Dennis & Valacich, 1993, 1994, Valacich, Dennis & Connolly, 1994; Gallupe, Cooper, Grize & Bastianutti, 1994; Pinsonneault et al., 1999) shows a larger performance of computer-based groups, due to three factors (Valacich et al., 2006). Firstly, computer-mediated communication allows all group members to instantaneously enter ideas, thus reducing production blocking. Secondly, because group members can simply review the ideas of others, there are lower levels of redundant submissions, relative to no interacting nominal groups. Thirdly, because group members can easily review the ideas of others, there are opportunities for cognitive stimulation (i.e., synergy) and enhanced performance.

According to these research projects, the use of the VRLE might support the teachers and students' work in IE. The VRLE invites students to share needs, problems and solutions and they can easily review the ideas of others: this might give rise to the opportunity for synergy, becoming a cognitive stimulation and enhancing their performance.

2.8.4 Creative Problem–Solving (CPS)

The Osborn-Parnes' creative problem solving (CPS) process categorises problems into five stages, which are: fact-finding, problem finding, idea finding, solution finding and acceptance finding (Parnes, 1999). Participants learn different techniques to control cognitive processes at each stage of the creative problem-solving process through practice. Progressing through these stages requires an appropriate application of idea generation and idea evaluation and brainstorming methods are used during the process for idea generation (Clapman, 2003).

2.8.5 Synectics

Synectics is a method of supporting idea generation and was developed by Gordon and Prince (Prince, 2009; Clapham, 2003). Synetics means the 'joining of seemingly unrelated elements' (Clapman, 2003) and is a problem-solving approach that stimulates the thought processes which the subject is generally unaware of. Synetics includes all stages of the creative problem-solving process (see section 2.8.4) and focuses on the difference between idea generation and idea evaluation (Clapman, 2003).

The synectics approach depends on the understanding of that which is apparently different (Prince, 2009; Gordon, 1961) and its main tool is analogy or metaphor, or advanced brainstorming (see section 2.8.2). The approach, when used by groups, can help participants develop responses to problem solving by helping them change existing mindsets and internalise abstract concepts. The technique emphasises the non-rational elements of thinking, in the anticipation that such an approach can provide a novel and a fresh outlook on a problem.

2.8.6 Lateral and Vertical Thinking

Edward de Bono explored innovative thinking in his works and referred to his theory as 'lateral thinking' (Sloane, 2006; de Bono, 1970). De Bono defines 'lateral thinking' as methods of thinking concerned with altering concepts and views and states that there are two forms of thinking: *vertical thinking,* which incorporates the implementation and utilisation of already existing ideas ('digging the same hole deeper') and *lateral thinking,* which is concerned with the developing of new ideas ('digging a hole somewhere else') (Parnes, 1999). De Bono's programme focuses on cognitive strategies to raise the development of new ideas.

According to de Bono, two processes are necessary to enhance lateral thinking: 'escape' and 'provocation'. Escape is concerned with suspending judgment (Sloane, 2006; Murray, 1992) and De Bono stresses the importance of positive emotions for lateral thinking: strategies such as humour fantasy, and play are thus used extensively (Sikka, 1991). Provocation is the generation of new ideas stemming from provocative statements and is designed to challenge limitations. A novel idea that is borne out of lateral thinking is not always a useful one, but when a good idea *is* discovered in this way, it is usually obvious in hindsight; such a feature of lateral thinking is in common with a joke.

2.8.7 TRIZ

TRIZ is a methodology, tool set, knowledge base and a model-based technology for generating innovative ideas and solutions for problem solving. The founder Genrich Altshuller (1994) asserted how innovative solutions may be observed by scientific methods and, after having analysed 200,000 patents, he developed a Theory of Inventive Problem Solving (TIPS, also known as TRIZ) (Zhang & Cao, 2011).

In addition to the strong laws of technical systems evolution, Altshuller developed an Algorithm of Inventive Problem Solving for the practical outcome of his theory. The algorithm (known as TRIZ) is a set of steps for problem solving and the TRIZ text includes multiple rules, notes and examples, supported by information resources, tables of contradictions and inventive principles, a set of standard solutions and effects databases (physics, chemistry, geometry, etc.). Particular leaders assist to beat psychological inactivity on the journey to a solution (Clapman, 2003).

TRIZ provides the tools and methods for use in problem formulation, system analysis, failure analysis and patterns of system evolution (both 'as-is' and 'could be'). In contrast to techniques such as brainstorming, which is based on random idea generation, TRIZ aims to create an algorithmic approach to the invention of new systems and the refinement of old systems. TRIZ has been used by many companies, especially in the United States, to solve manufacturing problems and create new products (Zhang & Cao, 2011).

2.8.8 Hemisphericity

The hemisphericity approach to innovative training was influenced by Ned Herrmann and was based on the idea that the two hemispheres of the brain are specialised in managing different types of tasks (Clapman, 2003). The left hemisphere is more effective at performing tasks that require the sequential processing of information and the right hemisphere is more effective at performing tasks involving the simultaneous processing of information; thus, the right hemisphere is better able to make associations between remote elements.

Hemispheric innovative training strengthens the right hemisphere of the brain by incorporating information-processing tasks, thought to require the increased use of the right hemisphere. Other tasks require a more balanced use of both hemispheres (Clapman, 2003) and these rely on imaginary techniques and relaxation, through art and music. Such tasks also incorporate physical and sensory exercises, including hetero-lateral walking, a form of walking in which the opposite arm and leg are forward, and upside-down drawing (Carter, 1983).

However, statements that assert that the right side of the brain is responsible for creativity are very broad generalisations, with little supporting research. It is important to emphasise that there is much about the brain which is not understood by scientists, but it *is* clear that processes like creativity, emotion, spatial reasoning and logical reasoning involve regions spread across the brain (Carter, 1983).

2.9 Research Studies Related to the Development of Ideation Skills in Education

This section identifies general avenues for developing ideation skills. Ideation is concerned with the social environment (see sections 2.3.3 and 2.7) and a number of techniques for improving ideation are directed at improving the individual from within, while other techniques are aimed at improving the environment in which the individual performs. The influence on ideation caused by changing conditions in the environment is referred to as 'the social facilitation or inhibition of ideation' (Clapman, 2003).

The majority of recent studies examining the development of students' ideation skills have focused on training pupils in educational settings (Clapman, 2003) and these studies were based on two suppositions:

1. It is naturally beneficial for the students.
2. It can make students more innovative, in relation to future employment.

A literature search identified a few studies that aimed to examine the development of young students' ideation skills, employing differing methods. All of these enquiries examined the improvement of student ideation and three of them examined how in-service teacher training affected teachers' attitudes and student performance in a conventional classroom. These projects differed from this study, in that they had different aims and used different research methods; however, the author found it useful to look at them, as they indicate how ideation training affects students and teachers in different school contexts. Some of the studies used *Torrance Tests of Creative Thinking* (TTCT) as criteria. This is based on Guilford's (1954) work and involves simple tests of divergent thinking and other problem-solving skills, which are scored on:

- Fluency: The total number of interpretable, meaningful and relevant ideas generated in response to the stimulus.
- Flexibility: The number of different categories of relevant responses.
- Originality: The statistical rarity of the responses among the test subjects.
- Elaboration: The amount of detail in the responses.

Markewitz (1982) found that 12 sessions of divergent thought had a significant effect on children, according to kindergarten TTCT flexibility scores. Jaben (1983, 1986) found that a 12-week training course based on creative problem-solving (see section 2.8.4) had a positive impact on the verbal fluency, flexibility and originality scores of behaviourally disordered children and those with learning disabilities.

Rabari et al. (2011) explored whether divergent thinking could be utilised to enhance innovative thinking amongst physics students in Nairobi and there were significant associations between divergent thinking scores and innovative attitude, critical thinking, extent of play with toys and originality. Furze, Tyler and McReynolds (1984) trained young students and artist educators for 14 weeks in a classroom with different principles and measured the originality of produced ideas. These studies indicated that extended programmes with an emphasis on ideation can have a significant positive impact on children's divergent thinking. One of the studies involved experts as evaluators of the students' ideation. Baer (1994) trained eight-year-old students in 16 one-hour sessions in divergent-thinking (see section 2.7.1). These lessons focused on brainstorming (see section 2.8.2) and showed significant improvements in the ideation skills (see section 2.3.3) concerning various verbal tasks, such as writing stories, telling stories and writing poems.

Studies conducted with teenagers from both gifted and non-gifted programmes yielded mixed results, with the studies involving brainstorming (see section 2.8.2) or the CPS (see section 2.8.4) generally showing positive results. Baer (1988) used CPS with other techniques, such as synectics (see section 2.8.5), over a period of three days of training and, six months later, found a considerably positive effect on creative problem solving scores.

Mountain (1996) found that the learning process for invention (see section 2.3.7) had a positive impact on divergent thinking, verbal skills and the number of ideas produced as invention. Although the study did not show a positive effect on the quality of ideas, the author was concerned with the theory and technique of educational and psychological measurement, which includes the measurement of knowledge, abilities, attitudes and personality traits. He referred to the psychometric properties of the measure to evaluate the quality showed in his study. Kovac (1998) trained a group of students brainstorming and imagination over a period of 10 months and the training group received higher flexibility scores than the control group. Russell & Meikamp (1994) demonstrated, through brainstorming exercises (see section 2.8.2), the positive effects of the meta-cognitive strategy on regular students, the gifted and the disabled.

LeRose (1987) conducted a 12-year longitudinal study on gifted students, beginning in kindergarten. Students in the experimental groups learned various divergent thinking strategies and showed higher TTCT flexibility scores in the 1st and the 9th grade than a comparison group of gifted students. Heiberger (1983) examined the effects of workbook activity sheets several hours a week for much of the academic year, featuring the 2nd-7th grades (ages 8-12), and found such activity increased scores on the figural TTCT.

Studies exploring the effects of providing teachers with ideation training have also yielded positive effects. McConnell and LeCapitaine (1988) found that students' ratings of teacher acceptance and openness to new ideas improved in classes run by teachers who participated in 40 hours of Synectics training (2.8.5).

The literature also indicates that the use of computer software in supporting idea generation is effective, with regards to learning (Nakakoji, Yamamoto & Ohira, 1999; Sturm & Rankin-Erickson, 2002; Nishimoto, Mochizuki, Miyasato & Kishino, 1994). Research findings generally showed that participants perform better in a concept mapping environment with computer support. Their attitude to learning also improved.

2.10 Virtual Reality Learning Environments

In this section, the author defines and describes the characteristics of the VRLE technology relating to this project and how it can be used in schools to support education. VRLEs are being used in many contexts, including industry and the armed services, but in this project the focus is upon its application within a school context and the impact on pedagogy.

This is a relatively new area of research and many new terms have subsequently emerged without clear meaning. Thus, it becomes particularly important to define the terms used in this project and to relate them to the literature.

2.10.1 Virtual Reality Learning Environment (VRLE) and Related Terms

The specific software used for this project is a basic Virtual Learning Environment (VLE), adapted to the needs of working with IE material and inside of the innovation process. In addition to the traditional virtual learning environment, it has a virtual reality environment (see figure 2.4) element, in order to support further computer collaborative learning communication. Thus, the author has chosen to refer to it as a Virtual Reality Learning Environment: a term that underlines the educational use and background of the work. The VRE element includes components in which students and teachers can participate in online interactions of various kinds when they are working throughout the innovation process. It underlines the possibilities of computer collaborative learning communication support and allows students and teachers in IE classes to explore and manipulate the 3-dimensional computer generated virtual reality environment in real time. The VRLE also includes an underlying database that meets the user's expectations as an educational environment (Innoed, 2011). Data may be revisited and treated like educational documents.

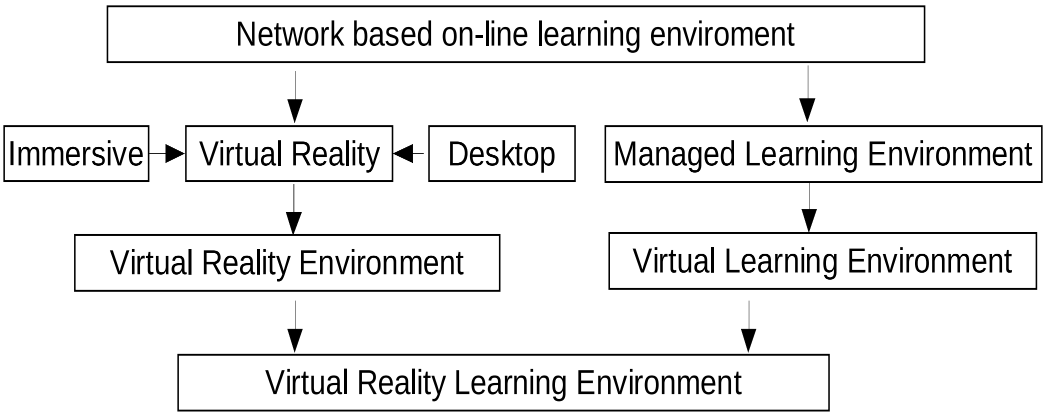

Figure 2.4: The diagram shows the relationship between the various online learning environments.

A Virtual Learning Environment (see figure 2.5) is a computer programme that facilitates computerised learning and can be used both in the context of open and distance learning and as a support for face-to-face education within a conventional school context. Example of such computerised learning systems include the Learning Management System (LMS), the Course Management System (CMS), the Learning Content Management System (LCMS), the Managed Learning Environment (MLE), the Learning Support System (LSS) and the Learning Platform (LP); these provide education via computer-mediated communication (CMC) (Paulsen, 2003).

Virtual learning environments are commonly considered learning environments mediated by computers and digital technology (Weiss, 2006) and Wilson (1996) defines the VLE as ‘a computer-based environment that is a relatively open system, allowing interactions and encounters with other participants and providing access to a wide range of resources’ (1996:8). The Joint Information Systems Committee (JISC, 2002) defines virtual learning environments as components in which learners and tutors participate in online interactions of various kinds, including online learning.

A virtual learning environment (VLE) (see figure 2.5) is a software system designed to help teachers facilitate the management of educational courses, especially by helping both themselves and learners with course administration. The system can often track learners' progress and may be monitored by both teachers and learners. Whilst primarily thought of as a tool for distance education, it is most often used as a supplement for face-to-face classroom instruction. The learning environment in a VLE is usually a series of web pages with appropriate links, applications and interactive capability.

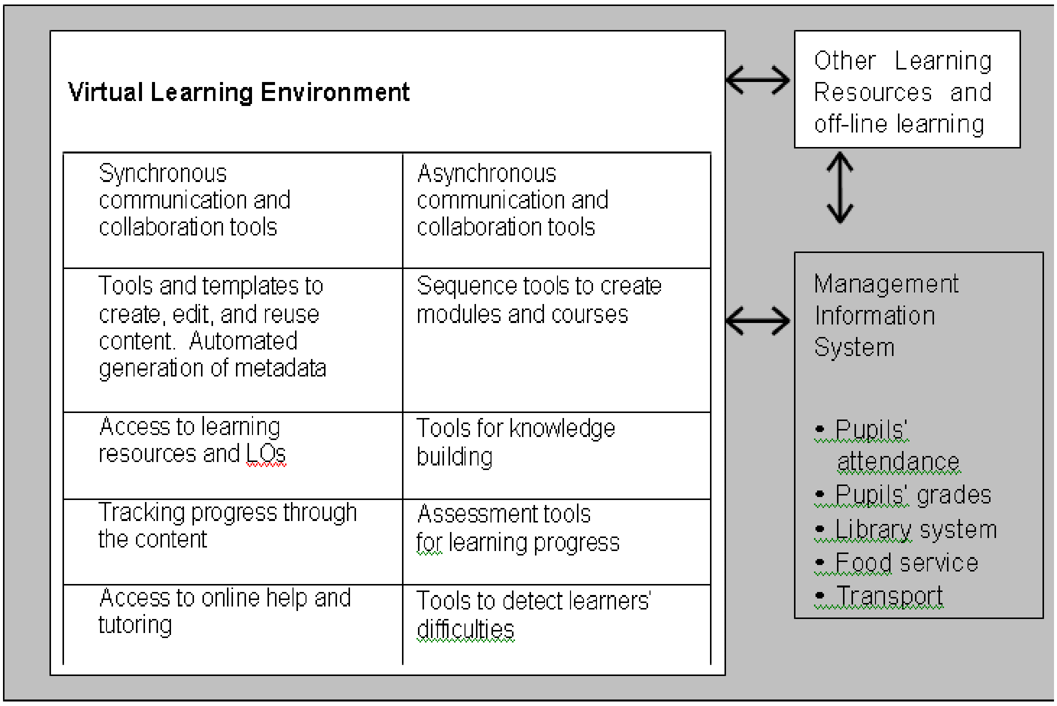

Figure 2.5: The figure represents some of the possible features of a VLE that can be linked with school's Management Information System (Vuorikari, 2004:9).

Hall (2001) describes VLEs (see figure 2.5) or Managed Learning Environments as terms used to describe a wide range of applications that track student training and may include functions such as:

- Authoring
- Classroom management
- Competency management
- Knowledge management
- Certification or compliance training
- Personalisation
- Mentoring
- Chat
- Discussion boards

The services provided by VLEs are aimed at teachers, pupils, administrative personnel and parents. Access to the VLE is via the Internet or an intranet and there is usually an option to work offline. A key characteristic of the VLE is that learning can take place 'anytime, anywhere' and is not dependent upon the traditional school timetable or whether the learning is taking place inside or outside the school building. It is therefore preferable that the VLE is connected to the users' schools Management Information System (Vuorikari, 2004:9), as illustrated in figure 2.5.

2.10.2 Virtual Reality Environment (VRE) and Related Terms

The term *Virtual Reality* (VR) was initially coined by Lanier (1989) and other, related terms include *Artificial Reality* (Krueger, 1970s), *Cyberspace* (Gibson, 1980s) and, more recently, *Virtual Worlds* and *Virtual Environments* (1990s) (McLellan, 2003; Kruger, 1991; Gibson, 1984). Virtual Reality Environment is used today in a variety of ways, but often in a confusing manner. Originally, the term referred to *Immersive Virtual Reality* and, in this, the user becomes fully immersed (see section 2.10.2.5) in an artificial, three-dimensional world generated by a computer.

Cruz-Neira, Sandin and DeFanti (1993) consider the term *virtual reality environment* better than *virtual reality,* as it incorporates the ability to touch, hear, and smell: to act on the environment. *Virtual learning environment* implies a total substitution of something synthetic for something real, whereas *virtual reality environment* is more suitable as a facsimile for a real or imagined environment; e.g., when using a computer screen presenting a virtual world, possibly including audio.

Virtual Reality Environments (VREs) can be described as a new communication technology that involves the human senses in new ways and allows the user to intuitively interact with data (McLellan, 2003). It can further be defined as *'the idea of* human presence in a computer-generated space' (Hamit, 1993:9) or, more specifically, 'a highly interactive, computer-based, multimedia environment in which the user becomes a participant with the computer in a virtually real world' (Pantelidis 1993:23).

According to Loeffler and Anderson (1994), there are four main elements of a virtual reality environment: it is three-dimensional, computer-generated, a simulated environment and it is rendered in real-time, according to the behaviour of the user. VRE has also been described as a communication tool and it can be used as a multi-user or single-user VRE communication interface. VREs have been used for many different purposes, but the most common applications are probably games and occupational simulators. However, VREs are also used for educational training and online meetings, as in this project.

Some claim that the VRE is no more than a direct addition of multimedia systems (Dede, 1995), yet a VRE has its own unique characteristics that might be used to improve students' understanding and learning performances. It is therefore important to identify the unique characteristics of the VRE that may improve this understanding and performance in an educational context. These characteristics can then be manipulated as independent variables in experimental studies of VRE.

Zeltzer (1992) has proposed a framework regarding the characteristics of a VRE, along with three dimensions that he refers to as *autonomy*, *presence* and *interaction*. There are also other important characteristics of VREs, such as autonomy, that are useful for understanding the application of VREs and the following sections describe these concepts.

2.10.2.1 Interaction and Control in a VRE

Virtual Reality Environments offer different modes of interaction and control and these have been considered as factors that give the user the feeling of being in the VRE (Ogle, 2002; Witmer & Singer, 1998). The environment offers the user different interaction techniques, including navigation, selection, manipulation and system control, in order to interact with and manipulate the environment (Vince, 1999c). These techniques play a significant role in the IE VRLE users' immersion, or presence.

2.10.2.2 Navigation

In most virtual environments, the user has the freedom to navigate from one place to another, via various routes. If a student travels around the VRE, they may explore locations, search the environment and manoeuvre within the environment (Bowman, 2000). This can establish a mental model of the architecture and a feeling of the space (Ogle, 2002).

According to Bowman (2000), there are different metaphors for travelling in virtual environments:

- *Steering* is a continuous specification of the direction of motion, often through pointing, using the mouse or a joystick.
- *Target-based* involves the discrete specification of a goal through pointing, choosing from a list, etc.
- *Route planning* includes the arrangement of a path to be travelled by placing markers or moving icons on a map of the environment. This can be done with the mouse.
- *Manipulation* is from the user's viewpoint and entails moving about and around some fixed object.
- *Natural* involves the use of a physical device, such as a bicycle for riding or an aircraft simulator for flying.

Wayfinding is a term that includes exploring and searching the environment, building a cognitive and spatial map of a VRLE. This is usually performed from one of two perspectives: egocentric or exocentric (Ogle, 2002). The egocentric reference frame involves an awareness of objects relative to the user's eyes, head and body, whilst the exocentric reference frame is the awareness of objects relative to the position and orientation of an object outside the user's body.

2.10.2.3 Selection and Manipulation

The terms *selection* and *manipulation,* in terms of a VRE, are closely related. Manipulation is the modification of the properties of an object or objects that must be selected prior to being manipulated, while common techniques for selecting objects in virtual environments include touching, naming and indirect selection (Bowman, 2000).

Once selected, common goals of manipulation include moving and placing objects for design, layout or grouping, using objects as tools and using objects for travelling. Common metaphors for manipulation include a *virtual hand*, *hand position mapping*, *indirect depth mapping*, the *scaled-world grab* and the *world-in-miniature* (Ogle, 2002).

2.10.2.4 System Control

System control is an interaction technique that makes use of other interaction techniques, such as selection and manipulation (Bowman, 2000). System control interactions usually involve tasks such as issuing commands to the system and selecting a tool and such control is often enabled through floating menus, voice recognition, gesturing and posturing and implicit controls (Ogle, 2002).

2.10.2.5 Immersion and Presence in Virtual Reality Environments

Witmer and Singer (1998) define immersion as the ‘perception of being enveloped’ in a virtual environment. *Immersion* is a term used in the sense of presence (McLellan, 1996; Winn, Windschiti & Thomson-Bulldis, 1999) and a strong sense of presence in a virtual reality environment has been considered a factor in the overall enjoyment of the experience. However, immersion differs from presence, as it is the physical blocking of the senses from outside stimuli. Immersion increases in accordance with an increase in the amount of sensory information provided by the system (Ogle, 2002). Immersion is considered a factor in the sense of presence: the product of a sense of immersion or presence in a virtual environment is an improved perception (augmented) of the realism of the experience (Winn, Windschiti & Thomson-Bulldis, 1999). Witmer and Singer (1998) state that, the greater the sense of immersion, the greater the sense of presence will be; they also argue that the sense of immersion is different for everyone.

2.10.2.6 Embodied Interaction in a VRE

The Oxford Dictionaries Online (2011) defines the term *avatar* as the manifestation of the human form or incarnation. Among people working in virtual reality environments, an avatar is a representation of a user in a shared virtual reality. An avatar is an Internet user's representation of themselves, whether in the form of a three-dimensional model used in computer games or a two-dimensional icon used on Internet forums and other communities.

With the availability of low-cost desktop virtual reality environments, real-time interactive 3D graphics have become a reality for many computer users and, over the past few years, a variety of desktop-based virtual reality environments have been created to enable social interaction. Nevertheless, their users’ interfaces do not yet promote a strong sense of user embodiment (Cuddihy & Walters, 2000); this is illustrated by the lack of clearly defined mechanisms for allowing rich interactivity between avatars and other objects.

The user’s control over their avatar, their personal representation within the virtual reality environment, is currently limited but nonetheless important. The concept of VRE is linked to the feeling of being in a location and a social setting other than where you actually are and this means that you can control an avatar or another device at a distance. Different communication and embodiment representations, such as the avatar representation, may also give the sense of emotional presence (Lehtonen, Hyvönen, & Ruokamo, 2005).

2.10.2.7 Autonomy of a Being in a VRE

The Oxford Dictionary (2005) defines autonomy as ‘liberty to follow one's will, personal freedom’. Autonomy reflects the degree to which the virtual environment functions on its own or without the user input. Systems with low autonomy, like many tutorials and drill and training programmes, do nothing until the student enters an answer to a question or clicks on a navigation icon. Highly autonomous environments, however, follow their own goals; they evolve and develop whether the user does anything or not. In self-directed environments, the student and the programme may be collaborators or adversaries. *Autonomy* is also related to the user’s ability to control the system and to take part in a multi-user VRE collaboration as an avatar.

2.10.3 Different Virtual Reality Environments (VRE)

Researchers use different classifications of VREs (see figure 2.3). However, two main types of technologies exist: immersive virtual reality environments (hardware VREs) and desktop-based virtual reality environments. Desktop-based VREs are based on traditional input/output devices such as monitors, mouse devices, keyboards, microphones and speakers, whilst immersive VREs may use simulators, data gloves or body suits, shared workbenches, etc. Immersive VREs are not suitable tools for everyday application, due to the high cost.

Web based ‘virtual tours’ are an example of a commonly available desktop virtual reality. Desktop-based VREs can be structured according to technological advancement and system-inherent properties (Schwienhorst, 1998) and this makes them fairly useful for the purpose of Innovation Education learning. The VRLE technology used in this research is a desktop-based version and provides a flexible, easy-to-use, multiple-user virtual reality that allows the integration of ideation learning tools and resources in a common environment (InnoEd, 2011).

Immersive virtual reality environments are presented on multiple room-sized screens or through a stereoscopic, head-mounted display unit. Additional specialised equipment, such as the data glove (worn as one would a regular glove), enables the participant to interact with the virtual environment through normal body movements. Sensors on the head unit and data glove track the viewer's movements during exploration and provide feedback that is used to revise the display, enabling real time, fluid interactivity. Examples of virtual reality environments include a virtual solar system that enables users to fly through space and observe objects from any angle, a virtual science experiment that simulates the growth of microorganisms under different conditions, a virtual tour of an archaeological site and a recreation of the Constitutional Convention of 1787.

2.10.4 Specific Software Used in this Enquiry (developed from section 1.3**)**

As the software used in this work is a virtual learning environment (VLE) and includes the InnoEd virtual reality environment (VRE), it has been named a virtual-reality learning environment (Furness, 1988). Hall (2001) defines the virtual learning environment or e-learning environment as an 'all-in-one solution software designed to facilitate online learning for an organisation' (see section 2.10.1). Such an environment includes the functions of a learning management system for courses within the virtual learning environment, in addition to teaching and learning materials. It is characterised by an interface that allows students to register and partake in courses and the learning environment usually includes self-instructional portions, along with an academic structure. A teacher often facilitates this model as instructor, where a group can proceed on a week-to-week basis with seminar assignments (Paulsen, 2003).

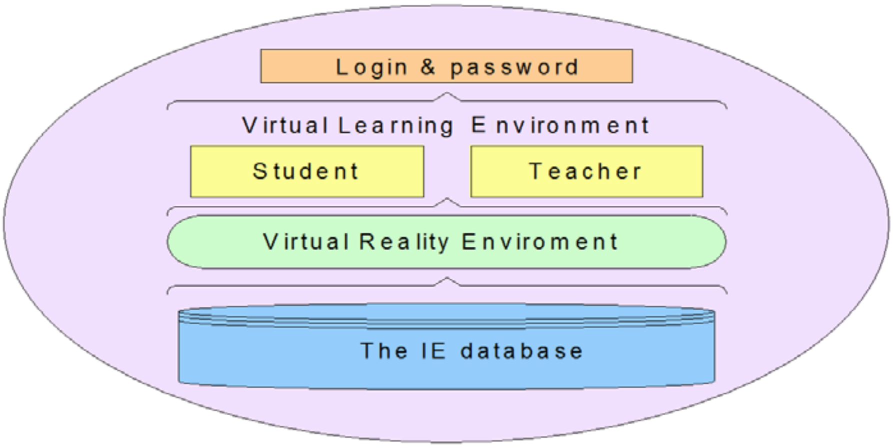

Figure 2.6: The VRLE is a combination of the Virtual Learning Environment and the Virtual Reality Environment. The students' work is hosted in the IE database.

The original idea behind the InnoEd VRLE was to find a new way of supporting ideation, using virtual tools inside a virtual learning environment (InnoEd, 2011). The VRLE is accessed from the InnoEd site (http://www.innoed.is) and it includes an e-mail system, a discussion forum and all features associated with content delivery and evaluations. Students can record identified needs and solutions and share them with others as text and drawings. The immersive VRLE 3D VRE-interface comprises of numerous functionalities: eight predefined avatars are available, which represent the user as a human (as a child and an adult), and these keyboard-controlled avatars perform five movements: nodding or shaking the head for yes or no, gesturing 'come here', waving hello and shaking hands with the right hand. Regarding communication functionalities, the 3D environment offers chat; audio; PowerPoint slide projection screens; websites; file sharing screen; smart board and video board. The 3D VRE part of the VRLE features different physical places where avatars can meet and these are the main entrance; classrooms; group workroom; conference room and corridors (Vézina, IsaBelle, Fournier, Dufresne & Doucet, 2004).

Being in a VRLE that offers VRE possibilities may give the student more freedom to think and act independently and communicate without borders (Vezina et al., 2004), (see figure 2.7 and section 2.10) as they can communicate with the outer world through the Internet. They can also access knowledge from many Internet sources and bring their ideas to fruition, with their work based on the IE innovation process.

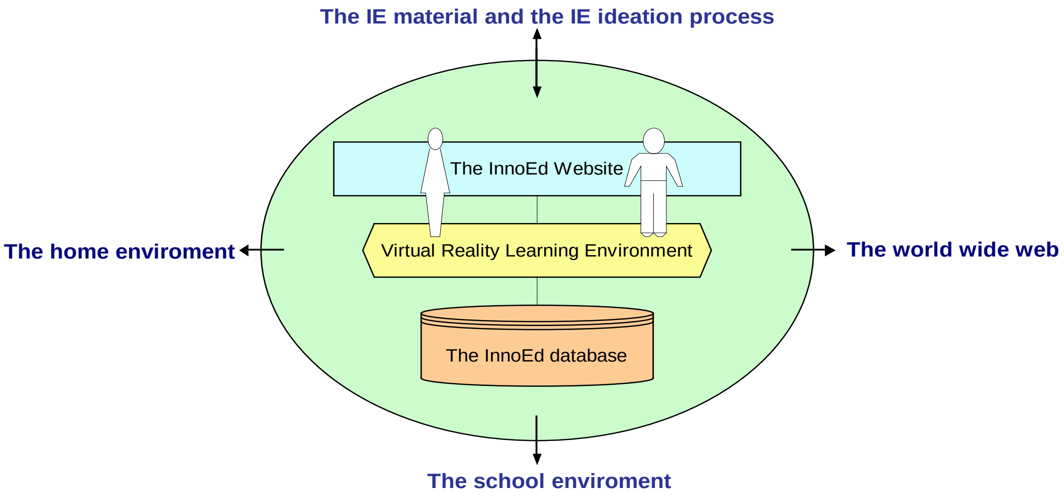

Figure 2.7: The VRLE opens many possibilities for communication and access to knowledge.

2.11 VRLE Technology for Education and Training

Many educational researchers believe VRLE technology offers benefits that derive from the capacity to support computer based collaborative supportive learning and constructivist-learning activities (Rose et al., 1996; Jonassen, 2000; Jonassen et al., 2008; Cavanagh, 2004). Another value is its potential to provide different forms of learning to support different types of learners, such as visually orientated learners. Several research projects sought to establish learning within a very general educational setting (see section 2.12), whilst a few studies have investigated the impact of immersion on the effectiveness of VRLEs. However, most of the studies aimed to observe whether or not a VRLE is an effective educational technology (Johnson et al., 2002; Song et al, 2000; Dede, 1995; Winn, 1993; Bricken, 1990; Osberg, 1996). Some of these research projects involve short-term studies, whilst others are based on longer case studies that develop virtual worlds for schools.

VRLEs have an important role to play in education because the user's interaction in a virtual environment can represent any three-dimensional world, whether real or abstract. For example, a virtual world may represent a building; the human body; underwater; a cruise; outer space; a museum; a crime scene or a dinner party (Jung, 2002).

Many educators and researchers support the view that VRLEs offer the opportunity to experience environments which, for reasons of time, distance, scale and safety, would not otherwise be available to many young children, especially those with disabilities (Cromby et al., 1995). The VRLE technology can be used to explore, create, play and learn in virtual scenarios, such as crossing roads, talking with strangers or emergencies. Through this technology, young children can experience places that would otherwise be impossible, impractical or too dangerous to visit.

A VRLE can be used to support collaborative learning and socially orientated theories of learning, using computer technologies to support collaborative methods of instruction. Instructional design is characterised by a systematic and reflective process of applying the principles of learning and instruction to develop instructional materials, activities, information resources and evaluation (Paulsen, 2003).

2.12 VRLEs at School Level

Many reports and demonstrations have been written on VRLE projects in education. However, studies regarding school education and children are still few and tend to be at a pilot level, rather than fully developed. So far, none have been found that concern the supporting of ideation within the context of innovation education. The majority of studies reported included positive indications, such as improved motivation and learning, and enjoyment in using the VRLE (Ainge, 1996; Johnson, Moher, Choo, Lin & Kim, 2002). Nevertheless, it is still unclear if VRLE support would appeal to students using the technology frequently over a long period and whether it would offer effective curriculum enhancement. Novelty effects might also be dominating at this stage and the positive outcome is therefore not as reliable as well designed, long-term research (Cohen et al., 2005).

2.13 Pedagogical Models for Using VRLEs in Education

This section reports the educational theories identified as relating to VRLEs in education. VRLEs used inside the conventional classroom largely relate to three main areas of educational theory: constructivism, computer supportive collaborative learning and computer mediated communication.

Approaches that represent a shift in instructional strategy (Graham, 2006) are often described as blended learning and virtual reality learning environments can be considered as such. Blended learning is usually defined as the use of multiple approaches to learning and it can be a combination of web-based and face-to-face learning (Graham, 2006). Blended learning can also be accomplished using 'blended' virtual and classroom resources. In the strictest sense, blended learning is where an instructor combines two methods in the delivery of instruction.

A virtual-reality learning environment is a place where students can access a multitude of learning experiences and share them with each other. By offering a three-dimensional, multi-sensory learning environment, coupling students' natural behaviours with the VRLE's functionality, participants are able to feel a strong sense of virtual presence (Zeltzer, 1992; section 2.10.2.5). The value of such an experience might provide the abilities essential for learning, as interacting in a VRLE involves 'purposeful movement that coordinates the cognitive, the psychomotor and the emotional domains' (Harrow, 1972:5). Students are engaged in their learning tasks and are helped to construct their own knowledge within a social context.

Children actively construct their personal categories of thoughts about the world (Piaget, 1929) and encouraging students to construct their own knowledge is demonstrably effective in learning (Jonassen et al., 2008; Spiro & Jeng, 1990; Jonassen, 2000; Cavanagh, 2004). In many instructional settings, students acquire only facts, rather than the tools for problem solving: they seldom experience problems in the conventional context that makes information relevant and useful and, subsequently, they may not or do not understand the value of digital information (Herrington & Oliver, 2000; Catanach, et al., 2000; Freeman et al., 2008; Sundem, 1994; Bransford et al., 1990). VRLEs are environments in which participants can create, manipulate and edit many forms of digital information. Objects, processes and programmed inhabitants of the virtual world are also elements for active problem solving (McLellan, 2004), where digital information can be useful and practical.

Vygotsky (1978) stated how 'human learning presupposes a specific social nature and social process' (p88). VRLEs can be networked to provide shared environments that enable Internet or network-based communication and collaboration between local and/or distant participants and the capability of sharing experiences through collaboration in multiple-participant virtual reality learning environments can make the social learning experience stronger (Brown et al., 1988; Cavanagh, 2004). Co-creating in virtual worlds for learning also allows teachers and students to use computers in a cooperative group situation, where, according to Belkin and Gray (1977), learners tend to be more productive.

Recently, many researchers have been looking at the possibilities of using Virtual Reality Learning Environments to support different areas in education. Many of these have based their work on a model of social constructivism, computer mediated communication (CMC) and computer supported collaborative learning (reported in the following sections), which focuses on giving individual learning support. This research is based on the early IE pedagogical model, but is also interconnected with these three pedagogical theories. In this work, these theories will be used to understand the dynamic social activities in IE classes when the VRLE is used and to develop the IE model further. The theories support VRLE activity in harmony with the already defined IE pedagogical model (see section 2.5.3).

The development of individual ideation is one of the underlying pedagogical processes of the IE pedagogical model (see section 2.5.3). VRLEs offer multiple options for Computer Mediated Communication (CMC) and such communication enables Computer-Supported Collaborative Learning (CSCL) (see further in section 2.13.2) as a support to individual work. This work looks at social interaction in the conventional classroom where the VRLE is used, in order to understand how it affects the IE pedagogical model. Such research concerns the teacher's role and the students' methods of working as individuals and within a group.

2.13.1 Constructivism Learning

Constructivism is considered a suitable theoretical background for VRLEs (Jonassen et al., 2008; Dede, 1995; Winn, 1993; Rose, et al., 1995; Jonassen, 2000; Cavanagh, 2004) and this is based on two assumptions:

1. Knowledge is constructed through social negotiation;

2. This knowledge construction is, to some extent, subjective; we all experience the same world, but we interpret it differently, according to our own knowledge and beliefs (Winn, 1993).

Thus, constructivists argue for a learner-focused environment in which the learner can explore a knowledge area and construct knowledge of that area through a combination of collaboration, discussion with their teacher, self-assessment and reflection (Ogle, 2002).

The constructivist learning theory was introduced by Jean Piaget and views individuals as active in constructing their knowledge of self and the environment; instruction is a process that supports the construction of knowledge, rather than the communication of knowledge (Duffy & Cunningham, 1996). Constructivists agree that there is meaning in the world around us, but state that we construct this through our experiences and perceptions (Duffy & Jonassen, 1991; Jonassen et al., 2008; Cavanagh, 2004). Meaning is different for each individual and learning is a process of interacting with others and the objective world.

There are many different directions inside of the theoretical background of constructivism. However, there are three main categories: Piaget's constructivism, Vygotsky's constructivism (Vygotsky's social cultural theory) and social constructivism: all include the same main characteristics for teaching and learning. Two of these are complex: real-life environments and social interaction. Central to the vision of constructivism is the notion of the personnel as ‘active’, with students' mental structures formed, elaborated and tested until a satisfactory structure emerges. Evolving constructivist perspectives on learning have fuelled interest in collaboration and cooperative learning.

2.13.1.1 Piaget's Constructivism

Piaget’s contribution to constructivism was an understanding of the development of learning in children (Shunk, 2000) and the key concepts identified as appropriate for learning at any age were assimilation, accommodation, equilibration and schemas (Bhattacharya & Han, 2001).

Piaget's two major principles, adaptation and organisation, guide intellectual growth and biological development. To survive in an environment, individuals have to adapt to physical and mental stimuli (Shunk, 2000) and assimilation and accommodation are both part of the adaptation process (Bhattacharya & Han, 2001). Piaget believed that peoples' mental structures assimilate outside events and then convert them, in order to fit in with their own mental structures. Furthermore, mental structures accommodate themselves to new, unusual and constantly changing aspects of the external environment (Shunk, 2000).

Organisation, Piaget's second principle, refers to the nature of these adaptive mental structures. Piaget suggests that the mind is organised in a complex and integrated manner, with the simplest level being the schema, a mental illustration of some physical or mental action that can be performed on an object, event or phenomenon (Bhattacharya & Han, 2001).

2.13.1.2 Vygotsky's Constructivism (Vygotsky's Social Cultural Theory)

Vygotsky, along with other educational psychologists, developed a theory of developmental cognition, which is now referred to as social cultural theory. His work underlines the fundamental role of social interaction in the development of cognition (Vygotsky, 1978; Wertsch, 1985), with its emphasis on the community role in the process of 'making meaning'. Vygotsky stated how 'learning is a necessary and universal aspect of the process of developing culturally organised, specifically human psychological functions' (1978:90). In other words, social learning tends to come before development (Galloway, 2001): this is in marked contrast to Piaget's theory that children's development must come before their learning.

Vygotsky's theories on cognitive development are based on two main principles: the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD). The MKO is, to some extent, self-explanatory: it refers to someone who has a higher ability level or a better understanding than the learner and who deals with a particular task, process or concept and has respect for it (Galloway, 2001). The MKO does not have to be a teacher or an older adult; a child's peers or an adult's children may possess more knowledge or experience. The MKO does not even have to be a person: it may refer to software-based tutors, such as the IE VRLE used to facilitate and guide students through a learning process.

The Zone of Proximal Development and MKO form the basis of the scaffolding component of the cognitive apprenticeship model of instruction (Galloway, 2001). Vygotsky (1978) defines the ZPD as the distance between the 'actual developmental level, as determined by independent problem solving, and the level of potential development, as determined through problem solving under adult guidance or in collaboration with more capable peers' (p86). Vygotsky considered that a student at the ZPD, undertaking a special task and provided with suitable help (scaffolding), would get the sufficient 'boost' needed to fulfil the task. When the student masters the task, the scaffolding can then be removed and the student will be able to do it again on his own.

2.13.1.3 Social Constructivism

Social constructivism is a variety of cognitive constructivism that focuses on the collaborative nature of learning (Derry, 1999 & McMahon, 1997; Kukla, 2000; Mallon, 2007). This perspective is closely associated with many contemporary theories, such as the social developmental theories of Vygotsky and Bruner and Bandura's social cognitive theory (Shunk, 2000).

Social constructivism builds on particular assumptions concerning reality, knowledge and learning. In order to recognise and use models of instruction rooted in social constructivism, it is important to be familiar with the presumption that underlies them (Kim, 2001). Social constructivists consider reality as constructed by human action; members of a society invent the property of the world together (Kukla, 2000). The reality cannot be discovered, as it does not exist prior to its social invention (Kim, 2001). Knowledge is also a human invention and socially and culturally constructed (Cavanagh, 2004; Ernest, 1998; Gredler, 1997; Prawat & Floden, 1994). Individuals create meaning through their communications with each other and their environment (Kim, 2001).

Social constructivists view learning as a social process (Kim, 2001). Learning does not just happen inside an individual; it is not an inactive development of behaviours shaped from outside forces (McMahon, 1997). Learning has meaning when individuals take part in social activities and, for social constructivists, it is very important how learning occurs and the social contexts learners bring to their learning environment.

Social constructivist activities are often based on collaborative learning methods, such as reciprocal teaching; peer collaboration; cognitive apprenticeships; problem-based instruction; web quests and anchored instruction (Shunk, 2000). Such activities concern the relationship between people and their environment, with people a part of this man-made environment: this is one of the characteristics that shapes an individual (Bredo, 1994 & Gredler, 1997), as people interact with the environment. If the environment and social relationships within a group change, the tasks of each individual subsequently change (Bredo, 1994 & Gredler, 1997). Thus, learning should not take place in isolation from the environment (Kim, 2001; Jonassen et al., 2008; Cavanagh, 2004). Gredler (1997) and Prawat & Floden (1994) believe that students should take part in social learning activities that engage hands-on, project-based methods and the utilisation of discipline-based knowledge-making tools. Such students then produce a product as a group and give it meaning during the social learning process. Of course, individuals can also work on individual assignments in a socially collaborative manner and probably gain from this, as constructivists have predicted.

2.13.2 Computer-Supported Collaborative Learning

Collaborative learning is usually defined as a situation in which two or more people learn or work together, but usually with different goals (Dillenbourg, 1999; Chiu, 2000). Students engaged in collaborative learning capitalise on one another’s resources and skills and this can include evaluating each other’s ideas, asking one another for information and monitoring each other’s work (Chiu, 2000).

Computer-supported collaborative learning (CSCL) can, however, be defined as computer-based network systems that support group work for a common purpose and provide a shared interface for groups to work with (Ellis et al., 1991; Stahl et al., 2006). CSCL is related to Computer Supported Cooperative Work (CSCW): CSCW aims to facilitate group communication and productivity, whilst CSCL supports students in learning together effectively (Stahl et al., 2006). Within the classroom, collaborative work entails a group constructing new knowledge interactively by helping each other, whilst, in IE classes, collaborative learning supports the process of ideation.

In CSCL, computers are used within an educational setting, in order to facilitate and support the collaborative group learning processes. CSCL may also be used as a support for conventional face-to-face classroom communication and to facilitate the group dynamic. The main purpose of CSCL is to scaffold or support students in learning together effectively. For example, CSCL can support the communicating of ideas and information, the accessing of information and documents and the providing of feedback on problem-solving activities (Stahl et al., 2006). Computer-Supported Learning can also be based on co-operation learning, which is generally defined as a teaching arrangement in which small, heterogeneous groups of students work together to achieve a common goal (Kagan 1994 & Ravitch 2007), with each student having a specific responsibility within the group.

2.13.3 Computer-Mediated Communication

Computer-Mediated Communication (CMC) focuses on the social effects of applying various computer-supported communication technologies and signifies any form of communication via computer-supported media, between two or more persons who interact with each other (Thurlow, Lengel & Tomic, 2004; Wolz et al., 1997). It can be a low-cost alternative for facilitating teacher dialogue with students and provides both teachers and students with an electronic form of individual and group learning support (Loiselle et al., 1998; Schrum & Berenfeld, 1997). An important element of CMC is the notion that the use of computers in this context is not just about the communication but also about supporting individual thinking (Thurlow, Lengel & Tomic, 2004; Romiszowski & Mason, 1996).

Many recent CMC studies have involved internet-based social networking, supported by social software such as VRLEs (Gilbert & Dabbagh, 2005; Gabriel, 2004; Schrum & Berenfeld, 1997). CMC includes various dissimilar forms of synchronous, asynchronous or real-time interaction that humans have with each other, using computers to exchange text, images, audio and video. For example, CMC incorporates e-mail and network communication, instant messaging, text messaging, hypertext and Internet forums. CMC is often used to facilitate student access to information within the conventional classroom and to enable multi-modal communication between students and teachers; this enables communication to society outside of the classroom, through the Internet (Gilbert & Dabbagh, 2005; Gabriel, 2004).

2.14 Understanding Pedagogical Issues Relating to CSCL and the Use of VRLEs

The aim of this section is to seek a further understanding of the use of VRLEs within the context of CCSL and to support meaningful learning in group settings. Furthermore, the section explores constructivism in relation to the use of VRLEs. Throughout the section, the author is referring specifically to the IE VRLE.

IE VRLE (see section 2.10.4) technology employs computers and interfaces designed to provide virtual realities to support IE learners' actual experiences. The VRLE runs on common desktop computers, yet attempts to immerse the learners in an experience as close as possible to reality. The goal is for the learner to interact with the VRLE environment and the classroom at the same time, in order to facilitate and improve on the collaboration that takes place within the classroom.

2.14.1 Collaboration through Desktop Computers in Physical Group Settings

Desktop-based VRLEs (see section 2.10.3) commonly use basic computer equipment, such as monitors, mouse devices and headsets, and attempt to immerse the learners in an experience as close as is actually possible, within the limitations of the equipment. The goal is for the learner to interact with the VRLE and the actual environment at the same time, in order to facilitate and improve the collaboration that takes place within the classroom.

Educators who employ the use of VRLEs often aim for improved thinking skills and problem-solving abilities and the collaborative development of knowledge within a field of practice: this includes an emphasis on both the individual and collaborative aspects of learning. Identification of social interactions becomes an important element of knowledge construction, with the focus being on the learner(s) and their activities (Jonassen et al., 2008; Cavanagh, 2004; Bricken, 1991; Bricken & Byrne, 1993).

2.14.2 Human-Computer and Human-Human Interaction

Interaction and interactivity between students and computer environments has been the foundation of the constructivism (see section 2.13.1) developed by Papert and others (Papert, 1993). Constructivism deals with the idea that people ‘construct new knowledge when they are engaged in constructing personally meaningful products’ (Bruckman & Resnick, 1995:9) and Papert saw constructivism as a combination of two strands. Firstly, it asserts that learning is an active process ‘in which people actively construct knowledge from their experiences in the world and, secondly, ‘people construct new knowledge, with particular effectiveness, when they are engaged in constructing personally meaningful products’ (Papert, 1993:9).

VRLE technology can be defined by ‘the interactions among the users within it, more than by the technology with which it is implemented’ (Hamit, 1993:26). Multiple-user interaction is one of the major factors in creating a VRLE and interaction is also of central concern in the concept of learner autonomy, which contains the idea that learning arises essentially from supported performances: this is central to the work of Vygotsky (see section 2.13.1.2) and the principles could be realised quite effectively in the VRLE that this project deals with. The students’ work has personal meaning, as it originates from identified needs and problems in their home environments. When using the VRLE within the conventional school context, students experience both human-computer and human-human interaction and this could support them in creating more meaningful solutions than in a formal, institutionalised classroom. However, it may be difficult to provide evidence that this actually happens, unless long-term quantitative research is undertaken within a laboratory setting.

2.14.3 The Students’ Ability to Modify the VRLE Supports Meaningful Learning

Production of knowledge in the innovation process, supported by the IE educational model, (see section 2.5.3) is important and poses the questions: ‘How is knowledge acquired in IE classes?’ and ‘How do IE students learn?’ (Gunnarsdottir, 2001a). Under the constructivist paradigm, there is autonomy and recognition for different methods of attaining knowledge (Jonassen et al., 2008; Cavanagh, 2004; Duffy & Jonassen, 1992; Lakoff, 1987; Bruner, 1973, 1990; Percy & Rossiter, 1992; Belenky et al., 1986; Pascuel-Leone, 1980). Duffy & Jonassen (1992:3) stated the following, with regards to the individual’s capability to attain meaningful context from experiences in their environment:

> Constructivism considers the world that we experience as real. However, the argument is that meaning is imposed on the world by us, rather than existing in the world independently of us. There are many ways to structure the world, and there are alternative meanings for any event or concept. Thus, there is not necessary a correct meaning we are striving for.

Research on the practical use of constructivist principles in classrooms (Jonassen et al., 2008; Cavanagh, 2004; Brooks et al,, 1996; Wittrock, 1987, 1991; Wittrock & Alesandrini, 1990) has shown that learning environments in which constructivist practices are applied can be beneficial.

In the past, pre-designed, knowledge-based material has been given to students by teachers, textbook authors or multimedia developers. Although knowledge construction does occur with pre-designed information (Maarit Virta, 2011; Carlile, 2002; Carlile & Rebentisch, 2003; Duffy & Jonassen, 1992; Bruner, 1990), there is the possibility for nurturing deeper understanding by bringing students into the process of designing their own knowledge (Etesam, 2008; Mones-Hattal & Mandes, 1995; Winn, 1995).

With interactive technologies, such as VRLEs, the process of constructing knowledge is created within visual and aural contexts. Students can establish their work within their own environments, modify their ideas, make their own set of objects and establish relationships; they may even behave in a way that is important and has meaning for them: for example, playing a role via the avatar. In VRLEs used within the classroom context, this can be shared and experienced through both real world and avatar interaction.

Constructivist learning models aim to support knowledge construction and to develop self-motivated, independent, intellectually stimulated learners (Jonassen et al., 2008; Wiske, 1994; Unger, 1994; Poplin, 1991; Duffy & Jonassen, 1992; Arnold, 1991). A VRLE can make an exclusive contribution to knowledge construction, as it is an environment in which students can embed and extend their understanding in both a visual and an interactive manner. When acting in a virtual world, students can ascribe meaning to objects, relationships and behaviours in a way that mirrors their personal understanding (Osberg, 1995a).

Student ability to construct and change the VRLE is an important part of knowledge construction. The concept of learning through a VRLE has proven to be of positive value in several cases (Chittaro & Ranon, 2007; Dimitropoulos et al., 2008; John, 2007; Mills & de Araújo, 1999; Shih & Yang, 2008; Tax'en & Naeve, 2002; Virvou & Katsionis, 2008; Byrne, 1993, 1996; Osberg, 1995b; Dede, Salzman & Loftin, 1996; Rose et al., 1996; McLellan, 1996; Bricken & Byrne, 1993). Nevertheless, a lot of research conducted to date has been concerned with pre-constructed VRLEs: environments created by designers and instructors, rather than by students themselves. These environments give limited opportunities for constructing knowledge and therefore limited opportunity for constructivist learning.

VRLEs provide students with the opportunity to interact directly with information embodied in a visual, virtual form (Ogle, 2002; Mones-Hattal & Mandes, 1995; Gigliotti, 1996; Rose et al., 1996). Interaction is an essential component of students' knowledge construction, both in a virtual or conventional educational environment (Ogle, 2002; Jonassen et al., 2008; Byrne, 1996; Psotka, 1995). Nevertheless, a VRLE can offer much more than an opportunity for interaction: it can connect the whole body in a way that is valuable for developing body (somatic) memory (Kraft & Sakofs, 1989; Samuels & Samuels, 1975; Dychtwald, 1977). This gives the students a chance to communicate with the environment as if they were physically present in the computer-generated 'space' (Ogle, 2002; Hoffman, Hullfish & Houston, 1995; Zeltzer, 1992). VRLE theorists have discussed the possible value of this duality (Hiem, 1993).

If students adjust the VRLEs they use, they get a degree of personal control over their learning process whilst developing the ability to facilitate their own learning at the same time (Jonassen, 2000; Winn, 1995; Osberg, 1995b): this strengthens their autonomy and control over the learning process, making it a stronger experience than that in a ready-made virtual world.

2.14.4 Constructivism Relating to the Application of VRLEs in Education

Bricken (1990) asserts that immersive applications of VRLEs are ‘very powerful’ educational tools for constructivist learning. The hidden curriculum of VRLEs could be: ‘make your world and take care of it. Try experiments safely. Experience consequences, then choose from knowledge’ (Bricken, 1990:2). Bricken (1990) and Osberg (1994) have also theorised about VRLEs as a tool for experiential learning, based on the ideas of Dewey, Vytgosky and Piaget (see section 2.13.1). According to Bricken, a VRLE can teach active construction of the learner’s environment and, as the VRLE is a computer-created reality, it is physically safe for the student and can be used for establishing a basis for different educational experiences that would both be impossible and unsafe in the physical world. The specific VRLE in this research is closed to visitors from outside the system via the use of access codes and passwords, thus protecting users.

The Piaget (see section 2.13.1.1) view implies that interaction in groups can create cognitive conflict and disequilibrium, which leads an individual to question their understanding and thus try out new ideas. Vytgosky (1978) highlights the role of opposition and equilibration in learning, with his interests lying in the role of inner speech and the learning of concepts. He studied the roles of the adult and the learners' peers as they converse, question, explain and negotiate meaning. Constructivists who favour Vygotsky's theory (1978) suggest that social interaction is important for learning because higher mental functions, such as reasoning, comprehension and critical thinking, originate in social interactions and are then internalised by individuals. As Woolfolk states: ‘Children accomplish mental tasks with social support, before they can do them alone. Thus, co-operative learning provides the social support and scaffolding that students need to move learning forward’ (2001:44).

Vygotsky (1978) noted that successful problem solvers talk themselves through difficult problems. In co-operative groups, children can ‘hear’ this inner speech loudly and this helps them to solve their problems through their approaches. The second key concept (see above) is the idea that children learn those concepts that are in their zone of proximal development (see definition in section 2.13.1.2). When children are working together, each child is likely to have a peer performing on a given task at a slightly higher, cognitive level, exactly within the child's zone of proximal development: the ‘zone of proximal development‘(ZPD) is the location where learning occurs (see section 2.13.1.2). This concept has been the focus of several educational research groups (Edwards, 2001) that underline the importance of learning as a collaborative process. It has also been suggested that computers may be used as media, in order to provide new contexts in which this collaborative learning might take place (Monahan et al., 2008; Newman, Griffin & Cole, 1989).

According to Vygotsky (1978), the zone of proximal development is the difference between what a student can do alone and what he or she can do through supportive collaboration. There are implications for co-operative-learning situations in an IE class in relation to this theory (Gunnarsdottir, 2001b & section 2.13.2) and, according to Bricken 1993 (in Bricken & Byrne, 1993); Bricken, 1991; Gilbert & Dabbagh, 2005 and Gabriel, 2004 the use of a VRLE in a conventional classroom may support such situations. The initial stage of the IE innovation process begins in the student’s own environment, when they identify needs and problems at home. In the school classroom, they communicate with co-students and the teacher and thus are exposed to thinking processes throughout their communication during the innovation process. This part of the IE school activity brings the students closer into their zone of proximal development and is one of the characteristics of the IE pedagogical model (see section 2.5.3). According to this, the use of IE VRLE technologies can be seen as a constructivist-learning tool, based on CSCL processes.

For constructivists, learning is not the result of development; learning *is* development (Fosnot, 1996; section 2.13.1). Teaching strategies using social constructivism include teaching in contexts that might be personally meaningful to students, negotiating taken-as-shared meanings with students, class discussion and small-group collaboration. The emphasis is growing on teachers using different ways to maintain dialectic tension between teacher guidance and student-initiated exploration, in addition to social learning and individual learning. According to Piaget’s (see section 2.13.1.1) perspective, interactions in groups can create a cognitive conflict and disequilibrium that can lead an individual to question his or her understanding and try out new ideas.

Bricken (1991) speculates that, in VRLEs, students can actively inhabit a spatial multi-sensory environment through immersion in the VRLE. Students are both physically and perceptually involved in the experience; they get a sense of being within a virtual world. Bricken suggests that VRLEs allow natural interaction with information: learners are allowed to move, talk, gesture and manipulate objects and systems intuitively, within the limitations of the system being used. According to Bricken, VRLEs might be highly motivational, almost possessing a magical quality; 'you can fly; you can make objects appear, disappear and change. You can have these experiences without learning an operating system or programming language, without any reading or calculation at all. But the magic trick of creating new experiences requires basic academic skills, thinking skills and a clear mental model of what computers do' (1991:3). Understanding multiple perspectives is both a conceptual and a social skill and virtual reality may enable learners to practice different skills in ways that cannot be attained in the physical world. However, in the longer term, the VRLE world might become ordinary for the students, causing them to fall back to normal levels of motivation.

Using the VRLE inside the conventional classroom, within the context of constructivist learning through CSCL (see section 2.13.2), is meant to minimise the cognitive load that students often experience in a traditional teaching and learning context (Schneider, 1996). The students' autonomy and freedom to make their own choices regarding their projects should be highly respected by the teacher (Gunnarsdottir, 2001a). The VRLE offers students access to the Internet and enables them to communicate with the world outside of school. At the same time, they are communicating with themselves, each other and the teacher. Using the VRLE in the classroom brings a multi-channel learning support (MSL) to the IE classroom. The students can access different sources of information and they have to choose and use the information channels that support the development of their ideas and close the ones that are not supportive; they may also get interrupted by entertainment material and thus get distracted from their work. In addition, students co-operating within a VRLE can experience emotional reactions (Lehtonen, Hyvönen & Ruokamo, 2005). However, this may be seen as a limitation; if the VRLE is being used in a conventional school environment, then the teacher can offer direct support.

2.15 Discussion of Material from the Literature Review

The aim of this section is to sum up the findings from the sections above and to discuss such findings. Initial questions were established in the introduction to the chapter, in order to guide the literature search (see section 2.1) and, to remind the reader, they are raised again, before providing a summary of the findings:

1. How are different terms used in these fields defined and how are they related?
2. What is the relationship(s) between the IE and the pedagogical background of Icelandic craft education?
3. What research projects have been undertaken that focus on ideation and/or VRLE in school education?
4. What are the most relevant pedagogical methods for developing ideation within school education?
5. Which pedagogical theories are most suitable for understanding the dynamic social interaction when VRLE is used for ideation in a conventional classroom?
6. How can the identified pedagogical theories be used to understand, evaluate, and demonstrate the values of VRLE for IE?

2.15.1 Terminology within the Areas of Innovation and Ideation

In this section, the author defined pedagogy within the context of Innovation Education in a broad sense, including how IE learners generate the course content in their environment, the approach to teaching and learning, how teaching occurs, how content is delivered and what the students learn as a result of the process. Subsequently, he identified and defined the terms relating to ideation and established the relationship between them. This helped to establish a clear position for the enquiry, within the context of Innovation Education in Iceland.

Identified terms were *creativity*; *innovation*; *ideation*; *idea generation*; *brainstorming*; *invention*; *design*; *discovery* and *heureka*. The author found that researchers use different terms for similar phenomena, depending on their area of work. The term *creativity* is one of these and is not used for this work, as the focus is on innovation and ideation. In this enquiry, the terms *innovation*, *idea generation* and *brainstorming* are most important. IE was initially based within general education and teachers could use different methods for ideation. The outcome of the innovation process may be based on the concepts of *discovery*, *design*, *invention* and *heureka*.

2.15.2 IE and the Pedagogical Background of Craft

IE developed inside Icelandic craft classes and became influenced by the rationale for craft and the principles of Nordic Sloyd pedagogy. Similarly, as Sloyd uses craft as a tool to educate the student holistically, IE seeks to build up their innovation skills by improving their ideation. Consequently, students become better equipped to deal with their world and take an active part in society (Gunnarsdottir, 2001a). In common with the Sloyd pedagogy, IE has a humanistic character and aims for individual development and self-realisation.

2.15.3 Prior IE Research Projects in Iceland

Two projects have been previously conducted on Icelandic IE (Gunnarsdottir, 2001b & Jonsdottir, 2005).The first increased the understanding of how students learned in the IE classes, prior to the introduction of the VRLE. This is key for this research, as it demonstrates how students learn through their social activities in conventional IE classes, as demonstrated in the pedagogical model (see figure 1.5) for teaching and learning in Innovation Education. It also highlights the importance of identifying the context of social constructivism and the role of the IE teacher in setting up circumstances to facilitate students' collaborative learning (Gunnarsdottir, 2001b).

The latter project (Jonsdottir, 2005 & section 2.6.2) looked for factors that influenced the implementation of Innovation Education as part of the Icelandic national curriculum and it showed that the teacher's role and understanding of the IE rationale are important factors for the subject's progress in schools.

2.15.4 Pedagogical Methods for Developing Ideation Skills

This section gave a short review of the general methods used for developing ideation skills. It showed the importance of developing students' ideation skills, both as individuals and when working collaboratively in groups. The actual methods discussed were brainstorming, problem-need identification and the use of computer- based software to support ideation.

Research studies related to the development of ideation skills in education have mostly focused on measuring ideation, but also looked at the effectiveness of environmental changes on ideation skills in group settings. The section highlights the importance of looking at the context of brainstorming and collaboration through a computer screen when students are working in the conventional classroom, as research shows proximal groups produce less ideas then nominal groups, when communicating ideas on a computer screen.

2.15.5 Virtual Reality Learning Environment (VRLE) to Support Ideation

This section explained how the IE VRLE is based on a combination of VLE and VRE and defined related terms.

IE activity inside the VRLE classroom is connected to society through the Internet and offers multi-channel learning opportunities: the learning characteristics of the VRLE enable the teacher to manage the IE material and support students' work. Both parts of the VRLE hold value for the IE educational activities: the VRE part of the VRLE is a place for socialisation, such as communicating ideas with different working tools, offering multiple possibilities for collaboration and enabling new learning experiences. The VLE part of the VRLE is a computer-supported managed learning environment that enables new possibilities for the teacher to enhance students' ideation work in Innovation Education, through online support.

When using the VRLE in the conventional school context, students experience both human to computer and human to human interaction face-to-face and human to human interaction via the computer, inside the classroom. This could support them in creating more meaningful solutions than in a formal institutionalised classroom. However, these possibilities have to be examined through further research (see chapters 4.0, 5.0, 6.0 & 7.0).

2.15.6 Virtual Reality Environments at School Level

In this section, research on VRLE projects in education was reported. Few projects were found specifically regarding VRLEs, school education and children and none were found concerning the supporting of ideation within the context of innovation education.

Of those projects examined, many were concerned with models of social constructivism, computer mediated communication (CMC) and computer supported collaborative learning (see section 2.13.2), which focus on the students' group as a support to individual learning. This research is based on the early IE pedagogical model (see section 1.6), but interconnected with these three pedagogical theories. In this work, the theories will be used to understand the dynamic social activities in IE classes where the VRLE is used and to develop the IE model further. These theories benefit the social level, support the planned VRLE activity and ensure that these are in harmony with the already defined IE pedagogical model (see section 1.6).

The majority of researchers (see section 2.12) believe that a VRLE can be used positively for different areas in education and students are usually interested and motivated as participants, but further and long-term research is needed to confirm these initial findings.

2.15.7 Pedagogical Models Regarding the Use of VRLEs in Education

According to the literature, the characteristics of VRLE support for conventional classroom-based IE are related to constructivism, computer supportive collaborative learning and computer mediated communication. For example, Gunnarsdottir (2001a) found relations between IE and social constructivist learning. The use of the VRLE in the conventional classroom includes the concept of blended learning (combining web-based and face-to-face learning). The effectiveness of these identified theories on the IE pedagogy, as an underlying theoretical background for IE, has to be explored through research.

According to the literature, the use of the IE VRLE technologies could be seen as a constructivist-learning tool based on CSCL processes (Jonassen, 2009). The context of Vygotsky's theories (1978) on the concepts of the *More Knowledgeable Other* (MKO) and the *Zone of Proximal Development* (ZPD) (2.13.2) also has to be examined within the context of the blended learning of IE.

2.16 Overall Discussion

The literature survey gathered professional and disciplinary literature relating to the effectiveness of using the VRLE in Innovation Education in Iceland (in order to support teachers' pedagogy and students' work) (see overall question in chapter 1.0). IE was established within the subject of craft and was influenced by its origin, the principles of the Nordic Sloyd pedagogy. In common with Sloyd, IE seeks to educate students holistically by focusing on improving their ideation through general education, in order for them to become good citizens.

The pedagogy of IE has a broad meaning, incorporating the contexts of the teacher's various roles and responsibilities and the social interaction during students' ideation work. Furthermore, IE is learner-centred; students generate the content of the IE course through their environment and their engagement with learning is influenced by social and cultural contexts. Learners are not seen as passive recipients of knowledge and skills; rather, they are active participants in their learning throughout the ideation process. It is thus important to consider IE pedagogy within the context of both the teacher's and the student's work.

Constructivist theory has been a useful basis in developing the pedagogy of the IE VRLE and earlier research has implied that the IE pedagogical model can be used as a socio-mental tool for bringing students closer into their 'zone of proximal development' (Vygotsky, 1978; Jonassen, 2000). One of the characteristics of the IE pedagogical model is the relationship with the students' environment, where needs and problems are identified at home: this part of the pedagogy gives IE a personal meaning for the students (Gunnarsdottir, 2001b). The using of VRLE within the classroom supports multimodal communication and offers Computer Supportive Collaborative Learning (see section 2.13.2) opportunities, in order to support ideation inside the on-going IE innovation process within the conventional classroom. Also, through the VRLE, students can communicate with society outside of the school in ways that may increase the possibilities of a meaningful education. This is in harmony with the characteristics of the IE model, which concern the pedagogical value of establishing the basis of the innovative work in society as real needs and problems identified in a student's home environment.

VRLE researchers (Jonassen et al., 2008; Ogle, 2002; Osberg, 1994; Bricken & Byrne, 1993; Johnson et al., 2002; Song et al., 2000) state that students can explore and safely make mistakes within a VRLE, as it is computer generated and physically safe: such an environment can be used to establish a basis for various educational experiences that would be impossible in the physical world. However, there is the potential for psychological danger when using any computer-created realities, particularly when web-based and in direct communication with others. Students may be subjected to ‘cyber bullying’ and there is also the risk of outsiders entering into the system. To combat this, the IE VRLE uses a secure access code system to combat external threats and the teacher continually monitors and tracks activity, in order to combat internal threats. There are also health and safety issues related to the use of computers and displays in schools: overuse of computers can cause stiffness in the neck and shoulders and eyestrain. In addition, the VRLE, as a multi-channel learning technology, can cause an overload of information, some of which may cause tropism, or the diverting of attention away from work (Denton et al., 2007; section 2.13.3).

The literature indicates the importance of examining the VRLE as a tool that can support constructivist learning based on CSCL processes (see section 2.13.2). Thus, the results of this research may highlight the pedagogical value of a collaborative VRLE for ideation and how this affects the earlier pedagogical model: this will be done by looking at activity within the classroom, while the students are using the VRLE, and observing the following:

- How long it takes students to learn to use the interface and become immersed in and comfortable with the environment.
- How often the students and the teacher use the VRLE in the classroom.
- Social interaction with and without the VRLE, how the teacher and the students communicate within and outside of the collaborative VRLE environment and the meaning of the collaboration, when ideation takes place.
- The difference between the students’ collaboration in a classroom with and without the VRLE and its role during ideation.
- To understand how teachers have adapted pedagogical models to accommodate the VRLE.
- How the teacher’s role differs from conventional based classes and how it affects the students’ ideation skills, when using the VRLE.

To explore the educational efficacy of using the VRLE in the classroom requires the development of appropriate and meaningful forms of evaluating this new mode of learning support: this could be achieved by looking at the differences between a traditional classroom- based pedagogical IE model and the same model supported by the VRLE.

A fuller pedagogical understanding of using the VRLE for ideation has to be further developed through empirical research. The basis of the technology is already part of the daily lives of young people but, to date, less advanced in general education. The literature indicates that we need to further explore the application of the VRLE in supporting ideation and its impact on IE pedagogy. Such research must be based on constructivist learning and computer supportive collaboration and it is anticipated that this will give a clearer picture of the pedagogical value of using VRLE for Innovation Education in Icelandic schools.

2.17 Overall Literature Review: Conclusions and Feed Forward

The literature review enabled the author to gain a greater understanding of how the VRLE supports students' ideation and teachers' pedagogy in conventional Innovation Education classes in Icelandic schools; it also helped him to establish the fieldwork outlined in chapters (5, 6 and 7). Furthermore, the literature contributed towards answering the overall project research question (how does the use of the VRLE affect teachers' pedagogy and students' work within conventional Innovation Education in Iceland?).

Regarding the terminology relating to this enquiry, related terms were identified, in order to gain a deeper understanding of the research. The literature review highlighted how researchers use dissimilar terms for similar phenomena within the context of their own working area and this demonstrates the importance of employing clear terminology for this enquiry: it also helped the author in analysing and reflecting on earlier research.

The term *pedagogy* used in this thesis has a broad meaning, incorporating the contexts of the teacher's various roles and responsibilities and the social interaction that occurred as a result of the students' ideation. To enable the progress of the teacher during the research, it was important to take the students' work into account and pedagogy is thus seen as the art and science of how something is taught and how students learn as active participants in the learning process.

The original aim of IE was 'to stimulate and develop innovativeness in students, so that they could improve their environment and their self-image' (Thorsteinsson, 1998:32). IE is not vocational training; rather, it is firmly based within general education. Teachers are free to use the different methods outlined above, in terms of the development of students' ideation skills within the IE process and the outcome may be based on discovery, design, invention, heureka or a combination of these.

The Icelandic educational authorities considered that the subject of craft was not consistent with the needs of modern society, in terms of educating innovative citizens (The Ministry of Education, 1994; Lemke, 1994; Thorsteinsson, 1994). Consequently, IE was supported as a curriculum project, within craft, with regards to the improvement of student's ideation skills (The Ministry of Education, 1994 & 1999; Thorsteinsson, 1994). From this, IE developed into a new cross-curricular subject and innovativeness became a general aspect of the Icelandic National Curriculum: classroom activities are based on real-life problem solving and ideation, which are fundamental aspects of learning.

Exploring the link between the backgrounds of IE and craft helped the author to develop an understanding of the pedagogy of IE (see section 2.5) and to formulate the focus of the research. When IE was introduced to craft classes, it became influenced by the rationale for craft and the principles of Nordic Sloyd pedagogy. Thus, in common with Sloyd, IE seeks to holistically educate students, encouraging them to become good citizens, with a focus on improving their ideation and promoting innovativeness through general education. A further purpose of IE is to ensure that students are better equipped to deal with their world and that they take an active role in society (Gunnarsdottir, 2001a; Thorsteinsson & Denton, 2003).

Sloyd pedagogy was of a humanistic character and its principles were guidelines for individual development and self-realisation. Thus, the originators suggested that it was taught by teachers, rather than artisans, in order to ensure that the teaching would be based on the need for the personal development of children. According to Sloyd pedagogy, the role of the teacher is not just to teach technical knowledge and skill, but also to provide flexibility for self-realisation.

The literature review highlighted the development of students' ideation skills as the main emphasis of IE pedagogy. The generation of ideas and the development of solutions based on the practical use of knowledge occur throughout the innovation process and ideation is thus seen as a learned skill, in terms of innovation. Ideation enables students to become self-directed and active participants in the IE learning method; however, to describe ideation as a process implies a relatively defined and linear approach, which is not an accurate description of the ideation employed in IE. It is preferable to describe two pedagogical processes; namely, ideation skills and innovation processes. This enables a view of ideation as a set of skills used in various ways and at different stages within the IE innovation process.

Summarising earlier IE research projects helped the author to gain an understanding of the pedagogy of IE and informed the direction of his own research. The project builds upon this earlier work: the curriculum development of IE, the InnoEd project and the IE research projects already undertaken. It is interdisciplinary and incorporates the pedagogy of Innovation Education, computer supported collaborative learning and socio-cultural and group pedagogical issues within the VRLE.

A review of the literature demonstrated the relationship between the pedagogy of IE and the social environment (see section 2.5). A number of techniques for improving ideation are directed at improving the individual from within, whilst other techniques are aimed at improving the environment in which the individual performs. Changing conditions in the environment to influence idea generation is referred to as the 'social facilitation or inhibition of ideation' (see section 2.8). Several researchers (i.e., Clapman, 2003) have begun to explore whether interactive group environments facilitate or inhibit ideation: such environments are an integral aspect of the modern workplace, classroom education and within the field of interior workspace design. As group approaches to idea generation and project development are becoming more common (Siau, 1995), there is a vital requirement to be innovative in different working conditions (Portillo, 1996).

The IE model was originally individually-based (Thorsteinsson, 1998; Thorsteinsson & Denton, 2003; section 1.6), due to the fact that students activate the IE process by seeking needs and problems in their own environment. The redefinition of problems may help students to identify solutions (Runco, 2007; Runco & Dow, 1999) and their prior knowledge becomes practical (see section 2.5.1). However, Gunnarsdottir (2001a) informed of the importance of student collaboration, in terms of their progress, and the teacher's role in helping students to bring their ideas to realisation. Thorsteinsson (1998), Paulus (1999) and Clapman (2003) reported that some of the negative aspects of group work, regarding ideation and innovation, can be counteracted using computer software designed to support ideation. According to the initial IE pedagogical model (Gunnarsdottir, 2001a), social activity plays a large role in the IE process (1.6). There are differences between conventional social activities and the VRLE supporting the IE process: the latter offers multiple dimensions for communications (see section 2.13.3).

The pedagogical methods for developing ideation skills can be taught in isolation or in combination with other cognitive processes and all place an emphasis on divergent thinking. PNs and brainstorming are important elements of the IE process and the VRLE is an example of computer software designed to support ideation. Creative problem–solving, synectics, lateral and vertical thinking, TRIZ and hemisphericity are, however, more all-inclusive and dominating as pedagogical methods including both divergent and convergent thinking and are therefore not used in IE. IE also builds on the identifying of PNs within a student's own environment and is an important part of supporting the pedagogy.

Educators have employed various pedagogical approaches to develop individual and group ideation skills (Clapman, 2003). Some of these have been laboratory based, focusing on measuring the quality and the quantity of generated ideas, whilst other approaches have examined changes within the contexts of teaching and learning. The research project here is an example of this, as it observes how the adoption of a VRLE environment within a conventional school context affects the pedagogy of developing the ideation skills of students.

The literature review highlighted the positivity of ideation training, in terms of the productivity of idea generation, students' attitudes to learning and cognition. Studies have outlined the benefits of teaching the ideation process, with a focus on divergent thinking and the use of computer software to support idea generation. Long-term training in divergent thinking has also indicated that teaching IE over several years might be effective, in terms of student learning. The literature further indicated the positive impact of teacher training, in terms of providing new teachers with personal experience and skill prior to teaching ideation. Such training should support students' learning through ideation.

The literature reported several projects that employed different methods for improving ideation. The majority of these were curriculum development programmes, rather than research based, largely focusing on measuring the quality and quantity of the use of idea generation; for example, the Torrance Tests of Creative Thinking. This project, however, seeks to understand the pedagogy of developing ideation skills; it aims to understand and interpret how the pedagogy of developing student ideation skills changes when the new VRLE technology is brought into the conventional IE classroom.

The findings in the reported studies involving young students indicated that the development of ideation skills through training can improve divergent-thinking performance. The majority of the studies incorporated brainstorming and this highlights the importance of brainstorming within the IE innovation process. The studies also indicated that training aimed at improving ideation can be effective for all students, including the gifted and the disabled. Furthermore, the literature indicated that the use of computer software to support idea generation, such as the VRLE, is effective, with regards to improving students' attitude to learning.

Many questions have arisen as a result of the literature review. For example, the IE innovation process begins with the identification of PNs and brainstorming in a verbal proximal active group, in order to generate initial ideas. Such groups (Paulus et al., 1995) appear to generate fewer ideas than nominal groups: would it therefore be better for IE students to generate their ideas through the VRLE, without direct contact with others in the classroom, as the presence of others may weaken their ideation?

Would ideation in IE be more successful in the form of a nominal group communicating though the VRLE, within the context of open and distance learning? These questions must be answered through future research, as the main aim of this project is to understand and develop the pedagogy of using the VRLE in the innovation process and also to examine the pedagogical changes associated with the use of the VRLE within a conventional school context. However, the majority of the projects studied yielded positive outcomes and indicated that the development of students' ideation skills is of educational value for all students.

Many methods of idea generation are used to support productivity; thus, the existing literature on ideation and idea generation may be useful for educators who wish to increase the productivity of idea generation in their classes. However, the author argues that researchers who focus on productivity without identifying problem needs in a student's environment are missing an important point; namely, enabling students to generate the content of their courses and give it personal meaning. Rather than simply making groups more productive, it may be beneficial to make them work harder at all stages of the innovation process.

The literature defined the various learning environments featured in this research and any related terms. It also illustrated the characteristics of these environments and explained the combination of the VLE and the VRE as the specific VRLE software used for this enquiry. Both are valuable, in terms of IE educational activities: the VLE is important for the management of online IE educational activities and it hosts both the teachers' and the students' work. The VRE part of the VRLE is a place for socialisation and the communicating of ideas with various working tools (see section 2.10.2). The characteristics of the VRE also enable novel experiences that may support students' work in IE. The VRLE has been described as two parts, yet these two parts work together to form one environment. The VRLE is based on the pedagogy of IE, with regards to computer collaborative learning, which enables new possibilities and enhances students' ideation work. The specific VRLE aims to offer multimodal communications, in order to strengthen ideation within the innovation process (Thorsteinsson & Denton, 2003).

The IE pedagogical model has been examined as the background of the specific VRLE and has been discussed within the context of related theories for teaching and learning. The VRLE was designed (Thorsteinsson & Denton, 2006; section 2.5) to enhance ideation via collaborative learning support within IE classes and thus offers individual and social educational opportunities. The development was based on work by Thorsteinsson (1998, 2002; sections 1.5 & 1.6) and Gunnarsdottir (2001a) and uses social constructivism and computer supportive collaborative learning theories (Osberg, 1994; Bricken, 1991; Jonassen, 2000).

Computer Supported Collaborative Learning (CSCL) has emerged as a new educational paradigm amongst researchers and practitioners in several fields, including cognitive sciences, sociology and computer engineering (Crook, 1994). The literature indicates that research should focus on students and teachers working together, seeking understanding, meanings and solutions or the creation of a product (O'Donnell et al., 2006).

Section 2.13.4 sought an understanding of the use of VRLEs within the context of CCSL, in order to support meaningful learning within group settings. It referred to the IE VRLE as contributing to the IE pedagogical model within the conventional classroom context and aimed to identify any pedagogical issues. The section also aimed to understand constructivist pedagogy, in relation to the use of VRLEs in education.

In accessing a VRLE within a conventional school context, students experience both human-computer and human-human interaction (see section 2.14.3) and computer supported collaborative learning support can facilitate group processes in conventional face-to-face, classroom-based communication. Using the VRLE in the classroom enables multi-channel learning (MSL) support within the IE classroom, allowing multiple learners to communicate ideas and access information; the system also provides feedback on problem-solving activities (Crook, 1994).

The literature review indicated that VRLE environments offer opportunities for constructing knowledge and therefore constructivist learning. Multiple-user interaction is one of the major factors in creating a VRLE and supports Vygotsky’s ideas (1978), with regards to the Zone of Proximal Development. Interaction and interactivity between students through the environment of the computer supports problem solving and the construction of new knowledge, as students are ‘engaged in constructing personally meaningful products’ (Bruckman & Resnick, 1995:9). This is further facilitated if students can modify the VRLE environment, as this supports the development of meaningful personal learning styles.

In IE, students establish their personal work when they identify ideas and problems in their environment through communication with their families and friends (section 2.5). Using the VRLE, students can communicate with the world both inside and outside school and experience different learning contexts relatively safely. Using the VRLE in the classroom requires self-discipline and careful supervision from the teacher, as students may be easily distracted by the entertainment material that is all too familiar on the Internet (see chapter 5.0). In the longer term, the VRLE may also become too familiar to students, causing them to lose motivation.

In order to develop and establish an appropriate research direction, it is important to pilot the use of the VRLE with IE material: this will enable the author to identify pedagogical issues and establish relevant areas of interest which require further examination in later case studies. An appropriate question in guiding a pilot study would be: ‘Which teaching and learning strategies influence IE activities, when the VRLE is used in the classroom?’

The literature further indicated the importance of examining the following areas during the pilot study:

- Students’ methods of working through the ideation process, when using the VRLE in the classroom.
- Students’ homework, in order to enable and personalise course content through the identification of problem needs.
- The role of problem needs finding and brainstorming inside the innovation process, within the context of the VRLE.
- The use of the VRLE at home and in school.
- The value of training the teacher in IE and in the use of the VRLE.
- The impact of both students’ collaborative and co-operative IE activities.

- The characteristics of the teacher’s role when the VRLE is used and how this differs from the earlier IE model (i.e., pre-VRLE).
- The elements of the IE course that support the idea generation of students.

An exploration of the educational efficacy of using the VRLE in the classroom requires the development of appropriate and meaningful forms of assessing this new mode of learning support. This may be achieved by looking at how VRLE technology affects the pedagogical IE model, when used in the conventional classroom, and incorporating the teacher’s role in the learning of students. In order to enable an understanding of the new pedagogical context, the author established that grounded theory principles via case studies (see further in chapter 3.0) were an appropriate paradigm for the research (grounded theory principles investigate actualities in the real world and thus give the researcher the freedom to generate new concepts explaining human behaviour). Conventional scientific paradigm models of research and evaluation cannot be used to explore such developments as IE is a complex and dynamic sociological/educational context (as the VRLE was specifically designed for IE at this time, it had rarely been used). The author will thus include an action research element (see further in chapter 3.0), in order to enable further development of the VRLE software for IE, incorporating the role of the teacher.

When using the grounded theory paradigm, the researcher usually begins with a broad aim and a literature review, in order to help identify gaps in the knowledge of the topic (Stern, 1980; Cutcliffe, 2000; Chiovitti & Piran, 2003). The literature review is used as a basis for the author’s professional knowledge (Strauss & Corbin, 1998) and/or ‘accumulated knowledge’ (Dey, 1993:66). There is no need to review all of the literature in the field beforehand, as it is impossible to know, prior to the research, what salient problems or relevant categories will be derived from the data. If everything about a topic is known beforehand, there is nothing new to discover and thus no need for a qualitative approach. Also, the researcher does not want to be so constrained or enamoured by the literature that he is over-influenced by it (Becker, 1986b; Strauss & Corbin, 1998). When the grounded theory is almost complete, during the sorting and writing up stage, the literature search in the substantive area will then be accomplished and woven into the theory, as further data for constant comparison (Glaser, 1998:360-67).

Chapter 3. The Research Design and Methodology

3.0 Chapter Summary

The research design, including overall aims, objectives and the research questions, is introduced. Methods of data collection and analysis are detailed. Limits and limitations of the general approach and methodologies used are considered and are also reported in chapters 1.0 and 11.0.

3.1 Introduction to the Research Design and Methodology

The initial IE pedagogical model (see sections 1.5 and 1.6), based on social events and related pedagogical theories (see section 2.13), led to the formation of research questions and a research framework. The literature, although limited on the pedagogy of using a VRLE for Innovation Education, indicated the importance of social interconnections between teachers and learners, in addition to between the learner and the wider world. These complex and dynamic relationships are at the core of the project and the chosen methodology needed to be able to encompass this. The starting point of the project was to identify the terminology and explore issues within the original programme of curriculum development (see chapter 2.0) and, from this, the project needed to explore the pedagogy of using the new VRLE software for IE through research.

The research follows a broad illuminative paradigm (Parlett & Hamilton, 1983; Alcroft, 2002; section 3.3), which aims to build pedagogical understanding through 'grounded theory' (Glaser & Strauss, 1967; see section 3.10): it primarily uses qualitative methodologies (such as case studies) (see section 3.5) as a means of developing understanding. In addition, part of the work involves action research (Cohen et al., 2005), in that it is a small-scale intervention in the functioning of an ongoing curriculum development project and an examination of the effects of that intervention.

This chapter firstly looks at the illuminative paradigm (Cohen et al., 2005). It then addresses grounded theory (Glaser & Strauss, 1967); iteration; triangulation; case studies and the specific methods employed; questionnaires; interviews; video screen capture and video recording. At each level, limits and limitations are acknowledged.

3.2 Setting the Research Direction

The research direction was based on:

- The initial IE pedagogy (chapter 1.0 and 2.0)
- Gunnarsdottir's (2001a) research (chapters 1.0 and 2.0)
- Curriculum development during the InnoEd project (chapter 2.0), which includes work undertaken by the author, with others, since 1992 (Thorsteinsson, 1998; Thosteinsson, 2002)
- The initial literature review (chapter 2.0)
- Pre-piloting the VRLE for IE (chapter 4.0)
- Participant experience and discussion in InnoEd (chapter 2.0)

A clear differentiation needed to be made between the on-going IE curriculum development and the research project and, to aid this, the author published a number of papers in reviewed journals and conference proceedings (see page iv). A pre-pilot study (see chapter 4.0) enabled the formation of the research focus and a formal research plan was established. The pilot case study helped the author to identify pedagogical issues and establish categories (see chapter 5.0) and, furthermore, it enabled him to develop appropriate research tools and gain experience of using case study methodology.

3.2.1 Overall Aim

To explicate the pedagogy of using the Virtual Reality Learning Environment (VRLE) to support conventional Innovation Education within Icelandic schools.

3.2.2 Overall Objectives

a) *Identifying the required pedagogy, in terms of using the VRLE within the specified context.*
b) *Demonstrating an IE pedagogical model, in terms of supporting the VRLE.*
c) *Describing students' ideation when using the VRLE.*
d) *Evaluating the students' ability to draw inside the VRLE.*
e) *Recognising the value of using the VRLE in IE.*
f) *The provision of indications that may enable further research.*

3.2.3 Overall Research Question

The central research question is:

‘How does the use of the VRLE affect the teacher’s pedagogy and students’ work in conventional Innovation Education in Iceland?’

3.3 Paradigm

The project attempted to understand a complex and dynamic sociological/educational context and thus it was necessary to search for an appropriate paradigm, in order to inform the research design. A hypothetico–scientific paradigm would have been inappropriate, as this does not consider the central issues of multiple and dynamic variables, curriculum development and the location of the author as developer and researcher.

This research was intended to be interpretive (illuminative), as it sought to understand and interpret the VRLE, the learning experiences of the students and the developing pedagogy used by the teachers. Therefore, the most naturally suited paradigm for this research was the interpretive paradigm. Neuman (1997:68) defines this paradigm as ‘exploring socially meaningful action through the direct detailed observation of people in natural settings, in order to arrive at understandings and interpretations of how people create and maintain their social worlds’.

The focus of the interpretive paradigm is to understand the subjective world of human existence and, to retain the integrity of the phenomena being investigated, efforts are made to ‘get inside’ the person and to understand them (Cohen et al., 2005). The interpretive researcher begins with individuals or groups and sets out to understand their interpretations of the world around them. Theory is emergent and must rise from particular situations; it should be grounded on data generated by research acts (Alcroft, 2002; Glaser & Strauss, 1967). In this paradigm, theory should emerge from data rather than precede research and must make sense to those to whom it applies (in this case curriculum developers, curriculum researchers and teachers).

Using this paradigm within this research context infers a qualitative methodology, as suggested by Yin (1989) (i.e., dealing with contemporary phenomena within a real life context). Anderson (1998) agreed that studying and interpreting human experiences in real settings cannot be best represented quantitatively. He stated: ‘qualitative research is a form of inquiry that explores phenomena in their natural settings and uses multi-methods to interpret, understand, explain and bring meaning to them’ (p119).

3.4 Research Design

As this project was based on curriculum development, the case study methodology was chosen as the logical approach: this enabled the author to be both curriculum developer and researcher, using live educational contexts. Case studies allowed the researcher to observe the complex and dynamic nature of the teaching and learning process in this context.

The author was not part of the data, as the teacher was responsible for the teaching. However, the data were social constructs; a product of the skills and the imagination of the researcher and of the interface between the researcher and the researches. Thus, the researcher’s presence was never neutral and recognition and awareness of the researcher’s effect on the process of collecting data was vital (Thomas, 2008). The researcher had to manage these issues through reflexivity, when analysing the data. As Ball informed, this involves ‘the conscious and deliberate linking of the social process of engagement in the field with the technical processes of data collection and the decisions that linking involves‘(1990:158). Ball further stated: ‘the fieldworker must weigh the impact and effects of their presence, their personae and the respondents’ perception of them‘(1990:68).

In the InnoEd project, the participants worked very closely with one of the key principles of participatory action research methodology: research through which practitioners work towards the understanding and improvement of their own practices (Kemmis & McTaggart, 1992:22-25; Brown, 2002). The author undertook three case study series, which included an element of action research. The first aimed to ‘scope’ the context of the project, develop the use of the VRLE and to practice the use of the specific methodologies used. An analysis of the data from the pilot study was used to generate a sharper focus on the overall project and a new series of research questions. Later, two case study series were conducted, in order to observe the pedagogical effectiveness of using the VRLE in IE. Specific research questions were set up for each case study and these were then used to answer the project’s overall questions. The figure below shows the development of the approach.

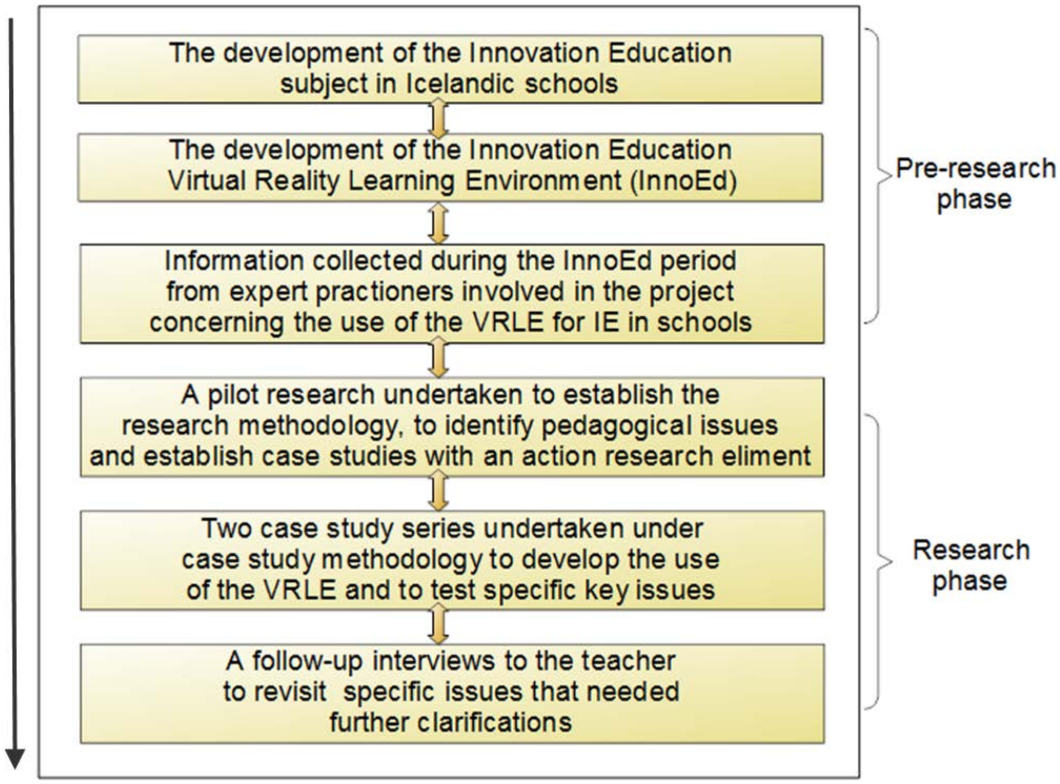

Figure 3.1: The research was based on curriculum development and experience of the IE and InnoEd projects.

3.5 Case Study Methodology

Adelman et al. (1980) stated that case studies are carried out in real-life situations, in which the professional responsibilities of those concerned may interfere with the purity of research methodology. Case study work in schools is a minute-by-minute existence and one must gain the best perspective possible at the time, with the resources available. The methodology has to respond to altering situations and changing perceptions of what is under investigation.

A self-conscious awareness is required, with regards to the effects the participants and researchers have on the research process; it must be noted how their values, attitudes, perceptions, opinions, actions, feelings, etc., have a bearing on the situation being studied (Cohen et al., 2005). In this case, the author tried to closely and continually monitor his own interactions with the participants, their own reactions, roles, biases and any other factors that biased the research (McCormick & James, 1988; chapter 11). The author had participated in the development of the IE project as a teacher/leader/developer and thus it was necessary to develop a professional detachment from the enquiry whilst maintaining a teaching enthusiasm within each learning context: this was not easy, but it was not impossible. The process and discipline of the research enabled this to a large degree (van den Akker et al., 2006).

3.6 Action Research

Action research is an approach to research, rather than a specific method, and the term was first used in 1946 by Lewin, a social scientist (Smith, 2001). Action research is now identified as work in which researchers work explicitly with and for practitioners, rather than conducting research on them: its strength lays in its focus on generating solutions to practical problems and its ability to empower practitioners, encouraging them to engage with the researcher and the subsequent ‘development’ or implementation activities (Brown, 2002). However, the practitioner can also observe his own work and act at the same time: in this double role, he has to be aware of his limitations (biases) that may affect the research.

Action research offers an approach to introducing innovation within teaching and learning and seeks to do so by putting the teacher in the dual role of producer of educational theory and as the user of such a theory (Elliott, 1991). This is a way of producing both knowledge regarding the use of new technology in education and a powerful way of improving learning and teaching practice and understanding what is going on. No separation needs to be made between the design and delivery of teaching and the process of researching these activities, thus bringing theory and practice closer together (Riding et al., 1995): this requires critical reflection on the part of the researcher, within a cyclic process. At all stages, the researcher attempts to find exceptions to the data collected so far and confirm the emerging interpretations.

There are many ways of describing the cycles and Susman (1983) describes them as having five elements: diagnosing, action planning, taking action, evaluation and specifying learning. Kemmis and McTaggart (1992), however, state that there are four elements: plan, act, observe and reflect. The important characteristic of each cycle is that the researcher plans prior to acting and reflects on the findings and the method after acting. The reflection feeds into the planning for the next cycle and knowledge and understanding are built up through data analysis.

Action research is an iterative process, involving researchers and/or practitioners acting on a particular cycle of activities, including problem analysis, data collection and reflective learning. Action research combines diagnosis with reflection on practical issues that have been identified by the participants and which are somehow both problematic, yet capable of being changed (Elliott, 1978:355-356; 1991:49).

The role of the teacher has always incorporated professional reflection and curriculum development and this model closely mirrors action research: the difference lies in the depth of evidence and the quality of analysis required. However, Wong (1993) cited research is to know and understand, while the purpose of teaching is ‘to do the right thing’ (p7); he further argued that the expected differences within researching and teaching could become ‘paralysing’ (p9). Foster and Nixon (1978) argued that the role of the teacher is too complex to include a research component; however, the author notes that Wong continued to argue that the potential differences within researching and teaching could become paralysing. In summary, three important factors can hinder successful teacher research: (a) increased time commitment (b) lack of distance from the research situation and (c) conflict between the roles of researching and teaching.

Action research has distinctive features, as outlined by Zuber-Skerritt (1982):

- Critical collaborative enquiry by
- Reflective practitioners who are
- Accountable in making the results of their enquiry public
- Self-evaluative in their practice and engaged in
- Participative problem-solving and continuing professional development.

According to this analysis, action research is critical in the sense that practitioners not only look for ways to improve their practice within the various constraints of the situation in which they are working, but are also critical change agents of those constraints and of themselves. It is reflective, as participants analyse and develop concepts and theories about their experiences (Brown, 2002: van den Akker et al., 1999). Action researchers are accountable in that they aim to make their learning process and its results public, both to each other and to other interested practitioners, using accessible terminology. Their practice is self-evaluated in that the reflective and analytical insights of the researcher-practitioners themselves form the basis of the developmental process. Action research is participative, as those involved contribute equally to the inquiry, and it is collaborative in that the researcher is not an expert doing research from an outside perspective, but a partner functioning with and for those affected by the dilemma and the way in which it is tackled.

All research is open to bias and action research, where the researcher is the curriculum developer, is clearly at significant risk. Bias can be defined as unfairly favouring one thing at the expense of another and it is an error that arises when we allow our own values and expectations to colour the way we conduct our research (Faulkner et al., 1993) (such bias may be subconscious). As the researcher was involved in the development of the VRLE, he attempted to minimise personal bias by avoiding directly teaching in the employed case studies. However, the researcher held a considerable emotional investment in the development work to date and this clearly was a source for potential bias. Bringing this to the fore assisted the researcher in attempting to maintain appropriate objectivity and, in making this fully transparent, the researcher is enabling the reader to make an informed judgement. In addition, the researcher has to be critically objective with the data received, when analysing, reflecting and drawing conclusions from the research.

Another form of bias is novelty/reactivity effects (Cohen et al., 2005), where participants behave differently when subjected to observation or new educational approaches. In this research, the use of the VRLE and ideation work was certainly novel to the students; in addition, there was also the occasional presence of the researcher, who was a stranger to the students: this could influence behaviour and results. Similarly, the researcher's prior experiences or upbringing may introduce bias towards observing or recording certain phenomena and, later, in how patterns in the data are viewed. Cohen et al. (2005) stated that this subjectivity should be honestly acknowledged. In addition, in this context, it was important that the participants became familiar with the researcher as a natural participant within school life.

Several authors (Bailey, 1999; Wong, 1993) cited time as being a significant weakness in conducting action research. All noted that engaging in action research requires an increased time commitment: the additional time needed is inherent within the research procedures necessary for conducting an action research study.

3.7 Action Research Elements inside the Enquiry

Throughout the case studies, the cyclical method of planning, taking action, observing, evaluating and critical reflecting, prior to planning the next cycle (O'Brien, 2001; McNiff, 2002) was used to aid the teacher and the students. At the core of action research is a way to increase understanding of how change in one's actions or practices can mutually benefit a community of practitioners (McNiff, 2002; Reason & Bradburym, 2001; Carr & Kemmis 1986; Masters, 1995). The action research approach was mainly related to three categories: ‘the teacher´s approach to his work’, ‘drawing’ and ‘use of the VRLE’ (see further below and the discussion section of chapter 10).

3.7.1 The Teacher´s Approach to His Work

The core category in the research project was the teacher’s approach to his work. As he was new to IE and using the VRLE for the first time, he had to test and develop many new ideas, in order to enable his work and implement action for change. The teacher participated in the dynamic research process, while the author monitored and evaluated the effects of the teacher’s actions, with the aim of improving practice. These actions included methods employed by the teacher for teaching IE in the new context, managing the new technology, his preparation for the courses, training students in using the VRLE and IE and training them in idea generation, such as using different setups for brainstorming.

3.7.2 Students’ Drawing

Various types of digital output devices and computer aided design software (cad) were employed during the case studies and their usage was developed. This included using the computer mouse with the ‘paint’ software, digital pens with a specific cad belonging to the VRLE and, finally, wireless digital pens (Pegasus), which were digital ink pens with specific software. The specific VRLE cad was also developed. The methods for enabling and supporting collaborative and co-operative ideation were also built up throughout the research.

3.7.3 Use of the VRLE

A variety of issues regarding the use of the specific VRLE arose during the research:

these were based on technical faults and problems in use identified early during the case studies and a collaborative method for testing new ideas and implementing action for change. The software was thus upgraded accordingly, in order to avoid technical difficulties, and online tutorials were set up, in order to improve both the teachers' and students' knowledge and skills in using the software. The students learned to use the VRLE as a tool through experience, but also through training methods that were implemented throughout the research.

3.8 Principles

Yin (1989:23) defined the case study research method as an empirical inquiry that investigates phenomena within single and multiple case studies and can include quantitative data, based on manifold sources of evidence. He informed that they can be based on any mix of quantitative and qualitative evidence (Yin, 1994).

The nature of case study research and action research projects is usually qualitative, as so many variables are possible. This implies that the findings will not be capable of matching the reliability or validity (see section 3.8.1 and 3.8.2) of well-conducted research using a scientific paradigm and methods; however, the interpretative paradigm used by this author will enable a broader contribution to the on-going discussion in the field of study (Yin, 1994). As data collection in the research is limited to small (and purposive) samples, the generalisation of findings cannot be based on statistical techniques, focusing on generalisations from sample to population. Instead, one has to provide 'analytical' forms of generalisation. Readers need to be supported in creating their own attempts to explore the potential transfer of the research findings to theoretical propositions, in relation to their own context. Reports on formative research can facilitate the task of analogy reasoning by a clear theoretical articulation of the design principles applied and by a careful description of both the evaluation procedures and the implementation context (Miles & Huberman, 1994; Yin, 1994).

Qualitative research can produce descriptions or explanations: it can 'give voice' to those whose accounts tend to be marginalised or discounted and it may interpret what people have said, in order to explain why they may have said it. In addition, it aims to create links between micro-processes, such as doctor–patient communication, and macro-structures, such as economic and social relations (Cohen et al., 2003). Qualitative research may be designed to capture the subjective 'feel' of a particular experience or condition, or it may wish to identify recurring patterns of experience among a group of people. What kind of knowledge a methodology aims to produce depends on its epistemological position (i.e., its view of what can be known and how).

The author chooses to act as an external observer not involved in the teaching. Rather, he set up the proposal, made the plan, informed the teachers, trained them and helped them to set up the circumstances for the activities. Various data collection methods have been used to ensure triangulation of the findings and to avoid bias as much as possible. The enquiry took the form of a progressive focusing, using triangulated perspectives from within each case and across different cases and the process of enquiry became a close parallel with the structure as suggested by Hopkins and Bollington (1989):

a. A preliminary, anticipatory stage
b. Immersion in data and the generation of categories/hypotheses
c. Validation of categories/hypotheses
d. Interpretation by reference to theory, practice or professional judgement
e. Action for improvement and presentation of theory.

The pre-pilot (chapter 4.0) and the first case study (chapter 5.0) provided the initial stages, including the recognition of the enquiry as a project and the clarification of directions. Data was then generated through the case studies and triangulated using various methods: such data allowed the development of initial categories, which could be validated, modified or rejected by being tested against the data. Parallel to the fieldwork, the literature was being surveyed in the initial categories and this process allowed a form of grounded theory (Glaser & Strauss, 1967) to be established and suggestions for improvements to be proposed. The process was iterative and continued throughout all the case study series.

Case studies have been used extensively in different disciplines, such as in social sciences and humanities, and the case study is an ideal methodology when a holistic, in-depth investigation is required (Feagin et al., 1991). A case study is a specific research that is frequently designed to illustrate a more general principle (Nisbet & Watt, 1984:72); it is ‘the study of an instance in action’ (Adelman et al., 1980). Furthermore, a case study provides a unique example of real people in real situations,

enabling researchers to understand contexts. However, the results obtained from the case studies may not be generalised unless other researchers can read and visualise their impact. They may also not be amenable for comparing and contrasting; indeed, they may be selective, biased, personal and subjective (Cohen et al., 2005).
Yin (1993) asserts that there are three types of case study (exploratory, explanatory and descriptive) and that each can be single or multiple-case studies. In exploratory case studies, preparation and data collection may be undertaken before the research questions and hypotheses are defined; for example, the collection of readily available data, such as students' marks. This type of study has been considered as a prelude to some social research. Furthermore, explanatory case studies are appropriate for exploring causal studies. In very complex and multivariate cases, the analysis can make use of pattern-matching techniques. A descriptive case study requires that the investigator begins with a descriptive theory: failure to do so raises the possibility that problems will occur during the project. This type of study involves the formation of hypotheses witnessed through cause and effect relationships; hence, descriptive theory must cover the depth and scope of the case under study. The selection of cases and the units of analysis are developed in the same manner as other types of case study.

Stake (1995), however, outlines three other forms of case studies: intrinsic, where the researcher has an interest in the case, instrumental, where the case is used to understand more than what is obvious to the observer, and collective, where a group of cases is studied. Pyecha (1988) used this methodology in a special education study, using a pattern-matching procedure. In all of the above types of case studies, there can be single-case or multiple-case applications (Winston, 1997). This action research project started with an exploratory mode and it then entered an explanatory phase as it attempted to understand the complex, causal relationships involved. The project is also intrinsic, collective and instrumental as the researcher, involved in curriculum development concerning Innovation Education teaching methods, attempted to understand the unknown issues behind the VRLE, undertaking a series of case studies.

3.8.1 Reliability, in Relation to Case Studies

In qualitative research, reliability can be regarded as a fit between what researchers record and what actually occurs in the setting that is being researched (Cohen et al., 2005:119). Worthen et al. (1993) describe reliability as ‘the measure of how stable, dependable, trustworthy and consistent a test is in measuring the same thing each time’. Lincoln and Guba (1985:108) construe the notion of reliability as dependability and they identified a series of checks, including respondent validation and triangulation (see section 3.8.3) and independent audits (such audits identify acceptable processes in conducting the enquiry). In the research discussed here, this was achieved through the support of a tutor, peer review and triangulation (see section 3.8.3). Mehrens and Lehman (1987) address validity as truthfulness: in this, one may ask if a test measured what it was supposed to measure. Worthen et al. (1993) describe validity as ‘the degree to which it accomplishes the purpose for which it is being used’ (p445). However, for a test to be valid or truthful, it must first be reliable (Morrow, et al., 2010).

It is important to ensure reliability of data in a case study type research. However, such research cannot follow the classical forms of reliability and validity. While the researcher strives for this, it is simply impossible within a small scale, dynamic and multivariate context. Case studies, in common with other education research methods, are required to meet the challenges of reliability and validity and the researcher needs to be aware of this Reliability is a necessary precondition of validity (see section 3.8.2) and Yin (1984) suggests four critical tests for the case study researcher:

- Reliability (demonstrating that the study can be replicated with similar results)
- Construct validity (establishing correct operational measures for the concepts being studied)
- Internal validity (establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships)
- External validity (establishing the domain or population to which a study’s findings can be generalised).

The development of criteria for the evaluation of case study methodology requires the logical testing of the validity and reliability of the research methodology; in general terms, reliability ensures that the same conclusions would be drawn from a repeated inquiry. Bogdan and Biklen (1992:48) defined reliability in qualitative research as a fit between what researchers record as data and what actually occurs in the natural setting that is being researched; i.e., the degree of accuracy and the comprehensiveness of coverage. The methods of gaining data need to be reliable, especially when others are involved in the research, and definitions of the behaviour and the context of the research must be established. Instruments and methods must be tested prior to the research and the data must be systematically recorded, so that it can be checked by others. However, even though the methods used may be reliable, they do not always give true or valid information, with regards to the phenomenon being investigated.

Each data collection method acts as a filter and has its limitations and bias. In order to minimise these, the research design should employ multiple methods, in an attempt to minimise any limitations and bias; such an approach is known as *triangulation* (see section 3.8.3). A well-triangulated design can improve reliability and build a coherent picture, so that reliability assumes a slightly different meaning. If the data is not reliable, it is impossible to develop validity.

3.8.2 Validity, in Relation to Case Studies

Cohen et al. (2005:105) informed that early definitions of validity were based on the idea that validity was a demonstration of whether a particular instrument measured what it purported to measure; this definition is multifaceted. Hopkins and Bollington (1989) established eight ways of ensuring that qualitative research is as valid as possible, as below:

a) Be alert to threats to validity
b) Be clear about analysis
c) Call things by their right names
d) Know what you are looking for
e) Triangulate data
f) Be catholic in the use of data sources
g) Reduce and display data
h) Systematically use case studies.

Cohen et al. (2005) considered internal validity as being concerned with whether the treatment does make a difference and they viewed external validity as questioning whether the effects can be generalised to other situations. Hopkins and Bollington

(1989) also considered construct validity as indicating that the research must focus on the operational issues it purports to reflect.

Validity is a requirement of both quantitative and qualitative/naturalistic research. However, the definitions of validity in the hypothetico-deductive paradigm are not directly applicable to an illuminative paradigm. With an illuminative paradigm, we can improve our assurance in the findings, but can never really establish full validity. Some researchers consider validity as an unhelpful term in illuminative research and that the emphasis is on the researcher achieving reliability and communicating the context in detail. In this, other practitioners and researchers can interpret the findings in their own, unique context. Hammersley (1992:50-51) suggested that validity in qualitative research replaces certainty with confidence in the results and that, as reality is independent of the claims made for it by researchers, accounts will only be representations of that reality, rather than a reproduction of it.

The author attempted to establish validity in various ways when he constructed the research: each case study incorporated participant briefings, the design of lesson plans, data collection methods and setting up the aims, objectives and research questions. Similarly, the author designed the methods of collecting data, prepared the participants for the novelty of the VRLE, met with them, tested the methods and formulated the confidential contracts regarding use of participants' personal information. Furthermore, he pre-tested the VRLE and made course plans for the research and for introducing it to the participants, in order to ensure that the teachers were able to manage the technology and the lessons. He also tested the technology used for data collection, informed the personnel in the school about the research and the researcher and visited students in other lessons, in order to reduce the novelty factor concerning an external, visiting researcher.

3.8.3 Triangulation

As indicated above, triangulation is a method used to minimise any limitations and bias that may be inherent in any given data collection method (Cohen et al., 2005). In a case study, the researcher considers not just the voice and perspective of the actors, but also the relevant groups of actors and the interaction between them (Tellis, 1997). Such a complex and dynamic context cannot not be reliably recorded through a single data collection method and thus triangulated methods are required (Yin, 1984). Smith (1975) noted that, as research methods act as filters through which the environment is selectively experienced, they are never neutral in representing the world of experience. Thus, reliance on one method may bias or distort the researcher's picture of the particular aspect of reality that is being investigated. It is therefore necessary to use various ways of collecting data, in order to build reliability and consistency in recording such data, so that the research can be reported. The reliability of the findings becomes stronger if the data collection methods differ substantially and are correctly employed and the data generated indicates similar conclusions.

Triangulation is applicable to both general paradigms, but becomes essential within an illuminative approach, due to the limited reliability of single methods. Denzin (1984) defined four different types of triangulation:

a. Data source triangulation, when the researcher aims for the data to give similar results in different contexts
b. Investigator triangulation, when several investigators examine the same phenomenon
c. Theory triangulation, when investigators with different viewpoints interpret the same results
d. Methodological triangulation, when one approach can be used in parallel to another, in order to increase confidence in the interpretation.

Cohen et al. (2005:113) outlined six different forms of triangulation:

a. Time, when longitudinal designs are used to check on change and process
b. Space, which uses cross-cultural perspectives to reduce parochialism
c. Combined levels, individual, interactive and a collective or organisational level
d. Theoretical, which draws upon alternative theories rather than one theory
e. Investigator, when more than one observer is used
f. Methodological, when either the same method is used on different occasions or different methods are used on the same object.

The researcher in this project employs data source, methodological and investigator triangulation, in order to improve the reliability and validity of the project; for example, in case study series one, various forms of data were collected in order to investigate the same phenomena. This included video based recordings (both external and internal) of the student's use of the VRLE, interview transcripts through audio recordings of meetings with participants, questionnaires that elicited the views of participants, structured interviews and data obtained from the supporting database in the VRLE. In addition, the perspective of the teacher involved in the case studies added a degree of investigator triangulation. The researcher used a combination of levels a, c, e and f for each case study and this was due to the dynamic complexity of the investigation of social interaction, amongst students and teachers, within the VRLE.

3.9 Data Collection Methods

The choice of data collection methods was based on the projects aims, objectives and research questions and the author's possibility of accessing different types of data. Some of the data was automatically collected, such as the information from the VRLE database concerning the students' work. Various data were collected, in order to develop triangulation (and thus reliability and validity) within the enquiry.

One of the pilot case study objectives was to develop experience of using case study methodology and to question the values of different data collection methods. Once the aims, objectives and the research questions had been established, the author looked for ways to collect the data for answering the research questions; he also observed the specific VRLE software, in order to collect data regarding the students' work when they were using the VRLE. All the data collection methods were trialled prior to the research: these methods are shown in the table below, indicating the methods intended to highlight and triangulate the research questions in the case studies. The table also shows the connection between the data sources and the research questions.

	Data Sources	**RQ1**	**RQ2**
1.	Screen captured videos from the VRLE	x	x
2.	Interviews with the teachers	x	x
2.	Interviews with the head of the school	x	x
3.	Interviews with student groups about the course and their work	x	x

4.	The researcher’s logbook	x	x
5.	Drawings and descriptions from students	x	x
6.	Video recordings in the classroom	x	x
7.	Data from the VRLE		x
8.	The Inventors Notebook	x	x

Table 3.1: The specific data collection methods and how they answer research questions and establish triangulation.

3.9.1. Data from the VRLE

The author used the software *Camtasia 3.0* to video activity inside the VRLE. *Camtasia* is a software solution that runs in the background, silently capturing everything that appears on the screen and saving it to a video file. Data were also gathered from the VRLE database: this was done in order to facilitate an understanding of the social activities inside of the VRLE and to gain information about the students’ work delivered through the computers.

3.9.2 Screen Capture Video (Remote Tool Observation)

Again, *Camtasia* was used to record a video of the computer screen activity, resulting in a recording with no loss of details. Each frame of the resulting video serves as a screenshot and the video can be viewed at different speeds. *Camtasia* mimics the behaviour of a video camera and, as a result, it shares the many benefits of videotaping, while avoiding several of the pitfalls (Goodwin, 2005); it consists of three pieces of software (the recorder, the player and the producer) and records all activities on the screen. Recordings are saved in avi file format and sound can also be recorded. The *Camtasia* recorder also offers numerous features: it can record the whole screen or a particular window or region of the screen. The recorder can also be set to highlight the mouse clicks; for example, a highly visible red circle can appear around the mouse pointer as it clicks, making it easy for the observer to see essential actions on the screen. However, these highlights occur on the user's computer as they are applied and thus it may be too disruptive to use this feature when attempting to test a user in a natural situation (Goodwin, 2005). The recorded file is explored with the player: the capture plays back in real-time, but the player includes standard controls to pause, fast forward and rewind the recording.

3.9.3 Information from the VRLE Database

The VRLE is a specific, data-driven software, with an underlying database that hosts the students' work. The software uses SQL2000 and ASP database technologies and the database is hosted on a server in Iceland by Skyrr hf. The author was able to access all the students' workshops to see what they had done in the VRLE and one of the benefits of using such a method is that the data is automatically collated the entire time the students are working inside the VRLE. This does not disturb the students and is not under open access, so personal information is protected. From the database, is also possible to get statistical information; for example, the number of ideas students have worked with, the time they spend in the VRLE and how much work students have delivered (see table 10.3 and figure 10.9).

3.9.4 Video Recordings in the Classroom

Video recordings were made in the classroom, in order to record social interaction between the students and the teacher and enable any subsequent analysis. Recordings also show how these interactions affect the students' work, both in the classroom and inside the VRLE. Two cameras were usually used; one with a wide lens, in order to capture the classroom context, and the other to capture individual students working in the VRLE at the same time.

Many observers use camcorders as a means of gathering information on classroom activities. Indeed, camcorders allow the outside observer or the teacher to quickly observe the many facets of teaching (Elliott, 1991). Within the context of classroom-based action research, video can be used to record lessons, either completely or in part; however, video has its limitations. It can be very disturbing for participants, although this may diminish as the user becomes more skilful and the students being videoed become used to the presence of the camera. If a camera is pre-set, it may be unable to pick up certain things which are relevant and important; e.g., verbal exchanges between the teacher and a particular pupil during a non-class teaching episode (Elliott, 1991).

Portable digital cameras with built-in microphones are probably less distracting than the older method of using a tape recorder and an external microphone (Elliott, 1991). Different lenses can be used, as they capture different angles of areas where the social activities take place: a wider lens better captures collaboration between the teacher and the students. However, sometimes it is important to focus on single students, in order to see the individual process of learning activity, as when one is working and communicating with other students face-to-face and through the computer at the same time (Elliott, 1991). Such focusing, however, tends to be obvious and will probably influence the way the students react.

Video data is a potentially rich source of information: transcribing a video enables the researcher to extract and write a summary describing what is seen and heard. Generally, the summary is coded referring to certain clips on the video and this enables the researcher to move backwards and forwards through an episode more quickly. Transcribing by hand is immensely time consuming; however, there is computer software that is useful for making summaries and transcriptions. Such software can be useful, as it concentrates the mind on what is happening to a greater degree than simply listening and watching. Restrictions on available time will limit the extent to which transcriptions are possible (Elliott, 1991).

The degree to which a researcher generates visual records (for example, video) that may be used to collect valid information about the social world is the subject of considerable academic debate (Grimshaw, 1982). By implication, the method is assumed to have a limited impact on the data, as the taped image is treated as a replica of the unrecorded event (Vihman & Greenlee, 1987); however, it is suggested that the video camera has a uniquely distorting effect on the researched phenomenon (Gaede, 2004; Heider, 1976). It is argued that research participants demonstrate a reactive effect to the video process and, as such, data is only meaningful if special precautions are taken to validate it. Strategies suggested include ethical issues in a school, in terms of the data collection itself (Gaede, 2004; Albrecht, 1985), or the application of triangulation techniques, such as respondent validation.

As the author used a digital video camera, he was able to use a computer to work with the data. The quality of the video was reasonable and the sound was sufficient enough to detect sentences and the meaning of conversations. The process of extracting the data was similar to the other data sources, but more time consuming. Both verbal and non-verbal interaction shaped communicative meaning in the recordings and features of talk, such as emphasis, speed, tone of voice, timing and pauses, affected the way the video was interpreted. Interaction, such as body orientation, facial expression and gestures, also influenced the transcription. To enable this work, *Transana,* a software for video analysis, (www.transana.com) was used.

Transana is software that allows researchers to transcribe and analyse large collections of video and audio data; it also enables them to organise video clips and classify under categories as analytically coded graphical and text-based reports. The main aim of using the video data was to examine short examples of students' collaborations and the teacher´s activity during lessons. Firstly, the author skimmed the videos to understand their characteristics and indexed the content. He then transcribed the conversations, coded the clips (using relevant time quotes) and wrote analytical memos. After this, he wrote summaries and categorised the data. The data was finally analysed and conclusions were drawn.

The way video images were produced and used in this research project is also important, in terms of ethics. Prosser (2000) questioned the ethics of image-based video research, arguing that any research that involves images of the participants compromises the anonymity of such participants. The videos used and produced during this project are extremely important, in terms of the findings of the project, and it was also important to use them to underpin the effectiveness of the research methods chosen. However, if there were any remotely unethical parts in the videos, these were removed.

3.9.5 Interviews

An interview is a conversation between the interviewer and the interviewee/s, where questions are asked by the interviewer in order to obtain information from the interviewee (Smith, 1995). Cohen et al. (2005) outlined five types of interview often employed in educational settings: structured, unstructured, semi-structured, non-directive and focussed interviews. The depth and extent of information and feedback being sought will determine which type to use:

a. In the structured interview, the content and procedures are organised in advance and such an interview is characterised by being a closed situation. Structured interviews are similar to written questionnaires, in that they utilise a set of fixed questions (termed a schedule) with fixed response categories, covering a specific area or topic. These work well when the goals of the project are clear. The questions can only be constructed after the researcher collects information about the problem or the issues being explored (McClelland, 1995).

b. The unstructured interview is an open situation, offering greater flexibility and freedom. Unstructured interviews are used when the depth of information being sought is broad and non-specific and they are similar to the written survey questionnaire format of open-ended questions; such interviews are also similar to the questions used in brainstorming sessions. They are particularly good for investigating potentially emotional or sensitive personal issues (McClelland, 1995).
c. The semi-structured interview has a pre-designed structure and schedule, as with a structured interview, but also allows and encourages the respondent to raise issues that emerge during the interview that are valid to the research but have not been predicted by the researcher. This emerged as a key tool in this research, as outlined further below.
d. The non-directive interview derives from the therapeutic interview, where respondents express their subjective feelings as spontaneously as possible.
e. The focused interview focuses on the respondent's subjective response, based on a previous interview that has been analysed by the interviewer prior to the interview.

The researcher used semi-structured interviews and open-ended questions with the teacher, the student group and with individual students. This was done to explore ideation work, gain opinions and see how the teacher and students felt about the course. The interviews were recorded with a digital recorder and transferred to a computer, in order to facilitate the process of analysis. Even though the recording of interviews can potentially make the respondents less relaxed, it has the advantage of preserving a more complete record of the interview than would be possible when taking notes (Smith, 1995; Willig, 2001). Permission to use the recorder was always sought before use.

In semi-structured interviews, researchers normally use open-ended questions, which require descriptive answers. The aim of this is to gain the respondent's point of view, rather than generalising about their behaviour and activities (Smith, 1995). Some open-ended questions are planned by the researcher ('Tell me about…') and some arise naturally during the interview ('You said a moment ago…can you tell me more?’). When people have a discussion, they react to each other by probing and keeping the discussion going. Throughout interviews, the interviewer applies suitable probing techniques, which encourages interview subjects to speak further (Cohen et al., 2005). However, such probing has to be neutral, so it will not redirect interviewees.

According to Smith (1995) and Willig (2001), the most common probings are the silent probe, the echo probe and informed consent:

a) When individuals talk, they frequently take a break to collect their thoughts and get ready to say something and the silent probe is useful in this. The interviewer remains silent and waits for the respondent to carry on; such silence may include nods or encouraging noises. The silent probe can bring out more information than non-stop questions, as the interviewer does not disturb the interview subject.
b) When interviewers use the echo probe, they repeat informants’ phrases and encourage them to carry on.
c) Informed consent refers to putting the interviewee’s mind at rest by explaining the reason for the research, the use of data collected and the security and anonymity of information. The interviewer must inform interviewees that their involvement is voluntary.

The researcher attempts to build a rapport with the respondent and the interview is like a conversation (Smith, 1995; Willig, 2001). Questions are asked when the interviewer feels it is appropriate to ask them and these may be prepared questions or questions that arise in the researcher’s mind during the interview.

This sense of rapport implies ethical responsibilities and interviewers have to be sensitive, with regards to respondents’ readiness to talk about prearranged topics. Semi-structured interviews are designed to create a detailed description of respondents’ perceptions of a given matter (Cohen et al., 2005). Thus, they are flexible and it is not essential for questions to be asked in a set order or to be phrased in the same way with each participant. This flexibility enables respondents to focus on the topics that command the greatest attention and have the greatest relevance, yielding richer and more varied data. In this sense, participants play an essential role in shaping the direction of the interview.

The researcher has the responsibility of ensuring that the interview does not wander away from the research question (Cohen et al., 2005) and a cautiously constructed schedule can help in this. While some interviewers prepare a choice of topics, others prefer to word exact questions in advance. It is also advisable to design 'open' questions that cannot be satisfied by a 'yes/no' answer and to avoid using slang or the asking of leading questions (Smith, 1995; Willig, 2001).

Semi-structured interviews have many advantages:

- Positive rapport between interviewer and interviewee
- A simple, efficient way of gaining data on things that cannot be easily observed (such as emotions)
- The capability of achieving depth and detail. The meanings behind an action may be uncovered, as the interviewee is able to speak for themselves, with little direction from the interviewer
- With few 'pre-set questions', the interviewer is not 'pre-judging' what is and what is not significant information
- The data is easily collected by video/audio tape

However, semi-structured interviews have also limitations:

- The outcome depends on the interviewer's skill
- The interviewer may give out unconscious signals that guide respondents to give answers expected by the interviewer
- They are time consuming and relatively expensive
- They are significantly unreliable and hard to repeat precisely. Respondents may be asked dissimilar questions (non-standardised). Samples tend to be small
- Depth of information may be hard to analyse
- Individual character of interview may make findings complicated to generalise (respondents may in fact be answering different questions).

Validity is also limited:

- The researcher has no true way of finding out if the respondents are reliable
- The respondent may not lie on purpose but may have imperfect recall. If one is asked to recall things that happened days, weeks or months ago, it is likely

that they will actually remember very little about what happened

- An interview can occasionally be a ‘second chance’ to do something; having been given the time to reflect on something they did, the respondent tries to make sense of their actions by rationalising their behaviour. They are not knowingly lying (as they will think what they are saying is true), but their description for their behaviour, with hindsight, may be very dissimilar from what they actually felt at the time.

3.9.5.1 Interviews with Individuals

An interview is an occasion where a single individual is able to speak at length about specific elements. The individuals interviewed may be drawn from class or from key informants, such as other teachers, family members, information intermediaries or other people who may have some influence on the audience. Interviews with members of a class or a teacher are a useful method for gathering information about how individuals are likely to understand and interpret the activities in the lessons.

Children may find interviews stressful. Thus, before beginning, the interviewer should spend a few minutes discussing a neutral topic: this will create a relaxed atmosphere, warm up the conversation and build a level of trust, enabling more natural and honest answers. Simons (1982) and Lewis (1992) advise the following:

- be aware that the researcher may be seen as an authority figure
- keep the interview relevant
- keep the teacher away from the children
- pitch language at the appropriate level
- avoid children being too focused on particular features or situations
- be aware that some children will say anything rather than feeling that they do not have ‘the answer’
- in group interviews, be aware that some children will dominate the conversation
- be aware that children may not tell the ‘truth’.

Interviews have an ethical dimension, in that they concern personal interaction and produce information about the human condition. The University of Sussex (2010) recommends that individual interviews are conducted by two researchers or in areas where the researcher and the child are not entirely alone, to protect both the researcher and the child. According to Kvale (1996), interviews require permission from the child, the school and the parents. The interview should be confidential and the consequences of using the data should be considered. Cohen et al. (2005) noted that ethical matters are contestable and should be questioned and they provided a check list for this, as below:

- Is the interview to be conducted in a non-stressful, non-threatening manner?
- Has the informed consent of the interviewees, the parents and the school been gained?
- How can adequate information be provided in advance, if the study is exploratory?
- Has care been taken to prevent any harmful effects of the research on participants?
- Is the interview anonymous, non-traceable and are identifications hidden?
- Who will have access to the data?

3.9.5.2 Group Interviews

Group interviews have many advantages, in terms of the potential for discussions to develop and yield a wide range of responses, and Bogdan and Biklen (1992) stated that group interviews are useful for gaining an insight into what might be pursued in subsequent interviews. These are valid reasons to start this research with a series of group interviews. Cohen et al. (2001:287) outlined a series of practical reasons to support group interviews, stating: ‘group interviews are often quicker and involve minimal disruption…they can bring together people with varied opinions…and might also be less intimidating for them (children) than individual interviews’. However, managing the dynamics of a group is a challenge, as a small number of individuals can easily hijack it: the group interview requires skilful management to keep the situation focused. Group size is also an issue: if the group is too small, this can put pressure on individuals, but a large group can fragment and lose focus. Lewis (1992) indicates that the optimum size for a group of ten year olds would be around six, but may be smaller for younger children.

There are obvious limitations to group interviews, in that they are complex and it is not possible to follow up the views of individuals; in addition, group dynamics or power hierarchies affect who speaks and what is said. A particular problem is the dominance of one or two people (Macphail, 2001; Watts & Ebbutt, 1987), although an obvious appeal for other contributions can help. There may be indications from others' body language that they wish to contribute and the interviewer can capitalise on this.

3.9.6 Drawing Tests in Case Study Series 2 (section A6.3.17)

In case study series 2, digital drawing was identified as an important part of the students' work, as it affected both the time it took to generate solutions and quality of work. Furthermore, it concerned the students' ability to express and communicate their ideas. Thus, the following research question was set up to lead this part of the authors work: 'How may the students' abilities to draw inside of the VRLE be improved (RQ 4)?'

In lesson one, the author conducted a drawing test (see section A6.3.17), based on the following:

a) Using a normal pencil on paper, draw three-dimensional drawings of a box, a cylinder, a small shelf and a house with a car in front of it.
b) Draw a three-dimensional drawing of a house with the initial digital pen tablets and computer.

The drawings were compared with those produced when the students used the Pegasus digital tablets to draw solutions. This was conducted due to the fact that there would be maturation effects if the same exercises were repeated with the new pens. The Pegasus digital tablet was basically a PC Note Taker: an electronic pen that captured drawings and transferred them, via the USB-connected receiver, to a PC. This was based on specific software and was not compatible with other software applications. However, the students did not have to look at the computer screen at the same time as they drew, as with the initial pens: the Pegasus pens were ink based, so they could also see their drawings appear on the paper.

An assessment form was set up for the drawing tests. Two design & technology teachers at Loughborough University gave their comments and also piloted the test: the test was subsequently upgraded and was completed in 15 minutes by four postgraduate students at the same University. The drawing assessment (see section A6.3.17.3) also included drawings the students did with the Pegasus tablets and the main aim was to examine the students' ability to draw using the three different methods and to mark the quality of the drawings.

3.9.7 Diaries

It is useful to keep a diary on a continuous basis and this should include individual accounts of observations, feelings, reactions, interpretations, reflections, intuition, hypothesis and explanations (Kemmis et al., 1988). Accounts should not only report the 'bald facts' of the circumstances; they should also express a feeling of what was like to be there, as an outside observer or participant. Anecdotes, near-verbatim accounts of discussions and verbal interactions and deep-in-thought accounts of one's feelings, attitudes, motives, understandings in reacting to things, events and situations all help to report what it is was like at the time (Cohen et al. 2005).

Kemmis et al. (1992) recommended that teachers do their own classroom action research, in order to write their personal notes and encourage the students to do so as well; this enables the teacher to contrast their experience with that of the pupils. However, it is essential to bear in mind that keeping a diary is a private and personal matter and that the disclosure of its contents should be under control of its author and the data collection agreed by the participants, including parents and school (Elliott, 1991). The content of the diaries should be correctly dated and, within the context of classroom action, research information should be cited (i.e., form, time, subject) at the beginning of a lesson. Entries may differ in duration and the amount of detail: they should perhaps be fullest at those points where the heaviest monitoring and investigation is planned.

It is also possible to write a research diary in a more structured form. For example, in ethnographic research, it may make sense to differentiate data analysis from the data itself, using square brackets for systematic observations (Hammersley & Atkinson, 1983:164). In a more formalised approach, following Glaser and Strauss (1967), Richardson (2000:923-949) has recommended that the researcher organises diary notes into four different categories:

1. Observation notes (ON): accurate renditions of what I see, hear, feel, taste and so on.
2. Methodological notes (MN): messages regarding how to collect data.

3. Theoretical notes (TN): hunches, hypotheses ... critiques of what the researcher is doing, thinking and what he sees.
4. Personal notes (PN): feeling statements about the research, the people the researcher is talking to ... doubts, anxieties, pleasures (2000).

The saying that there is no one correct method applies to the keeping of research diaries, in common with many other aspects of research. Whether you use a more or less pre-arranged method of diary keeping, the most essential thing about keeping a research diary is that it will encourage the researcher to be careful in record keeping and to reflect on the data. As Hammersley and Atkinson (1983:165) asserted:

> The construction of such notes ... constitutes precisely the sort of internal dialogue, or thinking aloud, that is the essence of reflexive ethnography.... Rather than coming to take one's understanding on trust, one is forced to question what one knows, how such knowledge has been acquired, the degree of certainty of such knowledge and what further lines of inquiry are implied

Both the teacher and the observer wrote diaries after each lesson, which reported reflections concerning the teaching and the course. The students used their specific notebook at home, as a form of diary: this gave information about their homework and the origin of their ideas and helped them to record ideas as they came into their mind. They then brought these into school.

3.10 Grounded Theory as a Way of Building Understanding and Related Principles of Data Analysis

Grounded theory consists of a systematic, inductive strategy for collecting and analysing data, in order to construct theoretical frameworks that describe the collected data (Denzin & Lincoln, 1994). This enables the researcher to identify emerging categories within a set of data and then develop initial hypotheses that can be tested iteratively. Grounded theory focuses on obtaining an abstract analytical schema of a phenomenon that relate to a particular situation (Obenchain-Leeson, et al., 2008) Creswell, 1998). However, Strauss and Corbin (1998) explicitly pointed out that the value of grounded theory lies in its ability not only to generate the theory, but also to ground that theory in data. This inductive method is particularly helpful in identifying patterns of behaviour or thought in a particular group of people, as in this enquiry.

Glaser (1978) lists four characteristics of grounded theory:

1. A theory must have fit: grounded theory is loyal to the everyday realities of a substantive theory or must be carefully gleaned from various data.
2. A theory must have relevance: grounded theory signifies relevance, as it permits central problems and processes to appear.
3. A theory has to work: it should be able to explain what happened, predict what will happen and interpret what is happening within an area of a substantive or formal inquiry.
4. A theory must be easily modifiable: the generation of grounded theory is an ever-modifying procedure.

Strauss and Corbin (1998) added two additional features and these are that grounded theory is always traceable to the data that gave rise to it and such theories are very dynamic, in that they embrace the interaction of numerous actors and highlight temporality and procedure.

Smith (1995) notes the following, in terms of grounded theory:

1. The generative nature always takes it beyond the substantive area being studied.
2. It transcends precise data collection methods.
3. The researcher goes beyond his data, to new problems and ideas.
4. Grounded theory is transcending, in the sense that it conceptualises the data.

Smith (2001) states that grounded theory requires constant comparative analysis and views group comparisons as conceptual: these are continued by comparing diverse or similar evidence demonstrating the same conceptual categories and properties, rather than by comparing the evidence for its own sake. In addition, comparative analysis takes full advantage of the interchange ability of indicators and develops a wide variety of satisfactory indicators for categories and properties.

The core of grounded theory data analysis is a continuous coding procedure (see section 3.11.1) and analysis begins with open coding: the data are examined step by step, in order to define actions or events within the data. Coding analysis will likely lead to the ‘refining and specifying of any borrowed existing concepts’ (Strauss &

Corbin, 1998:115). Also, there is axial coding, which is meant to build conceptual relations between a category and its subcategories. Concepts and sub-concepts are then further defined by selective coding: ‘an integrative process of selecting the core category, systematically relating it to other categories, validating those relationships by searching for confirming and disconfirming examples and filling in categories that needed further modification and development (Strauss & Corbin, 1998:116). Codes and categories will be sorted, compared and contrasted until all the data are accounted for within the core categories of the grounded theory model and no new codes or categories can be formed; i.e., saturation is achieved. The researcher also needs to write analytical and self-reflective memoranda, in order to document and enrich the analytical procedure, to make understood thoughts clear and to expand the data. Analytical memoranda consist of questions and speculation about the data and emerging theory.

Creswell (1998) described the general structure of grounded theory as follows:

1. Introduction: problem and questions.
2. Research procedures: grounded theory, data collection, analysis and outcomes.
3. Open coding: categorising the information and examining properties and dimensions of the data.
4. Axial coding: identifying a central phenomenon, exploring causal conditions, specifying strategies, identifying the context and intervening condition and delineating the consequences for the central phenomenon identified.
5. Selective coding: identifying a storyline and writing a story that integrates the categories in the axial coding; presenting the conditional proposition or hypotheses.
6. Discussion of theory and contrasts with extant literature. Visually portraying a conditional matrix that explicates the social, historical and economic conditions influencing the central phenomenon.

3.11 Analysis of Data during the Research

The author needed a comprehensive range of instruments, in order to extract the relevant data relating to the research questions. One objective was to explore a range of data collection instruments, in order to enable subsequent work to be effective and to develop the author’s skills as a researcher. Varied data was needed, in order to triangulate the research and strengthen reliability, as described in the chapter. The specific instruments used were listed against the research questions, as in table 3.2 below.

Chapter	Appendixes	Data Sources	Q1	Q2
5.7.1	A5.3.1 - A5.3.4	Interviews with the teacher	x	x
5.7.3	A5.3.9 - A5.3.10	Interviews with individual students	x	x
5.7.2	A5.3.5 - A5.3.8	Interviews with student group	x	x
5.7.4.1	A5.3.11 - A5.3.14	The teacher's logbook	x	x
5.7.4.4	A5.3.15 - A5.3.18	The author's logbook	x	x
5.7.5	A5.3.19	Data from the VRLE	x	x

Table 3.2: Data collection methods used in the pilot case study

3.11.1 Using Coding to Support the Process of Data Analysis

Data is coded differently, depending on the purpose of the data and the stage of the project. Open coding was used to support the process of data analysis (section 3.10; section 3.11.4) in the initial stage of the acquisition of data and in the process of selecting and naming categories from the analysis of the data. Such coding relates to describing the overall features of the phenomenon under study and variables involved with the phenomenon were identified, labelled, categorised and related together (Creswell, 1998). This helped the author analyse summaries into key findings and form initial categories of information about the phenomena being studied (Creswell, 1998). Key findings in the data were marked with a series of codes, which were then grouped into emerging conceptual categories. At this stage of the analysis, the author was concerned with identifying, naming, categorising and describing phenomena found in the text. He kept an open mind, in order to identify as many ideas and issues as possible. Essentially, he read each line, sentence, paragraph, etc., in search of answers to the questions: 'what is this about?' and 'what is being referenced here?'

Axial coding was the next stage, after open coding. Axial coding is the process of relating categories and properties to each other, via a combination of inductive and deductive thinking. The author classified similarities in the outcome into main categories and this was used for discussions, conclusions, answering the research questions and feed forward (Emerson, 1995): he looked for any kind of relationships, including causal relationships, so-called by grounded theorists (Denzin & Lincoln, 1994). The categories were then related to each other as a theoretical explanation of the action(s) that continually answered concerns of the researcher in the substantive area (Denzin & Lincoln, 1994).

Selective coding was also used as a process of choosing one category to be the core category and relating all other categories to that category (see step 7 and the discussion in chapter 10). The essential idea of the use of selective coding is to develop a single storyline, around which everything else is based, and there is a belief that such a core concept always exists. In his work, the teacher's approach appeared to be the core category that all the other categories were related to (see further in chapter 10 discussion).

3.11.2 How the Data was Treated and Analysed

The raw data was collected and translated directly into English. The author attempted to retain the Icelandic language style and expression in the English translations, in order to avoid any misunderstanding when analysing the data (with regards to the characteristics of each language). Data from each source was then summarised; for example, there were two teacher interviews, which were summarised separately and then used to generate categories together. These categories were then discussed and the conclusions drawn. The process was repeated for all the data sources listed above in table 3.2.

Finally, the categories from all data sources were brought together under overall categories (see section A5.4). These categories were then used to triangulate the findings and were analysed, in relation to each other and the literature and conclusions were drawn. An example of this process can be seen in section A.5.7.

3.11.3 Codes Used in the Main Text

Transcripts and summaries can be found in the appendices and the appendices are referred to using an 'A' prefix. For example:

- A6.3 = appendix for chapter 6.3

In addition, data generated from video and audio transcripts of lessons is referred to with a 'CSL' prefix. For example:

CS2,L3:2,0:00:39.0 = Case study two, lesson 3; video clip 2; time code 0:00:39.0 minutes.

3.11.4 An Example of an Overall Category

Findings from various sources were classified into categories for each source and then classified as overall categories. The categories were then discussed (below is an example of the discussion process). Different colours were used to group the similar findings together, which assisted the author in writing the discussion. Finally, literature was introduced to the overall discussion, in order to enlighten the outcome.

Category 1. Teacher's Preparation

Data sources, followed by findings that were supported by open coding

interviews with the teacher

- The time to prepare for the lesson was not enough
  Pre-training for the IE is needed
  Pre-training is required, with regards to the use of the VRLE
  It is important to learn the general operation of the computer system
- The teacher had to set up emails, in order to enable the students to enter the VRLE
- The teacher experienced difficulties in preparing the facilities and upgrading the VRLE, as others were using the classroom before the lesson
- It was better to run the lesson early in the day, rather than after school, when students were tired.

The author's logbook

- The teacher had to create email accounts for the students and register them to the VRLE, as part of the VRLE personal security system
- It was difficult for the teacher to find time for the lessons
- The teacher needs to spend more time preparing for the course
- The teacher was better prepared in later lessons
- The teacher requires further training in the use of the VRLE.

3.11.5 An Example of Discussing an Overall Category from the Above: Teacher's Preparation

The teacher stated that the VRLE was user-friendly. However, he may have been more computer literate than most teachers and thus other teachers may have a different view of the VRLE. In order to ensure teachers are confident in using the VRLE hardware and software, pre-training is vital.

The teacher needed time to prepare himself, the computer facilities and the VRLE software for the lessons: this included learning the general operation of the computer system and setting up emails. This may lead to a conflict of roles, as the teacher switches between administrator and tutor. The pilot study was an after school activity and the teacher struggled to find time for this in his schedule: running such lessons can be tiring for a teacher in a full-time position and thus it may be better to run classes within regular school hours.

3.12 Ethical Considerations

Any research needs to consider ethical issues, particularly where children are involved. The *National Statement on Ethical Conduct in Research Involving Humans* (NHMRC, 2001) informs that researchers must provide for the physical, emotional and psychological safety of the children with whom they work; any research settings must be seen through their eyes and strategies supporting their abilities must be adopted (Mayall, 2000; Scott, 2000). Spencer and Flin (1993) noted that children's perceptions and thoughts should be regarded as competent. However, we need to be aware that their perceptions are relatively immature; for example, each child has 'the best mum in the world': this is true from their point of view.

Spencer and Flin (1993) asserted that one of the roles of an adult researcher is to prevent harm and that this is socially natural and expected. The researcher has to reduce the influence of ethical dilemmas in using the methodologies and act with clear and defined roles, in order to ensure the well-being of the participants. Furthermore, the methodology adopted must be congruent with the needs of children. As educational research involves close and open communication among the students and teachers involved, the researcher must pay close attention to the ethical aspects of such research.

Richard Winter (1996) lists a number of principles concerning ethics:

- Ensure that the relevant persons, committees and authorities have been consulted and that all accept the principles guiding the work in advance.
- All participants must be allowed to influence the work and the wishes of those who do not wish to participate must be respected.
- The development of the work must remain visible and open to suggestions from others.
- Permission must be obtained before making observations or examining documents produced for other purposes.
- Descriptions of others' work and points of view must be negotiated with those concerned, before being published.
- The researcher must accept responsibility for maintaining confidentiality.

Several more points may be added to this:

- Decisions made about the direction of the research and the probable outcomes are collective, also based on other persons involved in the research.
- Researchers are explicit about the nature of the research process from the beginning, including all personal biases and interests.
- The outside researcher and the initial design team must create a process that maximises the opportunities for involvement of all participants.

3.12.1 Fulfilling the Icelandic Requirements for Personal Protection

The ethical requirements for undertaking research in Iceland are stated in the Icelandic act no. 77/2000, as outlined in 'The Security of Personal Data' (Personuvernd, 2011). The purpose of this act is to promote the practice of personal data being handled in line with the fundamental principles of data protection and the right to privacy. This includes instruction for the protection of individuals, with regards to the processing of personal data and on the free use of such data. The act applies to any automated processing of personal data and to the manual processing of such data if it is, or is intended to become, a part of a file.

The Icelandic data protection authority (DPA) deals with specific cases concerning any enquiries from public authorities or private individuals, or cases taken up by the authority on its own initiative (Personuvernd, 2011). The Data Protection Authority supervises the implementation of and compliance with the Act and any pursuant regulations or orders. It addition, it maintains the registry of activities and can investigate and issue rulings. Undertaking research within the complex social education context of IE included both the teacher's and the students' experiences; thus, all participants (the children, parents and teachers) were made aware of the purpose of the research, the research methods, how information is collected and how such information is used (section A5.0.4; Greig & Taylor, 1999).

It is ethically important that the researcher has received the participants' permission for participation in the research and that they are provided with a clear description of the nature of the research and the consequences of participation (Personuvernd, 2011; Bogdan & Biklen, 1998:43). Within educational settings, one must gain permission from the head teacher of the school, the teacher and the parents to store personal information on a computer and implement the data. Thus, before each case study was conducted, the parents, the headmaster and the teacher undersigned a contract regarding the use of personal information in the data (see sections A5.0.1-A5.0.3). However, according to Act no. 77/2000, permission for a research study is often sought from the data protection authority. Furthermore, if permission has been gained from the parents, as in this case, this is considered enough in authorising the research (Personuvernd, 2011). However, the researcher has to disclose details of the research to the DPA.

When choosing security measures, notice should be taken, with regards to the risk of the processing and the nature of the data that shall be protected: the data controller will consider which security measures shall be employed (Act no.77, 2000). Thus, the author contained the data processor's position within what he considered to be an acceptable risk, in terms of processing. His security measures were gained from the supporting programmers who maintained the server.

If personal data are transmitted through the Internet, the higher risk associated with such processing should be noted. In addition, the data controller has to be aware of the risk of unauthorised persons gaining access to personal data, enabling them to change the data or to threaten security in some other manner (Act no.77, 2000). The data, therefore, was kept on a special server (which hosted the software), in order to prevent unlawful access to the VRLE and the associated data. The programmers were responsible for server security and this was crucial in establishing trust and protecting the students from intruders as they conducted their research on the Internet.

Data generation was introduced as part of the qualitative methods coursework in the autumn of 2003. In order to meet the Icelandic requirements (Act no.77, 2000) the researcher undertook the following:

1. He held a meeting with the lawyer of the Icelandic data protection institution, in order to seek advice and to ensure his undertakings were legal.
2. He outlined the study (all four cases) to the sitting head of the school and, in a staff meeting, asked for his permission to represent the research.
3. The project was introduced to all of the teachers in school, at their monthly meeting.
4. The researcher sent a letter stating the lesson plans to parents before the enquiry began. This informed them of the course, including the aims and purpose of the enquiry (see section A5.0.4).
5. He introduced IE and the research to all 7th grade students.
6. Meetings were held with the teacher, in order to inform him of the data collection methods.
7. A contract was made with the school and was undersigned by the headmaster, the parents and the teacher (see sections A4.0.1- A4.0.3).
8. In this contract, they agreed to participate in the enquiry and gave permission for the researcher to use the data.
9. The government (Personuvernd, 2011) was informed of the research and of the use of the data.
10. Access was controlled, with regards to the computers used in the research, through the allocation of user names and passwords and through the private access of personal computers.
11. All personal identification marks in the data (i.e., numbers used most often) were decoded or destroyed and identification keys were preserved in a secure way. However, due to the small size of the school community, it was impossible to ensure full confidentiality, although the names of all participants were changed.

12. The tracing of look-ups in the VRLE was prevented and the computers' processing operations were guaranteed.
13. Personal data preserved within the VRLE was not accessible from the school's computer network or the Internet.
14. Backups of the data on the VRLE server were created, in order to prevent or minimise the damage caused by malfunctions.
15. Active virus defences were continually employed.

3.13 Conclusion

This chapter has described the principles of the research methodology used for the enquiry. An expert practitioner´s approach and a background survey have been also reported, as the groundwork before the initial pilot study. A short overview of the case study series has been given and it has been explained how these were connected. The fulfilment of Iceland's ethical requirements for the conducting of a research project has been reported and, subsequently, the researcher's role, his position and possible biases. This preparation for the case studies was an important part of the project and part of the establishment of the initial case study series, which will be further discussed in the next chapter.

Chapter 4. Pre-piloting the VRLE for IE

4.0 Chapter Summary

The chapter reports a short pre-pilot study, including a background survey. This study enabled the author to establish a research direction that grew into a series of scoping case studies (see chapter 5.0).

4.1 Introduction

The research that this thesis represents is based on earlier curriculum development work and the initial literature review. In order to move from curriculum development and into a research phase, Cohen and Manion (2005) advise that research is systematic, empirical, self-correcting and open to scrutiny.

This chapter describes the design of the pre-pilot study (see section 4.2), the lesson it was based on (see section 4.3) and the data collection methods, including a summary of findings, the discussion and the conclusion (see section 4.4). Finally, section 4.5 offer pointers for feed forward.

4.2 The Design of the Pre-Pilot Study, including the Background Survey (A4.3.1)

The author already had considerable personal experience of IE and the VRLE as curriculum development, but he wanted to gain a more systematic understanding of related issues and relationships. The general aim for the research phase had already been established, which was:

To explicate the pedagogy of using the Virtual Reality Learning Environment (VRLE) to support conventional Innovation Education within Icelandic schools.

It was clear that a pre-pilot research phase was needed, in order to scope the work, establish the principle issues and enable limits to be drawn. Such a phase needed to be broad and inclusive, in order to be able to identify the range of issues involved; however, it also needed to be rigorous if it were to lead into a research phase. The author field-tested the VRLE with IE materials before he started the pilot study. A group of 8 students undertook one lesson, in order to ensure that the technology would work and that experience was provided, in terms of enabling a plan for the designing of the pilot study. Logbooks were independently written by the author and the teacher and then compared by the two authors, with a focus on the issues relating to the lesson that discussed the use of the VRLE within a classroom context. A survey in the form of a questionnaire (see section A4.3.1) was designed and sent out to parents and the aim of this was to gain background information about the parents' and the students' home activities, as these supported the initial state of their idea generation.

The survey was piloted with two academic staff, in order to ensure that it was understandable and gathered appropriate data. It was then improved, based on the feedback, and distributed amongst the target students. The parents received a letter outlining basic information about IE and a plan for two lessons; they also undersigned a contract that gave the author permission to use the information gained (see section A4.0.1). The questionnaire was based on 20 questions: 16 closed questions, which gave the author general information about the parents, and 4 open questions, which explored the students' activities at home. 24 parents took part and there were 16 responses. The number of participants was too limited to give secure statistic conclusions, but was useful as a part of the preparation for subsequent work.

The open questions concerned:

1. How the students found needs and problems at home and if any help was given.
2. How the students used the inventor's notebook at home and how important this was in their ideation.
3. If the students were interested in the work and if this could be supported.
4. If the IE activity was influencing the students' daily life.

The summarised questionnaire can be found in section A4.3.1.

4.3 The Pre-Pilot Lesson

4.3.1 Introduction

The students were introduced to IE. They were each given a copy of *The Inventors Notebook* (see section A2.0.1), prior to the lesson, and were asked to bring needs and problems identified at home to the lesson. They were also asked to enter the VRLE at home with the same login and password. The questionnaire was sent to the parents.

4.3.2 Using the VRLE

In the main lesson, the students were registered to the VRLE database and trained in managing the VRLE technology. They used a computer mouse to draw solutions, based on the IN (IN is explained in section A2.0.1), and uploaded these to the VRLE, with descriptions.

4.4 Method of Data Collection

The data was summarised, analysed, discussed and conclusions were drawn, to be used for a feed forward to the pilot study (see further in chapter 3.0).

4.4.1 Summary of Findings from Parents' Questionnaires (16 responses)

4.4.1.1 The General Part of the Questionnaire

The majority of parents were 41 to 50 years old and all had experienced further education. Both the students and the parents had good computer literacy and used the Internet daily. All of the parents, with the exception of two, used the Internet at home and most knew something about Innovation Education. All of the students, except two, used email at home and all played computer games; most used the computer to do their homework. None of the students had taken Innovation Education before and all of the students, except two, were able to use the VRLE at home but did not use it very much. The students discussed needs and problems at home.

4.4.1.2 How the Students Identified Needs and Problems at Home and Whether They Were Helped in This

In the two lessons the students undertook, they were asked to find needs and problems at home and nearly all of the parents gave their support in this. However, none of them talked about needs or problems, just about ideas. The students often discussed ideas with someone within their family, in order to identify more needs and problems.

4.4.1.3 Use of the Inventor's Notebook (IN)

All the students used *The Inventors Notebook* at home, with the majority using it very often. However, instead of reporting needs and problems, they were most often drawing solutions. Three of the parents noted that ideation work could be reinforced through a more comprehensive introduction to IE, establishing a course for the parents and encouraging the students to work more with their friends.

4.4.1.4 Further Motivation

The parents had different opinions on what might increase the students' interest in innovation. The majority of them suggested further schoolwork based on IE.

4.4.1.5 Influence on the Students' Daily Lives

The parents did not have strong opinions about the influence of IE on the students' daily thoughts and their behaviour at home. They often did not know or said it was new to them and exciting for the students.

4.4.2 Discussion

The parents' educational background was good, with the majority having entered further/higher education. However, they only had a limited understanding of Innovation Education, probably as they had no prior experience of the concept. The data highlighted that there was support available at home, although the parents' inexperience, in terms of IE, meant that there were limits as to what could be achieved. Most parents talked about ideas, rather than needs and problems, and this is an important distinction. Some parents were not convinced of the value of IE, as a result of the number of new ideas they saw coming into school. Many parents suggested a course for parents and thought that the students' motivation would increase through further schoolwork.

Both the parents and students demonstrated good computer literacy. However, the students did not use the VRLE as much at home as the author had expected: perhaps the two lessons they attended were inadequate in providing them with the required skills and confidence. The students did use the inventor's notebook at home.
The logbooks (see sections A4.3.2) indicated the importance of training teachers prior to the beginning of lessons; the teacher in this research was not familiar enough with IE. It is also important to train the students to use the technology involved: it took a considerable length of time for the teacher to register the students and get the computers set up. The teacher should have tested the computers the day before, as two of them were not working. Furthermore, the students were not familiar with

generating needs and problems themselves and discussion with the teacher highlighted that they were used to being given ‘problem briefs’, as in design and craft.

4.4.3 Conclusion

The pre-pilot was basic, but was useful in preparing for the pilot study. It is ethically (see section 3.12) necessary to inform parents about the nature of the course content and the students’ homework before the course begins. An introduction could be conducted in school (or offered though the VRLE) before the course starts, in order to enable the parents to support students’ ideation at home. The inventor’s notebook is important and useful for the students and it appears to reinforce communication with other people, both friends and family members. It is important to place an emphasis on explaining the difference between needs, problems and solutions, both to parents and students.

4.5 Feed Forward

The pre-pilot and background survey helped to formulate the subsequent pilot study (see chapter 5.0) and the following issues were fed forward to the pilot:

1. The teacher was further informed and trained in IE and in using the VRLE prior to subsequent phases.
2. The parents were invited to join the pilot study and were sent a detailed lesson plan and basic information about IE.
3. The difference between needs, problems and solutions were explained in a letter sent out to parents.
4. All the computer facilities were tested before the pilot course began, in order to avoid any problems that might reduce the students’ interest.
5. The students were asked to use the inventor’s notebook at home and to communicate with their family, friends and relatives.
6. The students were asked to use the VRLE at home.
7. The students were trained in using the VRLE before the course formally began.
8. The course for the pilot study included more lessons than the pre-pilot study.

Chapter 5. A Pilot Study

5.0 Chapter Summary

This chapter reports a pilot study series of four related case study lessons, implemented as an IE course incorporating the use of the VRLE. The IE course content and preparation is described, as are the overall research aims and objectives, and the research questions for the pilot study (the raw results and summaries are available in the appendix for chapter 5.0). Data summaries are reported and triangulated and the results are discussed and analysed. Conclusions are then drawn and used to guide the emerging research questions.

5.1 Aims, Objectives and Research Questions

The pre-pilot was useful as preparation for the pilot study: it ensured that the technology would work and established the principle issues. The aim of the pilot study was to identify the pedagogical issues involved in using the VRLE within the classroom, in the context of IE, and to test the methods of data collection.

The objectives of the pilot study were:

a) To develop an understanding of the pedagogy relating to the use of the VRLE in supporting the development of ideation skills within IE.
b) To establish an appropriate research methodology, in order to explore the use of the VRLE in IE.
c) To identify any issues and establish an appropriate research direction
d) To practice the specific methodologies.

The research questions for the pilot study were:

1. How could the VRLE be used with IE material within a conventional classroom?
2. What teaching and learning strategies influence IE activities, when the VRLE is used in the classroom?

5.2 Preparation for the Pilot Study

The pilot study consisted of a series of four related case study lessons, established as an IE course that incorporated the VRLE (the content is described in section 5.6). The author visited the class, in order to explain the purpose of the research. He asked for volunteers to attend a series of lessons after school and eight students (four girls and four boys) from class 7 (aged 12 years) volunteered for the activity. The teacher was interested in IE but had not used the VRLE before. The author sent out a letter to parents, outlining the lesson plans and containing information, with a request for parental support, in terms of students' homework (see section A5.05). The parents, the teacher and the school's headmaster undersigned the agreement (see sections A5.0.1 - A5.0.3) pertaining to the research and gave their permission for the researcher to use any collected data. The teacher was trained in using the VRLE for IE work and the computer facilities in the classroom were tested.

Before the students began the course, their teacher gave them a short presentation on IE and they were each given a copy of *The Inventors Notebook* (see sections A2.0.1 - A2.0.2). E-mail accounts were set-up for the students on the school server and they were registered in the VRLE, with personal logins and passwords. The teacher took digital photographs of the students, so that they could personalise their VRLE workshops, and the class were instructed on how to use the VRLE technology before the formal course started: this enabled them to comfortably use the VRLE right from the first lesson onwards.

5.3 Setting up the Classroom

The classroom used was an ordinary computer room, with 24 computers and a blackboard: this was a departure from previous non-VRLE IE lessons, which were typically held in general purpose rooms, with tables for drawing and modelling. For computer-based IE activities, 8 students were adequate. While this was a small sample, it did enable a close focus on the group and was consistent with enabling issues to emerge, in relation to objective A. The author split the room, so that one half contained the VRLE computers and the other half was used for instruction and brainstorming sessions.

5.4 Data Collection Instruments

The author needed a comprehensive range of instruments (see further chapter 3.0), in order to extract the relevant data relating to the research questions. One objective was to explore a range of data collection instruments, in order to enable subsequent work to be effective and to develop the author's skills as a researcher. Varied data was needed, in order to triangulate the research and strengthen reliability, as described in chapter 2.0. The specific instruments used are listed against the research questions below.

Chapter	Appendixes	Data Sources	Q1	Q2
5.7.1	A5.3.1- A5.3.4	Interviews with the teacher	x	x
5.7.3	A5.3.9- A5.3.10	Interviews with individual students	x	x
5.7.2	A5.3.5- A5.3.8	Interviews with student group	x	x
5.7.4.1	A5.3.11- A5.3.14	The teacher's logbook	x	x
5.7.4.4	A5.3.15- A5.3.18	The author's logbook	x	x
5.7.5	A5.3.19	Data from the VRLE	x	x

Table 5.1: Data collection methods used in the pilot study.

5.5 Preparing the Course

The author field-tested the VRLE and the IE materials with several students before he began the pilot study: this ensured that the technology would work, established how the facilities should be set up and provided experience, in order to enable a plan for the design of the pilot study.

5.6 The IE course Plan

The course plan (see section A5.0.6) was based on four 90-minute after-school lessons/case studies. The lesson sequence is outlined below:

- Introduction and training in the use of the VRLE.
- Individual students work out solutions using the VRLE.
- The students test the VR element of the VRLE.
- Individual students develop solutions for an exhibition in the VRLE.

5.6.1 Lesson One

The lesson began with a short introduction, then the students began using the VRLE. In this, they learned to open their workshop, add needs and solutions to the database and use the simple cad software *Paint*. The students entered the virtual reality learning environment, in order to learn how to use it and to gain experience. Before the lesson ended, the teacher briefed the students on how to use the inventor's notebook at home and instructed them to bring it to the next lesson, as they were to be used to identify a new set of problems.

5.6.2 Lesson Two

Lesson two began with an introduction. The entire group brought their inventor's notebooks and gathered in front of the blackboard as the teacher wrote up the needs and problems that the students had identified; this was followed by a short brainstorming session. The students then registered their needs into their personal workshop database within the VRLE and drew their solutions using the cad programme, using the computer mouse: some entered these solutions into the Icelandic Innovation Competition. Before the students left the class, the teacher informed them of the next lesson and discussed their VRLE experiences in the classroom. Finally, he asked them to continue to use the inventor's notebook at home, in order to identify further needs and problems.

5.6.3 Lesson Three

The teacher informed the students of the lesson content and recorded the needs the students had identified at home on the blackboard. The students were then divided into two groups of four. Each group had to choose one need from the blackboard and brainstorm, before meeting in the VRE part of the VRLE and working out a solution together. One student was chosen from each group by the teacher to guide others through the VRE and oversee the collaborative design work. Finally, the students saved their work to their database and the teacher introduced the next lesson.

5.6.4 Lesson Four

Lesson four was an iteration of the IE process, in order to reinforce the concept and the method of such a process. The teacher informed the students of the lesson content and the entire group, once again, brought their inventor's notebooks to the lesson. The students gathered in front of the blackboard and the teacher recorded the needs and problems the students had identified at home and conducted a brainstorming session. The students then worked individually within the VRLE, registering new needs to their personal workshop database. They drew solutions with the cad programme, using the computer mouse, and saved them to the VRLE database; some of the students entered their ideas into the Icelandic Competition. Finally, the students sent their ideas to an exhibition inside the VRLE.

5.7 Data Collection and Analysis

The data collection methods and the analysis process employed for the pilot case study are shown in table 5.1.

5.7.1 Interviews with the Teacher

Two interviews were conducted with the teacher; one after the first lesson and another after lesson four. The teacher was relaxed and cooperative: he focused on the learning process, was open to discussion and was self-critical. The author used a semi-structured interview schedule (see sections A5.1.1 - A5.1.3) to ask about teaching methods, preparation for the lessons, the lesson plan and the student's work. At this stage, it was important to allow flexibility in responses: the author needed to know of issues from the teacher's perspective.

5.7.2 Interviews with the Student Group

The interviews took place in the classroom the students were familiar with and a digital recorder was placed on a table. Both the author and the teacher were present and the interviews were conducted after each lesson. The author noted that the teacher was dominant in the conversations and acted like an instructor in the lessons; he also asked the students about their homework, their interest in the course, their opinions on the VRLE and their ability to use it. The students were relatively passive during the interview.

5.7.3 Interviews with Individual Students

The interviews took place in the teacher's workshop, after the last lesson late in the afternoon: it was quiet in the room at this time and there was a relaxed atmosphere. The author used a digital recorder to record the interviews: the first interview was with a boy (Ragnar) and the second with a girl (Helena) (these names have been changed, in order to protect the interviewees' identities). The author began the interview by asking the students about their hobbies, in order to establish trust. The students were familiar with the author from the lessons and appeared comfortable. The author asked about the students' attitude to IE, the relationship between schoolwork and homework and their understanding of the innovation process.

5.7.4 The Teacher's and Researcher's Logbooks

The logbooks were written at the end of the day, after each lesson, when the content of the lesson was still fresh in the teacher's and the author's minds. The focus was on how the lesson went, how the students' use of the VRLE could be improved and the teaching. The logbooks were a mix of observation and reflection.

5.7.5 Data from the VRLE

As an administrator, the author had access to the VRLE database and was able to extract information, regarding the students' work, submitted to the database during the pilot study; this included recorded needs, drawings and solutions. The author could see the time of delivery and the students' communication.

5.8 Established Categories, Discussion and Conclusion

The main pedagogical categories that were established through the analysis can be seen in the appendices for this chapter (see further in section A5.7). They were:

1. Teacher's preparation
2. Teacher's role and handling teaching
3. Computer literacy
4. Motivation
5. Inventor's notebook/homework
6. Drawing
7. Ideation
8. Use of the VRLE
9. Collaboration

5.8.1 Teacher's Preparation

Discussion

The VRLE may be relatively user-friendly, as the teacher stated in the first interview. However, he also reported his need for more time to prepare lessons. This is probably an issue of teacher confidence, in terms of teaching a new subject and the use of new software. In order to establish the teacher's confidence, more thought will be required, in terms of pre-training and managing the VRLE hardware and software within the school environment.

During the pilot study, the teacher also needed more time to prepare the computer facilities and the VRLE software for the lesson; nevertheless, his own experience in running such lessons can also be informative in training. This includes learning the general operation of the computer system, such as setting up emails. However, this can easily cause conflict between the roles of tutor and administrator.

Conclusion

Many countries have discovered the value of improving teachers' computer literacy. Indeed, a report from The Southern Regional Education Board (1998:1) stated: 'linking technology skills assessment to licensing requirements helps ensure that teachers have the skills to guide students and to increase student learning using technology'. Research examining issues regarding teachers´ workloads when using ICT in English schools (Bailey et al., 2004) discovered that, whilst teachers found it difficult to quantify the exact amount of time saved (or lost) by using ICT for specific tasks, some teachers reported little timesaving in the use of ICT; indeed, some reported that particular tasks took longer when using ICT. Good leadership, appropriate training and technical support and effective networks and connectivity were factors that supported ICT in addressing workload. A lack of confidence in ICT skills, an ICT strategy that lacked focus on addressing workload, ineffective networks and a lack of proper training or technical support tended to be factors in ICT failing to improve workload gain. However, the issue is not simply whether ICT can speed up work; rather, it is whether it is used to improve the quality of learning.

To reduce teacher workloads, in terms of the use of ICT in more schools in the future, ICT strategies must include specific workload aims and outline the ways in which ICT can raise quality and pupil performance.

5.8.2 Teacher's Role

Discussion

The teacher's role is more complicated within the context of using the VRLE in the conventional classroom. In the first interviews, the teacher talked about role conflicts between being a computer administrator and a tutor. As the students were self-reliant and more IT capable than he expected, the teacher found he was not always active in lessons.

Johannsdottir (2008) pointed out that teachers need on-going support and guidance, particularly with regards to the new technologies in schools. The teacher has to switch between being a tutor and a facilitator or supervisor with general knowledge in ICT, able to support the students in their studies. Teachers also have to be able to constantly adapt to new circumstances and must learn to develop the curriculum accordingly. The focus moves from instructional teaching methods to supporting students' independent studies (Matthiasdottir, 2001b).

The teacher used multiple teaching methods: at the beginning of the lesson, he used direct instruction, but also requested collaborative work from the students. He tried to make the students self-reliant by teaching the fundamentals skills needed for working in the VRLE; this gave him time to administer the VRLE software and hardware and was supported by the IE-based VRLE, which provided a guiding structure for students. Also, the teacher was always nearby when the students needed help. From this experience, he realised that he could have demanded more from the students, had he known their ICT ability.

Educators (Hreinsdotter, 2003; Ihmeideh, 2009; Fidalgo-Neto et al., 2009) have observed that there has been insufficient research on the use of computers in schools and the role of the computer, the teacher and the students. However, many educators have expressed their opinions about the influence of ICT on the students' way of learning and the teachers' role, as below:

- The students get more independent in their studies (Hreinsdottir, 2003) and they are better able to control their own direction (Johannsdottir, 2001)
- The students become more active and conscious participants in their own education (Matthiasdottir, 2001b).
- More possibilities arise in transferring responsibility to the students and the parents (Karlsson & Hjartarson, 1998)
- It can make the work more cross-curricular (Thorsteinsson et al., 1997; Johannsdottir, 2001) and it is easier to establish more flexibility and diversification (Jonasson et al., 2002).
- More possibilities for innovation in teaching (Jonasson et al., 2002)

- Computers could make the teachers' work more interesting and change them into a facilitator and supervisor (Nordal, 1983:32), thus changing the process of teaching and learning
- Virtual Reality Learning Environments appear to have the potential to affect the way students learn positively (Ainge, 1996). Ainge's research with upper primary students shows that virtual reality learning environment experiences can offer advantages over traditional learning experiences.
- Many educators believed that the teacher would change from an instructor to a guide and overseer (Matthiasdottir, 2001b).

Conclusion

As seen from the above, the use of VRLE asks different requirements of the teacher and offers new ways of teaching and learning. According to the literature (see in chapter 2.0), the characteristics of VRLE support for conventional classroom-based IE are related to constructivism, CSCL and computer-mediated communication.

5.8.3 Computer Literacy

Discussion

The background survey (see section A4.3.1) and interviews with both the teacher and the students indicated that the students demonstrated good computer literacy; this was an important factor in enhancing their work. Students were also able to use the VRLE to guide themselves through the IE process, just as it was meant to do (see section 5.8.8). Thus, little training was required, in terms of the use of the VRLE; students' confidence in the use of the software was readily apparent. Such confidence may have affected the students' interest in IE, as the VRE reminded them of computer games. It is thus clear that good computer literacy is a pre-condition in the use of the VRLE for IE.

The students' computer literacy enabled the teacher to take up the role of facilitator,, as it was unnecessary to spend time instructing this group of students in the use of the hardware and software (see also section 5.8.8). The teacher reported he needed more training in the use of the VRLE and more preparation time; this was the case, even though the teacher was also the school ICT co-ordinator and, it may be assumed, possessed above-average computer literacy, with an adequate ability to manage the system and hardware. It may be that normal subject teachers would find the use of the VRLE more difficult and thus require more training and practice/preparation time.

Conclusion

The students had been using ICT within school for several years and thus were capable in this (see section A4.3.1). They were able to use the VRLE fully at home (see section A4.3.1); however, due to the small sample size, it is not possible to extrapolate these standards to other schools, although Icelandic research (Statistic Series, 2007) indicates that Icelandic schools develop strong computer literacy in their students. The use of computers and the Internet is widespread amongst individuals in Iceland and all students access computers. In 2007, 89% of homes possessed a computer and 84% had an internet connection. In the same year, 91% of the population (aged 16–74 years) used a computer and 90% had used the Internet three months prior to the research. As in earlier years, the Internet was mostly used for information searching and communication (Statistic Series, 2007).

5.8.4 Motivation

Discussion

The students found the IE course interesting and discussing ideas at home increased this interest. Introducing IE, with examples of students' earlier work was a good starting point, as it contributed (along with other factors) to motivating the students. However, it is not clear whether part of the students' interest was connected to the author's presence as an outsider. The students enjoyed the course and requested that IE be made a compulsory subject: they asserted that the course was new and different and that they found the process of IE interesting. However, it is difficult to differentiate this interest from the motivation created as a result of experimental/novelty effects (Cohen et al., 2005). Nevertheless, motivation appeared to play a significant role in the students' demonstrated capability; they also showed interest in implementing the IE-VRLE course as an open and distance course, enabling them to work at home on their computer. This is an interesting point for the author, as the VRLE has not yet been used as a tool for open and distance learning; however, it may offer new possibilities for other schools.

Conclusion

Research in English schools showed that ICT (Passey et al., 2004) has a motivational effect on most pupils. The study was concerned with the rapid growth of ICT in schools and its effectiveness within the context of teaching and learning. One of the findings was that pupils and teachers recognised that some aspects of quality of work are improved when ICT is used: attitudes towards schoolwork and homework are often more positive and pupil confidence and ability to perform learning tasks are often enhanced. Again, this effect may be explained by novelty/reactivity effects (Cohen et al., 2005), where respondents behave differently when subjected to observation or new educational approaches. In this research, the use of the VRLE and ideation work was certainly novel to the students. Also, there was the occasional presence of the researcher, who was a stranger to the students. It was thus important to become familiar with the school and the participants.

Many of the studies reported in the literature (see chapter 2.0) concerning VRLEs include assertions such as improved motivation and learning (Ainge, 1996; Bricken & Byrne, 1993; Johnson, Moher, Choo, Lin & Kim, 2002). However, it is still unclear whether VRLE support would appeal to students using the technology frequently, over a long period, and whether this would offer effective curriculum enhancement. Novelty effects may be dominating at this stage; thus, a positive outcome is not as reliable as that from long-term research.

5.8.5 Inventor's Notebook/Homework

Discussion

The study showed the inventor's notebook to be an important tool that supported communication and collaboration with parents and as an important media in transporting homework to school; it was also a great help in starting off lessons. The IN also increased the students' interest in identifying needs and ideas at home, as they found it easy to use and practical. During the study, the teacher suggested using mobile phones to send IE needs and images directly to the VRLE, rather than using the IN. This is an interesting suggestion, but merits further research.

The students used the VRLE at home: they recorded ideas and solutions and tried to enter the VRE. However, most of them did not possess the appropriate graphics card and thus were not able to use the VRE. The IN was particularly useful, in this respect.

Conclusion

The inventor's notebook was used as a problem-needs identification tool and the initial state of the students' ideation activated the innovation process (see section 1.6). As seen in the teacher's interview, the teacher stated that the IN seemed to increase the students' interest in finding ideas. Runco and Dow (1999) informed that an essential step in solving problems is to define them first and the IN helps the students to remember, record and define identified needs and problems. Runco and Dow (1999) also asserted that, in training students to solve problems, they must be able to handle ambiguous tasks, in order to learn to clarify them.

Gunnarsdottir (2001a) stated that the IN is a tool for communication, supporting social interactions between the school and the home. This research (see section 1.5), however, shows interaction between the students' home, school and the VRLE. The IN plays still an important role in connecting these three elements together and it is fundamental in communicating ideas. Nevertheless, as the teacher pointed out, mobile phones connected to the VRLE could possibly have better enabled this process: brainstorming could have been conducted entirely inside the VRLE (see section 5.10.4). However, this may be better applied within the context of open and distance learning, where there is no physical communication inside of the school.

5.8.6 Drawing

Discussion

The students quickly learned to use the cad programme and the drawing tablets through experience; their drawings were inaccurate, but showed sketches of initial solutions. Further training might yield a better outcome and increase the students' ability to develop the solutions. Graphics tablets were better than using a mouse, but there may be much better equipment available, closer to the traditional method of sketching with a pencil. The students experienced difficulties drawing inside of the VRE because they were not experienced in using the cad programme. There might possibly be better, computer-based drawing equipment that might bring students closer to the natural method of sketching.

Conclusion

IE is about training students in idea generation (see section 1.6) and the use of advanced cad programmes is not central in this. However, the students are required to sketch their basic solutions. Goldschmidt (1999) informed how sketching is effortless and natural; indeed, we learn to sketch as very young children. While the author would challenge this statement, in that it implies a uniform, inherit ability in all, Goldschmidt's point is generally accepted. Goldschmidt discussed how the sketching process occupies almost zero cognitive loads and this is important, as it allows the designer to externalise a design, while directing all the cognitive effort to the design process.

More recently, the development of pen-based tablets has improved the user's ability to sketch on a computer. The students in the pilot study moved from a simple mouse to computer-based drawing tablets with digital pens and they found it much easier to use this equipment: they finished their drawings much faster and they were more detailed (evidence from data). This probably also improved the students' understanding of their own ideas.

5.8.7 Ideation and Innovation Education

Discussion

The teacher was convinced that the students' motivation for the course positively affected their ability to generate new ideas. They had quickly understood the innovation process and were able to identify needs and problems in their own environment; thus, they identified ideas easily. The novelty of the students' ideas was doubted by the parents and this implies that some of the parents may not have understood the educational value of the IE course for the students. The needs and solutions identified at home were useful in starting the IE lessons, as input for the brainstorming sessions; short brainstorming sessions were also useful in refreshing the students when they got tired. An interesting input from the teacher referred to the usefulness of ideation skills for subjects other than IE. In fact, IE is now part of the general chapter of the National Curriculum in Iceland and can be incorporated into all subjects (1999).

Conclusion

The students' communication with their families was important: the majority of their ideas were connected to family members or based on personal problems. The innovation process was thus a natural way of solving problems in everyday life and this is a realisation of the conceptual background of IE (see further in section 1.2): to strengthen the individual ability to solve problems in daily life and participate in society (The Icelandic Ministry of Education, 1999). However, the parents possibly lacked an understanding of the pedagogical values of IE, as they doubted the novelty of the ideas. For the students, this was part of the course training and the ideas were probably new to them.

The brainstorming sessions served different purposes: they were both a method the teacher used to bring the students' experience to the course, in the form of identified needs and problems; they also helped students get started in the classroom and were useful in training the students in idea generation. This relates to Vygotsky's (1978) Zone of Proximal Development (ZPD) (p86), as students were in their ZPD in the brainstorming sessions. Vygotsky's other principle, the More Knowledgeable Other (MKO), was also noted, as the teacher had a higher ability level in the lesson and a better understanding than the learner in dealing with the concepts of IE (Galloway, 2001). During lessons, the MKO applied to more than just the teacher: it was also the students' peers and the VRLE, which facilitated the work and guided the students through the Innovation Process. The teacher also used brainstorming sessions to refocus students when they got tired and despondent and this helped them find more solutions to work with inside the VRLE.

5.8.8 Use of the VRLE

Discussion

Good computer facilities enabled the students' work in the pilot study. The students had no difficulty in using the managed learning part of the VRLE, once they had opened their email accounts. The teacher gave them basic training, but their own experience helped them in using the VRLE and the drawing tablets. It was, however, more difficult for them to use the VRE part of the VRLE, when they were asked to design together: using an avatar inside the VRE is difficult at first. Nevertheless, the students were happy, as it was fun for them. Being able to speak between computers, via headsets, helped the students to work inside of the VRLE, as it enabled any collaboration. However, the teacher had to be aware of the possibility of outsiders manipulating the security of the VRE.

Conclusion

The school had good computer facilities and a fast internet connection: this enabled the students' work, whilst quality graphic cards allowed them to use the VRE part of the VRLE. Poor facilities could have changed the outcome of the research and made the teacher's work more difficult. There are big differences between individual schools in Iceland and this affects the possibilities of using the VRLE and thus may affect teachers' attitudes towards using it. Students may also be affected, if a school's technology does not meet the requirements for running educational software.

The managed learning part of the VRLE was easy for the students to use, as their computer literacy was sound. It was also simple to use, due to the fact that it was based on the IE process (see section 5.8.7). The students were learning to use the VRE as it was new to them; thus, it was difficult for them to collaborate inside it at the beginning of the course. However, this may partly have been due to a lack of experience in students working together in communicating ideas and drawings; it may also have been difficult for them to be in two 'worlds' at the same time. Being physically together and being able to speak to the teacher, both inside the classroom and over the Internet, assisted their work.

5.8.9 Collaboration

Discussion

The students were communicative and collaborated well inside the MLE and the multimodal possibilities for communication may well have enhanced such communications and collaboration (see section 2.13.3). The students had problems collaborating inside the VRE because they were learning to use it; however, the smaller the group, the better the students were able to work together. The students used the possibilities for sharing needs and problems with each other inside the VRLE. They could also use brainstorming to communicate needs and ideas, both inside the classroom and inside the VRLE, as two parallel worlds.

When using innovative teaching methods, instructors need to be supported by their authorities and colleagues. The teacher in the pilot study, whilst an experienced user of ICT, reported that he needed more time to practice and prepare (Bailey et al., 2004). The headmaster of this school supported the IE course and was interested in making IE a compulsory subject; however, he was unable to give the teacher extra time to do additional preparation for these lessons and thus they were in addition to his normal workload.

Conclusion

There were multimodal possibilities for communication within the conventional classroom and the students used these as required. Students sometimes spoke face-to-face, while, at other times, they used computer-mediated communication methods (see section 5.8.8): this type of communication facilitated their work, as the students collaborated and thus learnt from one another (Vygotsky, 1978 & Galloway, 2001). The teacher, the students' peers and the VRLE (which facilitated the work) guided the students through the innovation process. The above needs further examination through observation and by collecting video data from the students' activities inside the classroom. This is necessary, in order to establish the value of the different modes of communication that the students use in the course of their work. The students did experience problems collaborating inside the VRE part of the VRLE, when they were given the task of designing together. However, it is not clear if the reason for this was the new technology they were using or whether it was the fact that they had not been trained to design together. Thus, this requires further exploration.

The IE brainstorming sessions were a form of training in collaboration. The VRLE offered the same possibilities, but on an individual basis: the students could share needs and solutions and help each other, if they wanted to do so. This is an important element of CMC and, within the context of the VRLE, it also supported individual thinking (Romiszowski & Mason, 1996). The VRLE facilitated the students' access to information and also enabled multimodal communication between students and teacher. The VRLE is an internet-based social network, supported by social software (Schrum & Berenfeld, 1997), and also offers communication with the world outside of the classroom (through the medium of the Internet). However, security requirements need to be high (see section 2.10.4): one student spotted an unidentified avatar inside the VRE but, thankfully, the author recognised the avatar as one of the workers from the Smartvr company, who was testing new possibilities. This is a reminder of the danger posed and the possibility that unauthorised visitors may be able to gain access to the VRE; it is an area of concern in schools where internet security is weak.

The teacher was the only person inside the school who dealt with IE and the VRLE. However, the headmaster and his colleagues were informed about the research and supported and encouraged him in this. This is important when research is conducted within a school context; however, it may have further promoted the novelty factor and placed pressure on the teacher.

5.9 Answering the Research Questions

This chapter has covered the pilot study, which was based on the evidence and conclusions from the pre-research study (see chapter 4.0). The main activities included the identification of the pedagogical issues associated with the use of the VRLE within a conventional IE school context and the rehearsing of data collection methods. The pilot study also sought to establish an appropriate research methodology, in order to explore the use of the VRLE within the IE context and to establish an appropriate research direction.

Using various data collection methods provided evidence, which enabled triangulation inside the established categories. In the following sections, the research questions for the pilot study are revisited and subsequently answered:

The research questions for the pilot study were:

1. How could the VRLE be used, with IE material, within a conventional classroom?
2. What teaching and learning strategies influence the IE activities, when the VRLE is used in the classroom?

5.9.1 Question One

The teacher’s observations and lesson plans, interviews with the students and the teacher, the logbooks and the students’ work in the VRLE database all provided information about how the students used the VRLE for IE work. The diagram below highlights this process and the arrows show the path the students took: in this, they incorporated methods from traditional IE. As the diagram shows, there are many other possibilities for IE work: one would be to use the VRLE tool for open and distance educational IE courses.

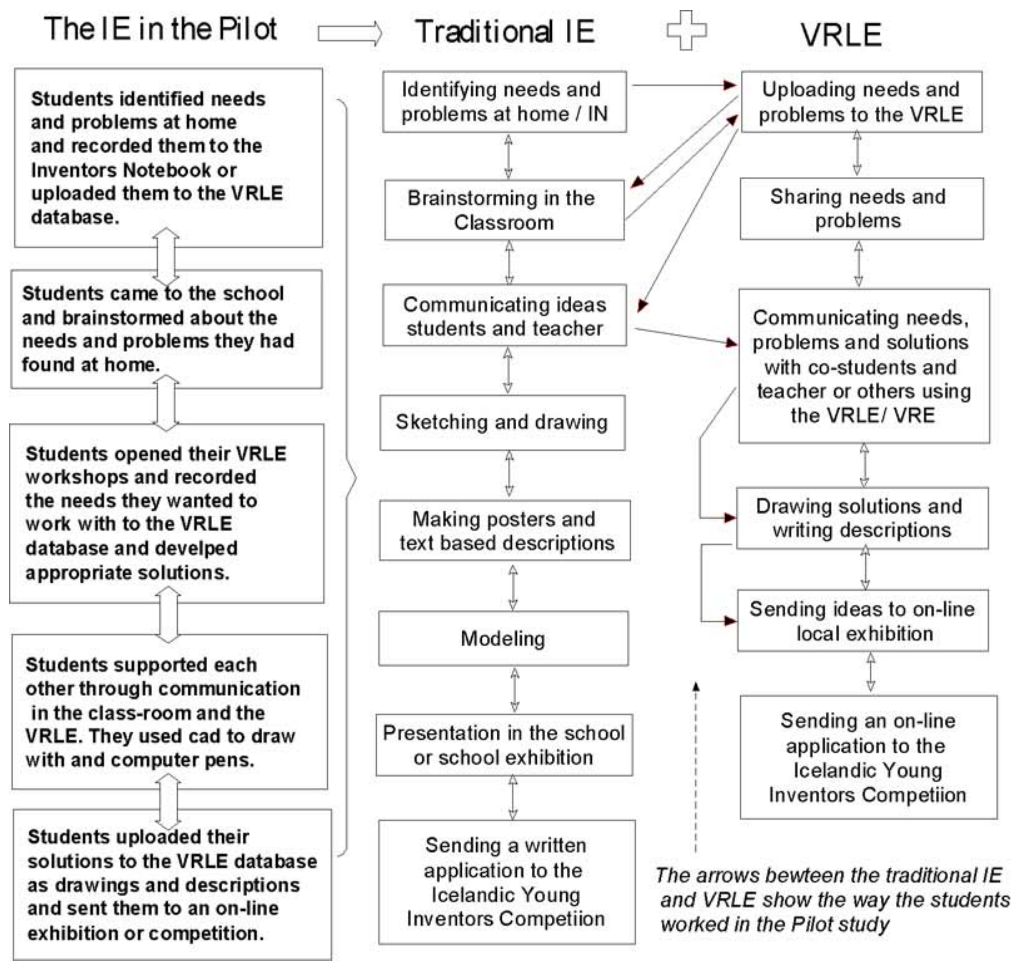

Figure 5.1: The way the students used the VRLE to support their work inside of the innovation process (note the arrows between traditional IE and VRLE).

This model connects the home environment and the school together; indeed, the students originated their ideas at home by identifying needs and problems and then brought them to school. They recorded ideas in the IN and uploaded these ideas to the VRLE database from home: this highlights the underlying IE pedagogical background (described in chapter 1.0) and the relationship with the constructivist theories identified in the literature (see chapter 2.0).

5.9.2 Question Two

The main teaching and learning strategies that arose in the data were computer literacy, managing the VRLE within the school context and the role of the teacher.

5.9.2.1 Computer Literacy

Interviews with the students and teacher, in addition to observations, indicated that the students easily learned to use the VRLE and the cad software; little teacher assistance was required. However, the students did experience difficulties in using their computer mouse to draw and the cad they used was too basic. At the beginning of the course, they used a mouse and, later on, a pen that connected to the computer. With this, the students had to look at the screen as they drew: this shows how the new VRLE technology can be used in schools for pupils from class seven upwards.

5.9.2.2 The Teacher has to be able to Manage the VRLE within School

The interviews with the teacher, the teacher's logbook and classroom observations all highlighted the importance of the teacher managing the VRLE hardware and software in school. Appropriate facilities are needed to run the system, such as graphic cards, headsets and digital pens; however, this represents extra cost for the school. Introducing such new approaches and technology does require a great deal of effort on the teacher's behalf and training would be necessary, in order to enable teachers to manage the hardware and the software.

5.9.2.3 The Teacher is the Key to Successful IE Lessons

In interviews and in his logbook, the teacher mentioned the importance of being trained to use the VRLE; it is also necessary for him to understand the innovation process, in order to be able to guide the students. In his observations, the author could see a lack of teacher understanding of the innovation process. However, he was usually in the role of facilitator, rather than instructor. Teachers' self-confidence was also identified as important: this teacher had experience as an ICT teacher and was the school's administrator, but it was noted that he often lacked confidence in running the IE course and when dealing with the software and hardware.

The VRLE was found to be user-friendly and enabled the students to be self-reliant. Nevertheless, the teacher still had to use familiar pedagogical principles, such as giving clear instructions. It was important to link the students' homework with their activities inside the VRLE, through brainstorming sessions in the classroom. After this, the students could work independently. When they had to undertake their work in the VRLE, they sometimes got tired after 20-30 minutes but, by employing short brainstorming sessions, the teacher found it was possible to refresh them.

5.10 Feed Forward to Case Study Series Two

It was necessary for a pilot study to examine the pedagogical context from a general perspective, and, from the data gained and the conclusions drawn, it was decided to look more closely at five specific areas:

1. Student's homework and the inventor's notebook
2. The teacher's role and preparation
3. Drawing
4. Ideation
5. Use of the VRLE and collaboration.

It was also considered necessary to examine the school's attitude to the research and the value of the new context, in addition to the changes in the data collection methods. It was decided that this would be done through a set of four related case studies, incorporating an action research element. The aim was to develop further understanding of the pedagogical issues identified in the pilot study. The author had to identify what he thought were the most relevant areas to take forward to case study series two. This was largely based on the discussions and conclusions in chapter five (see section 5.8).

The following paragraphs highlight five areas:

5.10.1 Students' Homework and the Inventor's Notebook

The pilot study showed the inventor's notebook to be an important element in homework, as it appeared to activate the innovation process. It also showed that the parents gave feedback to their children when they discussed the ideation process, using the IN, and that this increased their motivation (see section A5.3.1). Key points are thus the IN, parental support and motivation.

In case study series two, the parents will be sent a letter informing them of the course content and explaining the homework; they will be informed of the innovation process and will be asked to support the student. In addition, they will be given the course plan, in order to increase their understanding and assistance. Students will also be asked to upload needs and problems from their homework directly to the VRLE while at home, so that the material is ready for them when they are next in the IE classroom.

5.10.2 Teacher's Role and Preparation

In the pilot study, there was a conflict in roles, in terms of the teacher being both administrator and tutor: part of this problem was the fact that the teacher felt he was badly prepared and disorganised (see section 5.8.1). In the pilot study, the teacher had reported that, whilst an experienced user of ICT, he needed more time to practice and prepare (see section 5.8.1). Thus, in case study series two, the teacher will be given further training and preparation for the lessons: this will include general use of the computer system, use of the VRLE and the teaching of IE. Specific help pages for the teacher will also be set up inside the VRLE. The teacher will be encouraged to spend time developing his own experience of using the VRLE for IE, mirroring the work the students will have to do (see section 5.8.1): he will also be asked to prepare the technology before lessons. The teacher will be given more responsibility in organising the course and the observer will not teach, but will instead focus on observation: this will enable a better picture of functioning inside the classroom.

The pilot study was run as an after-school activity and it was difficult for the teacher to fit it into his schedule. Running after-school lessons can be tiring for a teacher in a full-time position and it would be better to run the class within normal school hours.

5.10.3 Drawing

In the pilot study, the students quickly learned to use the drawing tablets and the cad programme inside the VRLE, even though they were not formally taught how to use the software or the tablets. However, their drawings were inaccurate, but did show the initial solutions to identifying needs. As the teacher stated: 'further training in the use of cad programmes and drawing tablets might give a better outcome and increase the students' ability to visualise and develop solutions' (see section A5.3.2). The first graphics tablets were preferable to using a mouse but, in case study series two, more advanced equipment will be used. A pre-test will be carried out before the course, in order to ascertain the students' general drawing skills and to see how they cope with a cad programme. The author will also set up home lessons in using the cad programme, in order to develop their drawing abilities.

5.10.4 Ideation

The students' communication with their families and their use of the IN (see section 5.8.7) were important in activating the innovation process: the majority of their ideas were connected to family members or were based on personal problems. The innovation process was, therefore, a natural way to solve problems in daily life, in harmony with the IE philosophy (see section 1.2). However, the students' reported that brainstorming, both inside the classroom and the VRLE, also affected their ideation. Case study series two will examine how activity inside the classroom affects idea generation: both brainstorming sessions and collaboration within the VRLE. It will also be explored whether students use the possibilities for sharing needs and problems with each other inside the VRLE.

In addition to the inventor's notebook, a specific experimental website will be set up, in order to enable the students to send text, images and voicemails to their workshop, using their mobile phones.

5.10.5 Use of the VRLE and Collaboration

Since the pilot research was undertaken, the VRLE has been slightly upgraded. As indicated above, help pages will be set up for the teacher, the cad element will be improved and an upgrade of the VRE will be introduced (including new avatars). In pilot study one, the avatars were all mature figures, whereas, in the upgraded version, there are child avatars available, for a range of cultures, and adult avatars. A short course introducing IE will be set up and will be accessible to both teachers and students.

In the pilot study, students were communicative and collaborative inside the classroom, when using the VRLE. The VRLE is used as a tool in enabling the innovation process; it allows the students to illustrate and communicate their ideas. It also enables communication and collaboration supportive of multiple pedagogical models working together, including IE, CMC, CSCL and constructivism (see section 5.8.9 and chapter 2.0). It works in harmony with Vygotsky's (1978) social cultural theories and thus is a key part of the research and has to be the main focus; for example, what happens in the classroom when the students are working together inside and outside of the VRLE? How do they communicate and what does this mean for their ideation work (see section 5.8.7)? Do the students learn though collaboration and how? Does this facilitate the students' work? What are the different communication modes the students use? These are the general questions which are to be addressed in the case study series two, as they may help to understand how using the VRLE affects the pedagogical context of IE.

In the pilot study, the students had problems designing together inside the VRE and these difficulties will be examined further. Data will be collected in the form of video recordings in the classroom, when the students are working together inside the VRE, and also from interviews with the students and the teacher. Questions will include: 'how do the students communicate together inside of the VRE?', 'how do they manage to design as a group?' and 'how do they manage to draw together inside the VRE?'

5.10.6 The School's Attitude to the Research and the Value of the New Context

The teacher was the only person inside the school who dealt with IE and the VRLE, but he was supported and encouraged in this by the headmaster and his colleagues. This enhanced the novelty factor and put pressure on the teacher, in terms of proving his teaching ability. In case study series two, this area will be examined through observation and interviews with the head teacher and the class teacher.

5.10.7 Changes in Data Collection Methods

The pilot study was important, as it identified issues associated with using the VRLE for IE. Furthermore, it enabled the author to review the purpose and significance of the research and refocus: this gave the author experience in collecting, analysing and interpreting data. Initial categories were established as a basis for the next phase and limits, limitations and biases were experienced and identified. The position of the author as a solo researcher was reviewed. The pilot study also helped the author to set up a plan for case study series two, with new aims, objectives and research questions. Methods of data gathering and analysis were reviewed and adjusted and the overall research question was revised, in the light of the conclusions and further literature research. The author and the teacher were both present in the pilot study, with the author contributing to teaching, in addition to gathering data. The author noted that the teacher was dominant in conversing with the students and acted like an instructor during lessons: this was probably the reason why students were passive during interviews.

In case study series two, interviews will be conducted after each lesson, without the teacher, in the hope that the students will be more open and communicative. A different classroom will be used, as the IE classroom was not appropriate for a group interview. The music room will be used and the students will be seated at a round table, enabling direct eye contact and facilitating ease of discussion. The author will focus on the students' idea generation within the classroom context: video recordings will be made of the group in the classroom, in order to collect data regarding their collaboration and communication when using the VRLE.

Chapter 6. Case Study Series Two

6.0 Chapter Summary

The chapter reports the second case study series. The IE course content and preparation is described, the overall aims, objectives and research questions are stated and the specific data collection methods are discussed. Categories are discussed and conclusions drawn (the raw results and summaries are available in the appendix for chapter 6.0). Research questions are answered and new questions are formed, in order to guide subsequent research.

6.1 Introduction

Case study series two was undertaken in March 2004. The conclusions from the pilot study were used as the basis for feed-forward and a new aim was formulated, as were objectives and research questions.

The case study methodology (see section 3.5) chosen was, as in the pilot study, a way to observe the complex social/educational activity in the classroom, when the VRLE was used. The research was interpretive and attempted to understand the application of the VRLE and the learning experiences of the students; it also aimed to develop the pedagogy used by the teachers. The author's role was planner and observer, with the teacher undertaking lessons. The approach thus incorporated an action research element.

6.2 Aim, Objectives and Research Questions

The aim for case study series two was to:

Develop further understanding of the pedagogical issues identified in the pilot study.

The objectives were to:

a) Provide evidence that enables the further development of the VRLE software
b) Examine the role of the teacher
c) Observe the innovation process in action, using the VRLE
d) Gather data on the use of more advanced drawing technology
e) Examine the effect of parents receiving more information about IE and the use of short brainstorming sessions
f) Practice the appropriate research methodology further.

The research questions for case study two were:

1. What characterises the role of the teacher, when the VRLE is used, and how does this differ from the earlier IE model (i.e., pre-VRLE)? How can its effectiveness be improved?
2. Is students' work supported by computer collaboration within the VRLE?
3. What elements of the IE course support the students' idea generation?
4. How may the students' abilities to draw inside of the VRLE be improved?

6.3 Preparation

A course plan and related research plan were established, based on the new aims, objectives and research questions (see also feed forward, section 5.10). The author sent out two new letters to the parents prior to the start of the course: the first (see section A6.0.5) concerned the research project, IE and requested support, in terms of student homework, while the second (see section A6.0.6) outlined the course plan. This was the feed forward from the pilot study, which indicated how important homework and parents' support and understanding was. The parents, the teacher and the headmaster undersigned the letter, giving their permission to use the data.

Four new girls and four boys from class 7 volunteered for the research. The teacher set up email accounts and registered them to the VRLE; he also took digital photographs, in order to enable the students to personalise their VRLE workshops. The teacher was the same teacher as in the pilot study, but he received further training in using the VRLE for IE work. The computer facilities in the classroom were tested before the activity started: this was fed forward from the pilot study, where the teacher had stated that he required better training and preparation.

6.4 Setting up the Classroom

The same classroom was used as in the earlier research and was an ordinary computer room, with 24 computers and a blackboard. The author split the room, so that one half contained the VRLE computers and the other half was used for instruction and brainstorming sessions. Interviews with the students were undertaken in the music classroom, as it was more appropriate than the VRLE classroom. The author conducted these interviews primarily to prevent any pressure from the teacher in their answers; this was meant to make the students more relaxed and expressive.

In the pilot study interview, the teacher was constantly manipulating the students and could not ‘switch off’ from his role as teacher.

6.5 The IE Course Plan and Lesson Synopses

The course plan (see section A6.0.4) began with a 90 minute IE introduction, prior to the main course. The course was based on four 90 minutes lessons/case studies and was implemented as an after-school activity. The introduction and the lesson sequence were as follows:

- Introduction to Innovation Education and registration in the VRLE
- Students trained in using the VRLE;
- Individual students work out solutions, using the VRLE
- The students test the VRE element of the VRLE
- Individual students develop solutions and take part in competitions.

6.5.1 Introduction

The author gave the students a short IE presentation; he showed prototypes from earlier IE students and explained how these students had got their ideas. The teacher then introduced the IE course to the students and gave them a letter to give to their parents, highlighting the course content. In the letter, help was requested from parents, with regards to the students’ homework. The students were subsequently registered to the VRLE database and a pre-test was used to examine the students’ drawing skills. Before they went home, the teacher informed them of the next lesson.

6.5.2 Lesson One

The teacher informed the students of the lesson content and they were instructed in managing the VRLE technology, drawing with digital pen tablets, using their personal VRLE workshops and uploading solutions; they were also each given a copy of *The Inventor’s Notebook* (see sections A2.0.1; A2.0.2). The teacher explained how to identify needs and problems at home and how to record them in the inventor’s notebook. He also gave an example of how the students could brainstorm with families and friends. Before the students left the class, the teacher informed them of the next lesson and discussed their VRLE experiences in the classroom.

6.5.3 Lesson Two

The teacher informed the students of the lesson content. The students registered needs and problems they had identified at home in the VRLE and gave each other electronic access to such needs and problems. The students then gathered in front of the blackboard and the teacher wrote up the solutions suggested by the students during a short brainstorming session. Subsequently, the students began to develop solutions in the VRLE and uploaded these to their personal database; they then entered the VRE, in order to learn how to use it. Finally, the teacher informed them of the next lesson and asked them to identify a new set of problems at home.

6.5.4 Lesson Three

The teacher informed the students of the lesson content and recorded the needs the students had identified at home on the blackboard. He then divided the students into two groups of four, of mixed gender. Each group had to choose one need from the blackboard, brainstorm with regards to that need and work out a solution together, within the VRE part of the VRLE. One of the students in each group was chosen to guide the group though the VRE and to control the collaborative design work. Finally, the teacher informed the students of the next lesson and briefed them in identifying needs and problems at home, using both the IN and a specific blog site.

6.5.5 Lesson Four

The teacher informed the students of the lesson content. The students then gathered in front of the blackboard and the teacher wrote up all the needs and problems the students had brought from home; this was followed by a short brainstorming session. The students worked individually within the VRLE, registering new needs to their personal workshop database. They drew their solutions using a CAD programme and digital pen tablets and some of the students sent their ideas to the Icelandic and European Young Inventors' Competition.

6.6 The Measuring Instruments

The author used various data instruments, in order to enable triangulation and increase validity. Following on from the pilot study, the author also collected video files from the lessons and drawings from drawing tests. In terms of analysing the data, he employed the qualitative and inductive methodology developed by Glaser and Strauss (1967), as described in chapter 3.0. The specific instruments used are listed against the research questions in table 6.1 below and the way the data was treated is outlined in chapter 3.

Section	Raw data	Data Sources	Q 1	Q 2	Q 3	Q4
A6.7.1	A6.3.1 - A6.3.2	Interviews with the teacher	x	x	x	x
A6.7.2	A6.3.3 - A6.3.5	Interviews with students group	x	x	x	x
A6.7.3	A6.3.6	Interviews with individual student	x	x	x	x
A6.7.4	A6.3.7 - A6.3.15	The teachers and researchers logbook	x	x	x	x
A6.7.5	A6.3.16	Data from the VRLE			x	
A6.7.6	A6.3.17	Students' drawings from tests in the classroom.				x
A6.7.7	A6.3.18	Video recordings in the classroom	x	x	x	

Table 6.1: Data collection methods used in case study series two.

6.7 Data Collection and Analysis

The data collection methods used for case study series two are shown in table 6.1 above and the analysis process is explained in chapter 3.0. The summaries of transcripts can be found in the appendix; for example, section A6.7 covers all the summaries of transcripts in chapter 6.

6.7.1 Interviews with the Teacher

Two interviews were held with the teacher; one after the second lesson and one after the last lesson. The teacher focused on the learning process, was open to discussion and was critical of himself. The author employed a semi-structured interview schedule (see section A6.1.3).

6.7.2 Interviews with the Student Group

The interviews were conducted in the music room, using a digital recorder, after lessons two, three and four. The author conducted the interview, as the teacher had been too controlling in earlier interviews. The author thus expected the students to be more communicative than before.

6.7.3 Interview with an Individual Student

The interview took place after lesson four in the teacher's workroom and was based on a semi-structured interview schedule. The author had planned to interview two students, a boy and a girl, but the boy was sick. The girl's name was changed (to Bjork), in order to protect her identity; she was familiar with the author from the lessons and appeared comfortable. In the interview, the author focused on her attitude to IE, the VRLE and her understanding of idea generation.

6.7.4 Logbooks

Logbooks were written up after each lesson, when the contents of the lesson were still fresh in the teacher's and the author's minds. The logbooks were a combination of observations and reflections, largely based on the following structure:

- Use of the VRLE
- Circumstances in the classroom
- Student's circumstances
- Teaching methods
- Preparation
- Equipment
- IE and ideation
- Other subjects.

6.7.5 Data from the VRLE

As an administrator, the author had access to the VRLE database and was able to extract data from it, regarding the students' work. This included any uploaded needs, solutions and whether they were generated from needs identified at home or in school. Requests to the VRLE database may also show when the students were active inside the VRLE and where they worked from.

6.7.6 Drawing Tests

Digital drawing was identified as an important part of the students' work, as it affected both the time it took to generate solutions and the quality of that work. Furthermore, it concerned the students' ability to express and communicate their ideas. The following research question was thus set up, in order to lead this part of the authors work: 'how may the students' abilities to draw inside of the VRLE be improved?' (RQ 4).

The drawing assessment also included drawings the students did with the Pegasus tablets. The main aim of this was to examine the students' ability to draw, using different methods, and to assess the quality of their drawings. Three different pieces of equipment were used in this: a) the computer mouse with the software *Paint*, b) digital pens (number 1), and with the cad inside the VRLE and c) Pegasus wireless digital pens (number 2).

6.7.7 Video Recordings in the Classroom

Video recordings inside the classroom aimed to enable an understanding of the pedagogical context in which the VRLE was used, the teaching methods, the teacher's role and the students' communication. The raw video data was broken down into three main parts:

1. From lesson one.

Students working inside the VRLE: this alludes to the beginning of the course, when the students learned to use the VRLE.

2. From lesson three.

This refers to the beginning of the lesson, when the teacher introduced the lesson content. The students reported the solutions they had identified at home.

3. From lesson four.

The teacher prepared the students, in terms of working inside the VRLE, and asked them to upload solutions to a local exhibition and The Icelandic Young Inventors' Competition.

6.8 Overall Discussion and Conclusions from Case Study Series Two

The main pedagogical categories that were developed from the data can be seen in section A6.4. These are:

1. Teacher's preparation
2. Teacher's role and teaching handling
3. Motivation (pupils and teacher)
4. Drawing
5. Ideation
6. Use of the VRLE
7. Collaboration.

6.8.1 Teacher's Preparation

Discussion

Less preparation was a critical issue, both for the students and their teacher. In the pilot study, the teacher had requested further training and guidance, in terms of lesson preparation; thus, a help page was set up inside the VRLE, to support lesson preparations. However, with regards to the logbook, he again asked for such guidance: he failed to access the help page provided and, instead, he continued to complain about the lack of help and instructions. One consequence of this was the teacher and students experienced technical problems during the first two lessons. It should be noted that the teacher was familiar with WebCT (a MLE) and volunteered for this case study. On this basis, the author assumed a significant level of knowledge and confidence.

The teacher felt he was well prepared for the course. However, it was noted the VRE had not been upgraded and his preparation was limited, with the exception of lesson four. Perhaps the content of the course was difficult for him. A more likely reason, however, was his workload, as it limited his ability to use the help already given. He was also relying on the author's help and it should also be noted that the teacher had not practiced using the VRLE, as the students did. The teacher experienced hardware problems in lesson one (with regards to the use of the graphics tablets) and asserted that solving these problems was very time-consuming. Again, this appeared to relate to lack of experience in the use of the equipment and not spending enough time 'de-bugging', prior to teaching. The course was an after-school activity and thus an addition to the teachers' schedule. Nevertheless, the teacher managed to organise two of the lessons inside the school's regular schedule and reported this as easier.

The teacher considered how upgrading the VRLE was too difficult for a non-specialist. However, he did not mention any conflict between the roles of teacher and administrator, as in the pilot study. Perhaps he had more self-confidence, as he had been given pre-training and was more experienced than in the earlier course. This is evident in his attempts to set up a blog site for the students, to use in conjunction with the IN (the setting up of the blog site was, technically, a more complex task than using the IN). However, the blog site was never used properly by the students; the IN was probably an easier way for them to record identified needs and problems at home. It was also an important tool in supporting communication with their parents and starting off lessons.

Conclusion

A successful IE/VRLE course is dependent on the ICT skills of the teacher and their knowledge and preparation, in addition to their ability to adapt to new contexts and approaches. The teacher's preparation was important, with regards to avoiding technical problems during the course, as was his confidence in using the VRLE and the change in the dynamics of his relationship with the class, in terms of his increased confidence.

Pre-training and personal experience was important in increasing the teacher's confidence in the use of the VRLE. This relates to the concept and pedagogy of IE itself and the VRLE: the latter includes the equipment and software required, but also the differences in pedagogy, in terms of its use.

The case study underlined the need for teachers to undertake development work so that they may practice the skills they intend to use and prepare for both courses and lessons. This should be done within their normal workload (rather than being an additional load), in order to prevent fatigue.

The teacher requested tutorials that would support his work and, subsequently, a help page was set up inside the VRLE. However, the teacher did not access the tutorials implemented to support him in managing the course and the VRLE technology and this was probably due to his workload.

The students had the opportunity to use their mobile phones and a blog for recording any identified needs and problems at home. However, the Inventor's Notebook appeared to be a more popular method of recording and discussing ideas with parents, rather than the blog.

6.8.2 Teacher's Role and His Method of Teaching

Discussion

The teacher was responsible for the course and preparation was thus a part of his role. Preparation was important, in terms of ensuring that both the hardware and software worked and to enable him to support students, in terms of solving technical problems. Each lesson began with a short introduction and it was apparent that this was important, with regards to focusing the students' generation of ideas. During the introduction to lessons, the teacher underlined the importance of the students' homework and the value of identifying needs and problems and recording them in the Inventor's Notebook. This helped the students to get started and to understand the IE innovation process. Had the students not been given this basic understanding, they may not have identified with real needs and problems.

The lesson introduction lasted a few minutes, before the teacher quickly moved onto a brainstorming session, checking homework and triggering idea generation. This indicates two factors: the basic teaching skill of the pupils, knowing the teacher will check homework, and moving quickly to brainstorming. Brainstorming was used by the teacher to help students identify and share need/problems: such brainstorming gave students the opportunity to report and reflect on this, before they began to work inside the VRLE. However, it was observed that their reflection was limited and this could have been due to several reasons, such as the teacher's experience of IE and reflection based on brainstorming. IE was also new to the students and the development of reflection in brainstorming is probably not achievable in one session.

The teacher saw his control of the pace of the lesson as important; he felt that, if he were not in control, the students might get distracted from their idea generation. Pressures on time appeared to be beneficial in keeping the students on task and, as in the pilot study, this case study indicated that using time limits and pace appears to promote student focus. However, if time pressure is too great, the students may not be able to reflect enough. A teacher undertaking new tasks has to be flexible, but also has to find his own teaching style. During the course, the teacher considered the teaching methods as too basic and thus stated that they needed to be developed further. The teacher used multiple teaching methods, such as direct instruction, written instruction and short brainstorming sessions.

Unlike the pilot study, the teacher was not always in the classroom when the students needed help. However, as in the pilot study, the teacher tried to make the students self-reliant by teaching the fundamentals skills needed to manage the work inside the VRLE. He also supported the students' work through discussion and advice and asked them to explore the VRLE and familiarise themselves, without direct help: this was possible as a result of the students' high computer literacy and may have made the students more self-sufficient, as they subsequently learned to use the VRLE through their own experiences, with little support from the teacher. The VRLE may also have enabled the students to become more autonomous learners, as it was structured around the IE process. Moreover, the students might have become familiar with the VRLE through using it at home.

The teacher performed brainstorming sessions with the students and, when they were sitting in front of their computers, they were focused on their work. To get the full attention of the students, the teacher placed them directly in front of the blackboard. The teacher, however, considered it preferable to undertake short, re-focusing brainstorming sessions later in the lessons, with the students sitting in front of their computers, in order to save time and so as not to distract them from their work. This was also done to refresh them when working inside the VRLE and in finding more solutions to work with and such sessions appeared to enhance students' idea generation.

In the third lesson, the teacher requested that students work in groups, inside the VRE. However, this slowed down their idea generation, as they tended to focus on one solution together. Thus, to enable the task, the teacher gave the students detailed instructions and asked them to work in two groups of four. He then asked them to select and work with one of the solutions listed on the blackboard. However, the students could not agree amongst themselves and the teacher had to suggest a solution.

IE originated as an individually-based activity and thus students were not given tasks (see section 1.2). Rather, the origin of the students' ideas was based on personal experiences identified in their own environments and it is perhaps this individual nature of idea generation that is central to IE: it may thus be better suited to individuals rather than groups. The development of group working skills in a VRLE is also more complex and demanding than realised and is not achievable in one session.

Conclusion

The teacher had a good basic understanding of IE and introduced it well to the students, prior to the start of the course: this helped them to get started and become more self-sufficient. He also understood the purpose of the homework; i.e., to prepare for idea generation. Therefore, he underlined the importance of the identification of needs/problems during the course and supported the students' idea generation.
Part of the teacher's role was to plan and prepare for the course, solve technical problems and assist students when working inside the VRLE. Thus, he often undertook the role of facilitator, as opposed to didactic teacher

The teacher was professionally skilled and used a variety of teaching methods: this supported the students in becoming self-reliant and capable, with regards to using the VRLE for IE. He supported the students' self-reliance by giving them time to independently experience the VRLE. The students' homework also supported their self-reliance and their capability in using the VRLE.

The teacher attempted to reinforce the students' self-reliance by teaching them fundamental skills and allowing them (to some extent) to learn from their own experiences. It was noted that the students sometimes ran out of solutions to work on in lessons. In an attempt to remedy this, the teacher employed short brainstorming sessions, but these could have been more productive and more time could have been given for reflection. This may have enabled the students to generate more ideas to work with during lessons.

A good lesson plan and improved pace-setting supported the students in undertaking their tasks, increasing their productivity. However, too much pressure may limit students' ability to reflect on their work and may also minimise the number of generated solutions (Lupien et al., 2007).

The students were engaged in their work inside the VRLE during lessons and it was thus important to support them without distracting them from their idea generation. An example of this was the use of short brainstorming sessions within lessons, which aimed to refresh and refocus the students. These sessions also increased the number of solutions to work with and supported idea generation.

Group work inside the VRE was not straightforward for the students, despite their experience in computer literacy. Even outside the VRE, the students demonstrated limited teamwork skills, in terms of reaching an agreement on ideas to take forward. This was understandable, as the pupils were only 12 years old. Further consideration is required in this area, in terms of developing the skills surrounding student group work (particularly in reaching an agreement both inside and outside of the VRE).

6.8.3 Motivation

Discussion

Running the project as an after-school activity appeared to affect student motivation and performance: firstly, there will have been a positive novelty effect, at least in the early stages (Cohen et al., 2005; chapter 3.0). One aspect of this was the author's presence as a researcher, while a second factor was that IE had not been taught in the school. Eight students were allowed to join the course, as in the pilot study and, as many more students had wanted to join the course, their participation may have been seen as a privilege: this can be seen in the students arriving for lessons much earlier than expected. The students showed their interest in IE as a part of the school curriculum, both in this case study series and the pilot study. However, if IE was a compulsory subject, they may not have been as interested. In turn, the teacher will have reacted positively to a small group of highly-motivated students. Feedback to the author indicated that the students were happy with the teaching and this was known by the teacher.

Secondly, as the lessons ran after school, when the students were more tired, it could be expected that they would be less capable. For example, it was observed that the first two lessons ran at lunchtime and the students appeared fresher and more capable than when in after-school lessons. Software problems also affected the students' and teacher's motivation at the beginning of the course and there were technical hardware problems in the first two lessons, which negatively affected the students. The teacher became irritated, but did acknowledge that the problem was caused by his limited preparation. He tried to increase the students' motivation by promising them they could use the school's server one year earlier than expected and he complimented them on their good work. His motivation was perhaps also affected by his own ambition to improve his professional ability. In addition, the fact that the course was implemented as a research project by the University of Iceland and was being observed by the author may have instilled further motivation.

Another factor that affected the teacher's and students' motivation was their participation in *The Young Inventor's Competition*. Submitting an idea to the competition was optional; however, the majority of students submitted most of their solutions. The teacher's ambition may also have been a reason why he pressured the students during lessons and, this subsequently appeared to increase students' efficiency and improved their focus on sending solutions to the competition.

Conclusion

The novelty factor positively affected both the students' and teacher's motivation and, therefore, the plausibility of the research. Undertaking the project inside the school's normal schedule would have improved the reliability of the data, as the students would not have been as tired. Nevertheless, the novelty effect would still have existed. A long-term study, well beyond the realms of this study, is required if novelty effects are to be minimised and a more accurate picture gained.

Problems with software negatively affected the teacher's and the students' motivation. However, the majority of issues were caused by the limited skills and knowledge of participants. The students' independence and self-reliance, in terms of computer literacy, increased their abilities in the use of the VRLE and thus enhanced their motivation.

The teacher's attempts to motivate the group by offering rewards above the usual positive feedback will have affected results. The Young Inventor's Competition also positively affected the students' motivation and the generation of ideas.

6.8.4 Drawing

Discussion

The students continued to use the mouse even after they had started to use the initial digital drawing tablets and observations indicated that the digital drawing tablets were not flexible enough and slowed down work. The students stated that scanning the drawings would have been easier for them than drawing with the digital drawing tablets. The new digital pen tablets, however, were easier to use and more accurate.

As in the earlier course, the students were able to learn how to use the digital tablets through their own experiences and without specific training. Their drawings became more accurate during the course, as a result of the students' growing experience and improved drawing tablets (Pegasus) (see section A6.7.6).

The CAD inside the VRLE was only accessible from the VRE and, as with the earlier course, the students found it difficult to use. Observation and interviews indicated that this was due to the fact that the collaboration facility enabled them to disturb each other by drawing on the same virtual whiteboard. After some basic training and the upgrading of the CAD, it was apparent that they managed better in drawing collaboratively. To meet the students' reported desire to be able to draw individually, the CAD would have to be accessible from the MLE.

The students' drawings were not advanced or accurate, but showed the initial basic solutions for identified needs. The differences would be due to the small sample, in addition to the students' limited maturity and experience. The drawing tests highlight how important it is to teach the students to draw and to give them related homework. Part of the course should involve teaching the students to draw with digital pen tablets.

Conclusion

It is important to train the students to draw and instruct them in the use of the digital pen tablets. Drawing exercises increased the students' skills and the quality of their drawing, particularly in terms of accuracy. The students found that individual drawing was easier than collaborative drawing.

It is preferable to use a digital ink pen that enables students to see their drawings appear directly on paper, rather than non-ink digital pens, which requires users to look at the computer screen when drawing. The ink pen is also closer to the natural way of drawing and thus improved the students' work. The students' drawings were inaccurate, but did demonstrate basic solutions.

6.8.5 Using the VRLE

Discussion

The VRLE appeared to support the teacher's work, as it was structured on the IE process (1.6); good computer facilities were also beneficial. The VRLE usually worked well, both at the students' homes and the school, and it was easy to register the students. However, the teacher had some technical problems at the beginning, due to a failure to update the software, leading to issues with passwords. As in the pilot study, the teacher considered that upgrading the VRLE would be too difficult for a non-specialist teacher and he was able to solve most technical problems without the author's help. The VRLE had been improved, but the users had not been informed about the upgrades before they were released.

Help pages had been set up for both students and teacher in the upgraded version of the VRLE; however, they did not access them, with the teacher stating that such pages should be more advanced and interactive. He stated that the students should not just have to learn from their own experience and that they would not use the VRLE if they were having problems. He thus suggested that hard-copy learning material be made, including examples of uploading images to the VRLE. Students considered it easy to use the VRLE, both at home and in school. As in the earlier study, the students learned to use the VRLE without difficulty, as they possessed good computer literacy. As in the pilot study, the students were able to easily use the VRLE and quickly became self-reliant.

Using the VRLE at home was also beneficial for developing their skills, with, possibly, their parents help. However, only three solutions were uploaded to the VRLE from home during the course, out of a total of 40 uploads (table 6.2). The students were possibly largely playing inside the VRE at home, as they stated that the VRE was the most interesting part. The teacher stated that the VRE was not a toy to the students and logged this observation and he considered that the students required training in the use of the VRE for idea generation. Nevertheless, 'play' may be a useful preparatory exercise, building familiarity and confidence in their use of the software.

Observations indicated that the students felt it was important to be able to personalise the interface of their virtual workshops; for example, using a photograph of themselves. However, this did distract them from their idea generation at the beginning of the first lesson and, in future, it may be preferable to plan time for individual familiarisation and personalisation.

Conclusion

Both the teacher and the students did not access the tutorials inside the VRLE. However, the VRLE supported the students and teacher during the course, as it was structured around the IE process.

The students found it easy to use the VRLE and quickly became self-reliant in using the VRLE, due to their own experiences, the teacher's guidance, and support from their co-students and through accessing the VRLE at home. As the students' skills in using the VRLE increased, they became better adept at idea generation (the VRLE was structured around the innovation process).

Personalising the VRLE workshop was important for the students. Furthermore, playing inside the VRE appeared to make the students increasingly familiar with the VRLE and thus self-reliant.

6.8.6 Ideation and Innovation Education

Discussion

The majority of the work the students uploaded to the VRLE was completed during lessons, but some was uploaded from home. Table 6.2 below summarises the data, showing the origin of the students' work and the nature of their ideas.

Idea	*Title*	*What was it needed for?*	*Where?*	*Who needed it?*
1.	A box to hold the dust from an eraser	To be placed under the desk, in order to hold the dust from an eraser	Home	Everybody
2.	An indoor lift	To lift things at home	Home	Everybody
3.	Remote control	Remote control to operate everything in the home	Home	Everybody
4.	Belly stretcher	To help you look slimmer	Home	Everybody
5.	Paper stand	To hold up the manuscript when you are typing	Home	Everybody
6.	A double lighter	A lighter for both right and left-handed people	School	Everybody
7.	A vibrating blanket	To provide a light massage for those with muscular aches or rheumatism	School	Everybody
8.	Toasted sandwich pliers	To pick up hot toasted sandwiches	School	Everybody
9.	A speaking clock	A clock that speaks out the time, when prompted	School	Everybody
10.	Heated gloves	To keep frozen fingers warm	School	Everybody

11.	Shoe protectors	Plastic that you put over your shoes to protect them while you are walking	School	Everybody
12.	Motorised skate board	A skateboard with a motor that can reach speeds of up to 70 km/h	School	Everybody
13.	A candle lighter	An electronic cande-light that may be placed on a candleholder	School	Everybody
14.	A toasted sandwich timer f	So that toasted sandwiches may be made in the computer room in school, when students are working	School	Everybody
15.	A toast buzzer	A buzzer that let you know when toast is ready	School	Everybody
16.	Shoe heater	A flake to put under your shoe and when your toes get cold it begins to heat up your shoe	School	Everybody
17.	Speaking computer	To tell your computer to do something	School	Everybody
18.	Clock gloves	Gloves with an incorporated clock	School	Everybody
19.	A mirrored toothbrush	A mirror is placed at the end of a toothbrush so that you can see inside your mouth when you are brushing your teeth	School	Everybody
20.	A heel protector	A soft cloth to be placed inside shoes in order to prevent the rubbing associated with new shoes	School	Everybody
21.	Unbreakable lead	An unbreakable lead for pencils	School	Everybody
22.	Heated headband	A heater is placed inside the headband to warm up your forehead	School	Everybody
23.	Motor driven line-skate	A motor driven line-skate with an infrared remote control	School	Everybody
24.	Multi-language keyboard	A computer keyboard for many languages	School	Everybody
25.	Voice controlled television	A TV that may be controlled by you speaking to it	School	Everybody
26.	Computer that understands your voice	You can speak to the computer and it automatically writes down what you say	School	Everybody
27.	A toothbrush elevator	Use to lift toothbrushes from out of a tall glass	Home	For my uncle
28.	An antenna clamp	To secure the radio antenna in my room	Home	For my uncle
29.	A post box lock	A combination lock for post-boxes	Home	For my uncle
30.	Waterproof gloves	To protect my hands from the cold and the rain	Home	For my uncle
31.	Slide	Slide from the kitchen to my room, to get there faster	Home	For my uncle
32.	Extending shoe	I do not need new shoes if I have extendable ones	Home	For my uncle
33.	Threshold cover	A cover to place over a threshold, to prevent injury to toes	Home	For my uncle
34.	Coupling for TV	To connect many TVs together	Home	For my uncle
35.	Scented ‘toe reek’	To place in peoples’ shoes if they have smelly toes	School	For my uncle

36.	Renewable football boots	They have changeable soles	School	For my uncle
37.	A book holder	To place a book in while you are reading it	Home	My dad's friend
38.	A can for left handed people	A special can for left-handed people	Home	My dad's friends
39.	A meal informer	To inform everyone in the house when a meal is ready	Home	My mother
40.	A secure stapler	A stapler with which people cannot hurt themselves	School	My teacher

Table 6.2: Ideas submitted by the students in case study series two.

Table 6.2 outlines the ideas students uploaded to the VRLE (i.e., title, identified needs, where the needs were identified and whom they were intended for). Behind each solution submitted to the VRLE was a need defined by the students and they had to report what was needed, why it was needed and whom it was needed for. The students also reported how they developed their solution by describing the solution and drawing it. The students identified needs at home, with little help, and these were largely based on their personal problems and problems relating to family members. The students tended to record solutions in their INs, rather than needs, and this was probably because they generated solutions at the same time as they identified a need or a problem.

Students did attempt to use the blog site at home, but they did not continue to use it in school: this was an available feature of the VRLE, but they did not see a need for it. It could be assumed that further introduction and exercises, with regards to the blog, may encourage greater use of the blog; however, students did readily use the IN to record identified needs. During lessons, the teacher asked the students to use the IN to support their idea generation, informing them that the needs they had identified at home could be useful as a basis for generating further solutions. Consequently, the student used the IN when they ran out of ideas. Table 6.3 below summaries the information in table 6.2.

Case study series two	*%*
8 students and 40 ideas	
16 of the 40 ideas were generated from needs identified at home	40
24 of the 40 ideas were generated from needs identified at school	60
26 solutions were generated by everybody	65
8 solutions were generated by the students themselves	20
1 solution was generated by the teacher	2
5 solutions were generated by the students' families	13
All of the solutions were concerned with common problems in students' daily lives	100

Table 6.3: The outcome of case study series two

Table 6.3 and figure 6.1 provide information about the basis of the solutions. Forty solutions were uploaded to the database and all were solutions to common everyday problems in people's lives. The students established thirteen solutions at home and twenty-three in school.

Figure 6.1 below shows highlights who the solutions were intended for:

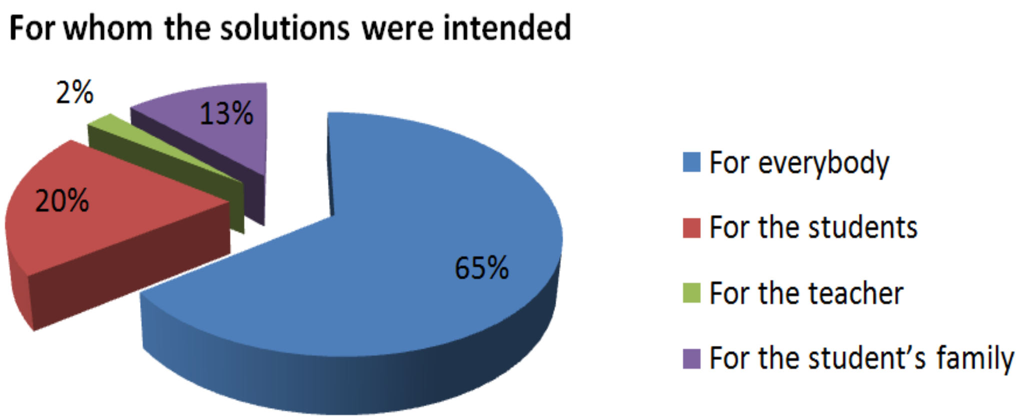

Figure 6.1: The figure show who the solutions were intended for.

The students' idea generation appeared to share similarities with the values of the pedagogy of IE as a tool for solving general problems in everyday life (see section 1.2). 60% of the students' ideas were based on needs obtained at school, while 40% were based on needs identified at home. The students based all their solutions on general problems and needs (see section INSERT SECTION HERE). 65% of the generated solutions concerned everybody (see section A6.3.16), 20% were based on the students' own needs, 13% of solutions were related to their families and 2% were based on the teacher's needs.

Table 6.4 below shows the main differences between students' idea generation in case study series two and in the pilot study.

The pilot study		*Case study series two*	
8 students and 12 ideas		8 students and 40 ideas	
10 solutions were generated from needs identified at home	83%	16 solutions were generated from needs identified at home	40%
2 solutions were generated from needs identified at school	17%	24 solutions were generated from needs identified at school	60%
5 solutions for everybody	42%	26 solutions for everybody	65%
1 solution for the student himself	8%	8 solutions for the students themselves	20%
1 solution for the teacher	8%	1 solution for the teacher	2%
5 solutions for the student families	42%	5 solutions for the student families	13%
Most of the solutions concern common problems in students daily live	100%	Most of the solutions concern common problems in students daily live	100%

Table 6.4: The main differences between the two case study series.

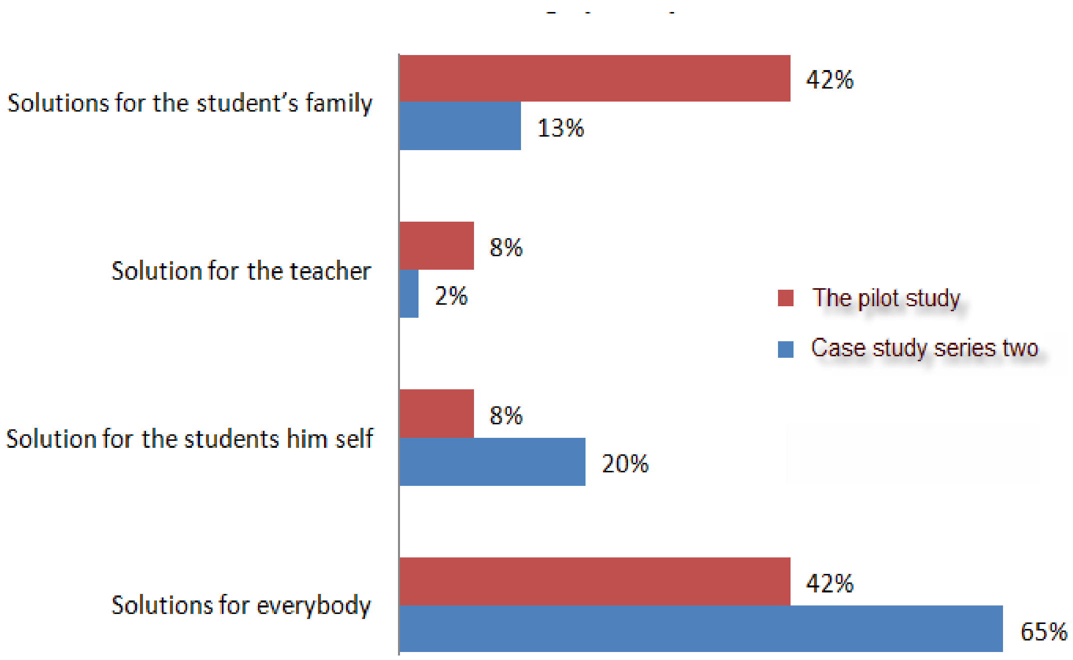

Figure 6.2: Bar chart showing the differences between the two case study series.

The number of participating students was the same in both case studies, but the students were more effective in case study series two, generating 300% more solutions in total. In case study series two, 43% more ideas were generated from needs identified at school and 43% less from needs identified at home than in the pilot study. The origins of the solutions in both case studies were associated with common problems in the students' daily lives and there was congruency between identified needs and solutions in both studies.

The author struggled to identify the specific reasons for the differences listed above: it may have been a random occurrence, due to the small numbers of students in each case study series. However, the differences could also be attributed to upgraded software, the teacher's increased experience, more frequent brainstorming sessions and the students playing inside the VRLE before lessons (which made them more skilled in using the VRLE). Student productivity in lesson four also has to be considered: in this lesson, the students generated about 50% of all their solutions and were motivated by taking part in *The Young Inventors Competition*, under time pressures imposed by the teacher. Perhaps the improved lesson plans and software, the new tutorials and the teacher's improved preparation and self-confidence all contributed to the students generating more ideas in case study two.

In the pilot study, the students' ideas were more related to their families and more solutions were based on input from the teacher. The students were helped by their families, but this was not the case in case study series two: this appears to be a random effect, due to the small group number. However, the students identified needs and problems themselves at home by examining their family life.

Figure 6.3 below shows the number of solutions submitted to the VRLE during the course. Four ideas were submitted in the first lesson: there was no lesson the day after, but three ideas were submitted from outside school. Seven ideas were submitted in the second lesson, while, in lesson three, seven solutions were submitted. Lesson four was the most productive, with the students submitting 19 solutions.

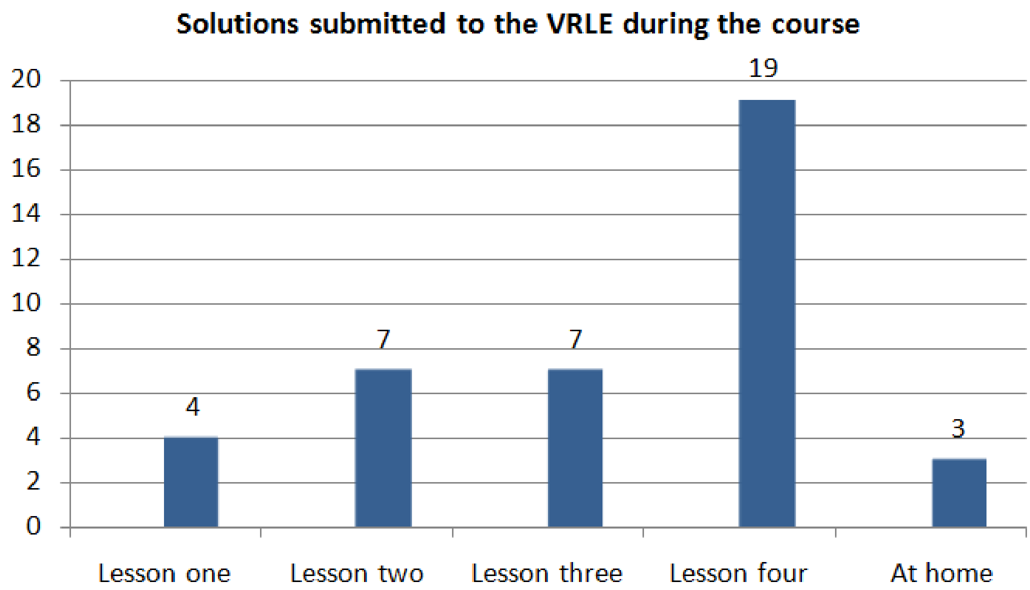

Figure 6.3: Shows number of solutions submitted during the course.

Table 6.5 below gives an overview of individual student's activities inside the VRLE and the abbreviations used are explained underneath the table. The context of the content of the table, in relation to the students' work and the course, is also demonstrated.

CSS2	S	N	SN	SS	C	GN	GS	C-SN	C-SS
Stb1	6	4	0	0	6	0	5	0	Stb2,Stb2,Stb2,Stb8,Stb8
Stb2	6	7	0	3	6	0	1	0	S8,S2,S2,S2
Stb3	5	2	0	1	2	0	2	0	S2,S2,S3
Stg4	5	7	0	0	5	0	1	0	S3
Stg5	3	4	1	0	0	1	1	S5	S6
Stg6	5	2	0	2	4	1	1	S5	S6
Stg7	7	7	0	0	7	0	0	0	0
Stb8	3	2	0	3	3	0	5	0	S2,S2,S8,S8,S8
Sum	40	35	1	9	33	2	16	2	20

Table 6.5: An overview of individual student's activities in the VRLE.

Stb: Male student; Stg: Female student; S: Solutions; N: Needs; SN: Shared needs with others; SS: Shared solutions with others; C: Solutions sent to *The Young Inventors Competition*; GN: Needs the group shared; GS: Solutions the group shared; C-SN: Collaboration or shared needs with the following students; C-SS: Collaboration or shared solutions with the following students.

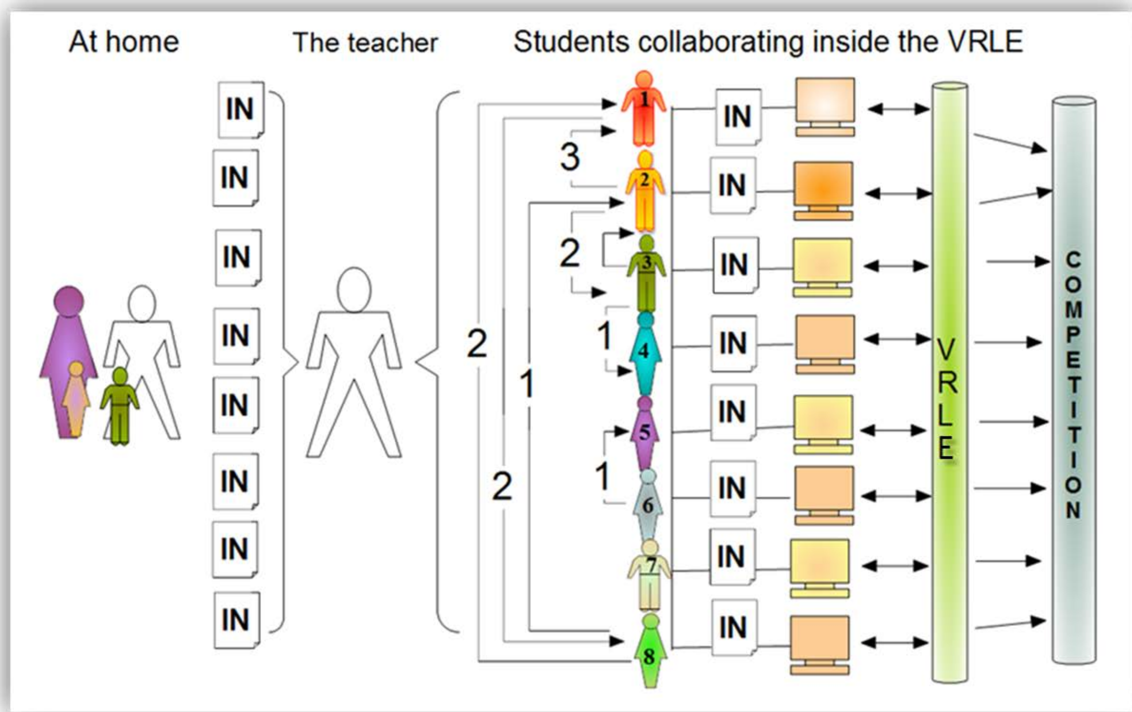

Figure 6.4: Demonstrates how students shared ideas inside the VRLE during CSC2.

The students generated a similar amount of needs and solutions and there was a balance between boys (20) and girls (20). Only one of the group shared their needs with one or more individuals, while two shared their needs with the group. Four students shared nine solutions with individual students and with the whole group. In total, 40 solutions were and 35 needs were delivered. Thirty-three of the students' solutions were sent to *The Young Inventors' Competition*. The students established two group needs and sixteen group solutions. There was often a congruency between the students' needs and solutions (see figure 6.5 below).

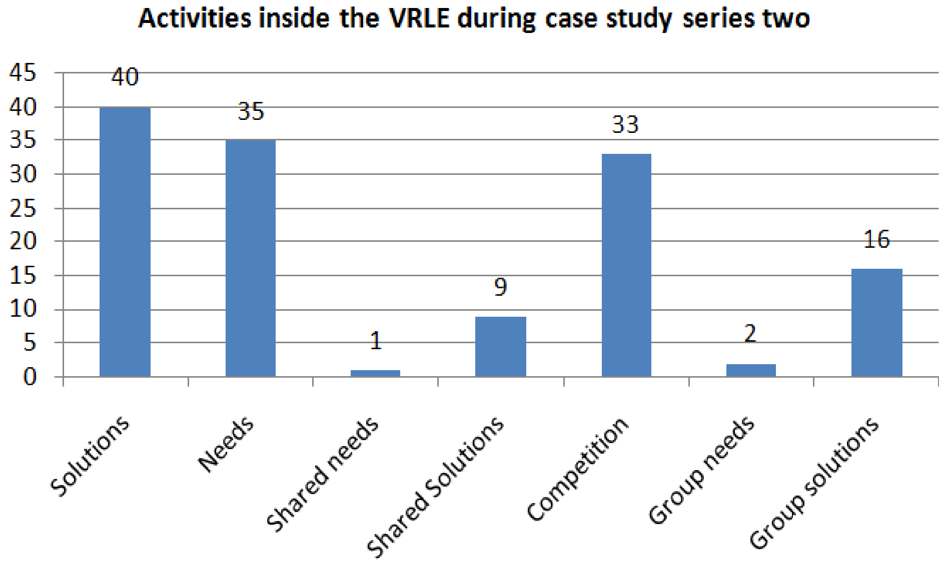

Figure 6.5: Highlights the output of students during the course.

Table 6.6 shows the four solutions delivered in the first lesson, on Friday the 12th of March. Seven solutions were delivered in both the second lesson (13/03) and the third lesson (14/03). There was no lesson on Sunday, but three solutions were uploaded from home. Seven solutions were discovered in the third lesson (15/03) and nineteen solutions were uploaded in the last lesson (16/03).

Friday 12.03	Saturday 13.03	Sunday (home) 14.03	Monday 15.03	Tuesday 16.03
12:28	11:14	19:47	16:21	17:18
12:30	11:14	20:07	16:26	17:19
12:26	11:17	20:15	16:26	17:20
12:35	11:18		16:29	17:22
	11:22		16:29	17:24
	11:23		16:31	17:25
	11:25		17:13	17:28
				17:32
				17:33
				17:35
				17:35
				17:39
				17:47
				17:49
				17:51
				17:53
				17:54
				18:10
Lesson one	Lesson two	No lesson	Lesson three	Lesson four
4 solutions	7 solutions	3 solutions	7 solutions	19 solutions

Table 6.6: Shows when the students uploaded their solutions to the VRLE.

Figure 6.6 below demonstrates the time the students concluded their solutions and uploaded them to the VRLE, during lessons. It was difficult for the teacher to control the factor of time, due to the novelty of the VRLE. The students were learning to use the VRLE and the author was testing the various ways of drawing. The students came early to the classroom to play in the VRE and they usually did not want to stop playing when the lesson began; thus, lessons often started later than planned. Time was also taken for the teacher to solve technical problems, when they occurred, and this was disconcerting for the students.

The activity of idea generation was, however, mostly in accordance with the course plan. The majority of the students' solutions were uploaded 14 minutes after the lesson began, when the teacher introduced the content of the lesson and conducted brainstorming sessions with the students.

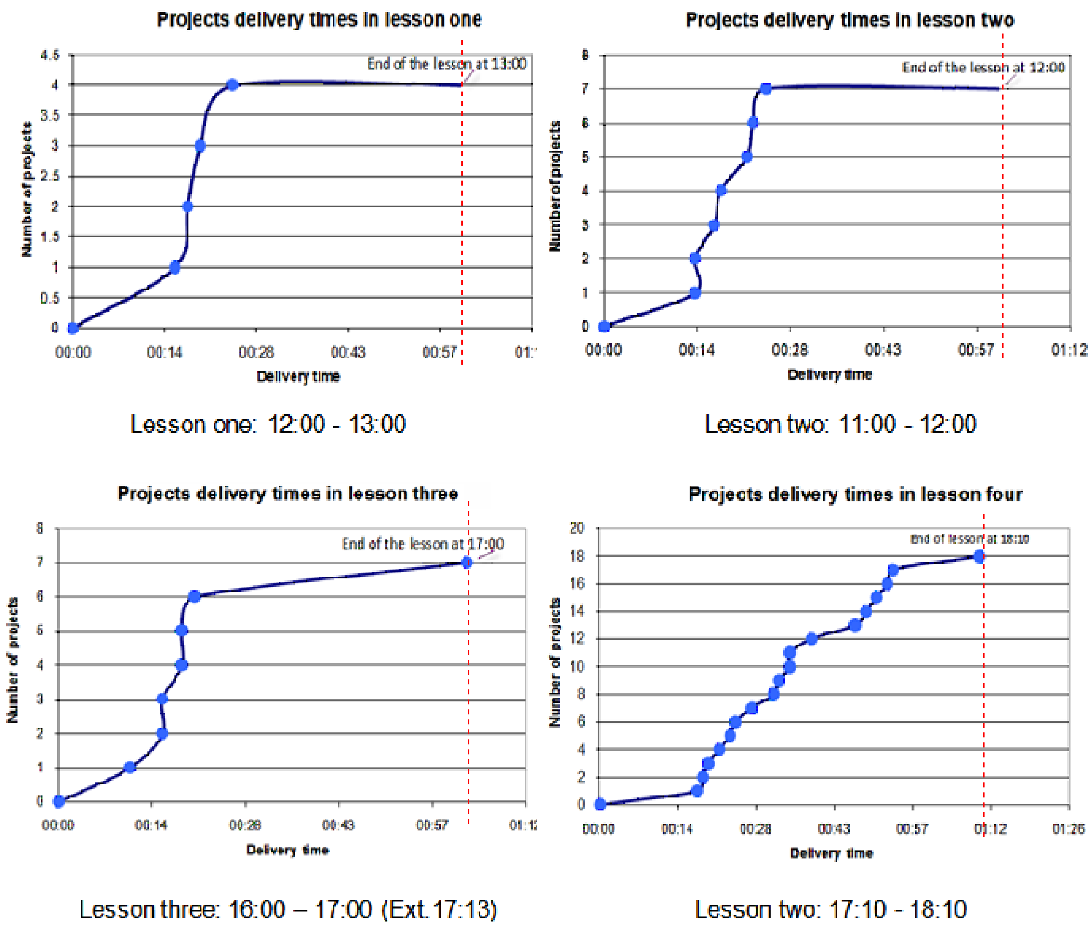

Figure 6.6: Shows the times when solutions were uploaded to the VRLE.

In lesson one, the students were learning to use the VRLE. They began late, due to the teacher's long introduction, and delivered a few ideas in the second part of the lesson. In lesson two, the students were most active at the beginning of the lesson, after the brainstorming session. In the second part of the lesson, when the teacher began to prepare the students for the VRE collaboration work in lesson three, the students did not upload any solutions. In lesson three, the students were most active at the beginning of the lesson, before they accessed the VRE. At the end of the lesson, they delivered one common solution that they had been developing together inside the VRE. The fourth lesson was the most progressive, as it was solely concerned with the generation of ideas. In this lesson, the students used the Pegasus tablets and they were probably highly motivated, as their task was to generate as many ideas as possible and upload these to The Icelandic *Young Inventors Competition* and a local competition inside the VRLE.

Training the students, in terms of both providing knowledge and opportunities to gather experiences, appeared to be beneficial for idea generation. Also, as in the pilot study, the students quickly understood the innovation process through experience and were able to identify needs and problems in their own environment: they reported that they were easily able to generate ideas. The teacher applied time pressure by setting short deadlines whenever he felt that group work was slow and this appeared to facilitate the generation of ideas. The slowing down of ideas was possibly largely associated with the physical staying power of the students, with the teacher noting that the students worked better early in the morning, rather than in an after school lesson (they were physically more alert in morning lessons).

Figure 6.7 below outlines the efficiency of idea generation, at intervals of every ten minutes, during lesson four. 70 % of ideas were generated during the first 40 minutes of the lesson: idea generation was at its greatest at 17:40 and then slowed down until 17:50, when it began to rise again. At 18:00 there was another peak, when the students delivered three ideas, and then the rate of efficiency slows down again. This peak is lower than the first, as the students' staying power is weaker. According to the lesson plan, the students were most active after the brainstorming session, in the middle of the lesson and near the end of the lesson, when the teacher had conducted a further brainstorming session. Unfortunately, the precise times for these brainstorming sessions were not logged.

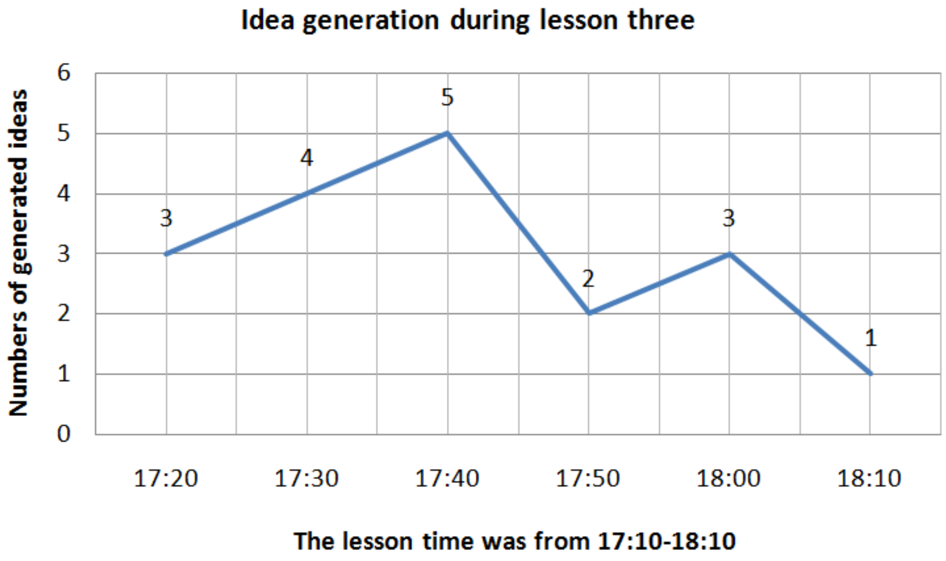

Figure 6.7: Shows the efficiency of idea generation at ten minute intervals.

Figure 6.7 shows the idea frequency of students during the last lesson, in relation to figure 6.6. The students' idea generation increased slowly at the beginning of the lesson and, after they had delivered most of their ideas, their idea generation decreased, only to rise again after about 17:48, when further ideas were generated, and then decreased after 17:58 and until the lesson ended. This means that idea generation was greatest in the first 25 minutes of the lesson and after 17:48. The students submitted most of their ideas after the teacher's introduction and the brainstorming session and, as the students were new to IE, this was to be expected: they were waiting for further guidance and presented relatively few, already sourced ideas and problems.

The brainstorming sessions used in the introductions were apparently useful in triggering idea generation and helped students to get started in the VRLE. Following the introduction and brainstorming sessions, the students worked even harder inside the VRLE; however, it was apparent that they were going to run out of ideas during the session and, to some extent, become tired. Observations showed that the teacher employed short brainstorming sessions (of 5-10 minutes duration) when the group became tired and began to run out of ideas: this refreshed the students and refocused them. The students were generally self-reliant and their initial ideas were individually based. Nevertheless, some ideas generated were based on shared needs and ideas conducted inside the VRLE. This collaboration appeared to support further idea generation.

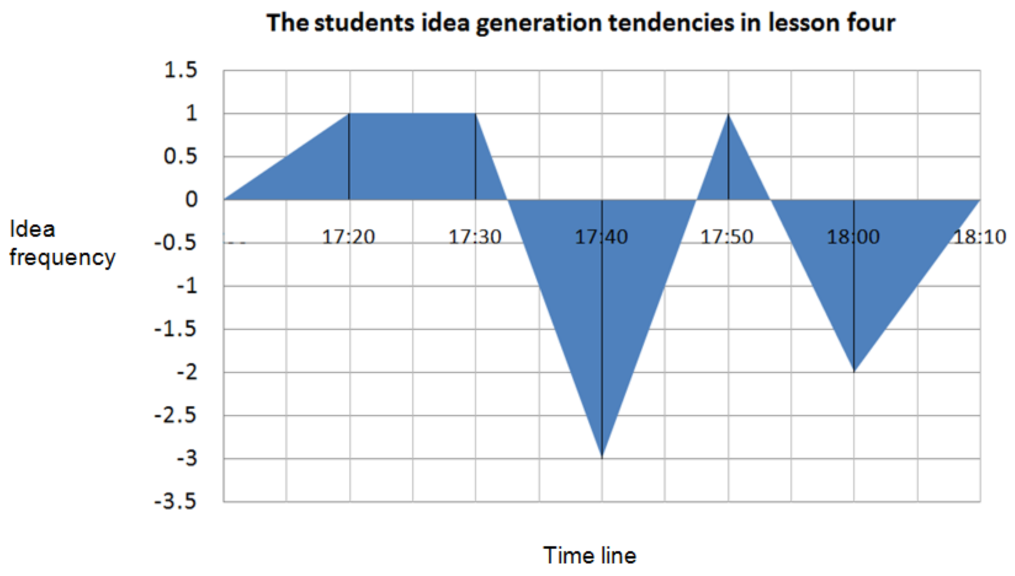

Figure 6.8: Table showing the tendency of idea generation during lesson four.

The students' drawings demonstrated basic solutions to identified needs and problems and highlighted how these solutions could look. These were basic concepts: they were not accurate, but were developed during the course. The quality of drawings improved when the students stopped using the original pens and began to use the Pegasus tablets. The students also worked faster with the Pegasus tablets and this positively affected their efficiency in lesson four, with drawings becoming more detailed.

Observations indicated that the digital pen tablets appeared to slow down the students' work and idea generation and a lack of familiarity and experience with the devices must be a significant factor in this. The teacher considered it important that the students should be taught to draw with both conventional equipment and digital input devices, in order to speed up their work. The students stated they were happy with the IE course and often demonstrated a light-hearted spirit. This atmosphere in lessons may also have influenced students' idea generation, as research has shown that good humour increases the frequency of idea generation (Runco, 2007; Cayirdaga & Acar; 2010).

Conclusion

The IN was a useful tool in recording identified needs, problems and solutions, both at home and elsewhere. It was used by the students and the teacher as a source of idea generation within the VRLE, particularly when they lacked ideas in school. Most solutions were identified at school, when working inside the VRLE. Students generated the majority of their ideas in lesson four.

Brainstorming sessions at the beginning of lessons were useful in triggering idea generation. When the students got tired and lacked ideas, later in lessons, brainstorming sessions refreshed them and thus enabled further idea generation. Time pressures and the students being in a happy mood appeared to enhance idea generation.

Collaboration in the classroom both triggered and enhanced the idea generation of students. Sharing needs and ideas online, through the VRLE, was also beneficial. However, students did not manage to effectively use the blog site at home (as an alternative to the IN).

Training, knowledge and experience were helpful for the students' idea generation; however, the initial digital pen tablets used appeared to slow down idea generation.

60% of ideas were based on needs obtained in school, while 40% were based on needs identified at home. 100% of the ideas related to everybody. In contrast to the pilot study, fewer ideas were related to the students' families and more were based on input from the teacher.

6.8.7 Collaboration

Discussion

The teacher wrote a letter to the parents, outlining the course plan and requesting that they help students with their homework. However, by examining the VRLE database, the author noted that the students did not get much help from their families, in identifying needs and problems at home. In the group interviews, the students reported that they did not ask for help at home, in terms of finding needs and problems. They mostly identified needs at home through personal problems, which would apply more generally and by identifying problems within their families. This was probably why the rate of ideas identified at home was lower in this study than the pilot study, where their homework was better supported by their families. As in the pilot study, the students were communicative and collaborated well together. The multimodal possibilities for communications within the classroom and the VRLE may have supported this.

The students' collaboration appeared to be of some value for their idea generation: it helped them to share ideas and made them work faster and more productively. The brainstorming sessions the teacher conducted are examples of collaborative work. In addition, the students could use brainstorming sessions to communicate needs and ideas, both inside the classroom and inside the VRLE, as two parallel worlds. This can be seen by comparing the data from the VRLE with the videos.

Sitting together in the classroom, when working inside the VRLE, appeared to support the students' communication in multimodal ways. In the video recordings, it was noted how the students were curious about each other's work, when working inside the VRLE (half of them shared their solutions with each other). However, just one need (rather than solutions) was shared. The students shared their solutions with each other, through face-to-face conversation, and the teacher also asked the students to help each other with their solutions.

The students worked independently, but supported each other during conversations, both inside the classroom and the VRLE. Their collaboration appeared to have helped them become more self-sufficient. Furthermore, when the teacher was not present, the students began to help each other. The students were allowed to interact together inside the VRE before lessons started and this probably made them more confident, self-reliant and independent in using the VRLE. In lesson three, the teacher asked them to develop a solution together, in groups of four, inside the VRE. In this lesson, as in the pilot study, the students found it difficult to collaborate, especially in terms of drawing together on the virtual whiteboard and interacting as avatars inside the virtual world. The main reason for this was probably, when they were working together, they disturbed each other, rather than acting in a more measured, collaborative manner.

In the group interviews the students appeared confident that they could learn to work together inside the VRE. As with the pilot study, it seems that, the smaller the group, the better the students worked together and were more productive (Hare, 2003).

Conclusion

The teacher implemented collaboration in order to enhance and motivate the students in idea generation. Students were communicative and collaborated well together, both in the classroom and the VRLE, accessing the multimodal possibilities for communication supported by the VRLE: this helped them to become self-sufficient in using the VRLE for idea generation. Furthermore, it appeared to enhance the idea generation of students. They communicated and shared needs and ideas, both inside the classroom and the VRLE, viewing them as two parallel worlds. Sharing ideas made the students more productive; however, it was difficult for them to collaborate inside the VRE: it is acknowledged that this is a complex skill and time was limited. It was apparent that small groups collaborated more effectively, both inside the classroom, the VRLE and the VRE.

The students did not often collaborate at home with their families, in identifying needs and solutions, and this decreased the number of solutions originating at home. However, collaboration during brainstorming sessions was beneficial for the students, as it helped them to generate more ideas and to refocus.

6.9 Answering the Research Questions

This chapter has covered the second case study series, which was based on the evidence and conclusions from the pilot study (see chapter 5.0), and the main activities included observation of the innovation process, when the students incorporated the VRLE. The study also examined the pedagogical issues identified in the pilot study and their influence on the students' work, in terms of the innovation process. The research questions for case study two are revisited here and subsequently answered in the following sections:

1. What characterises the role of the teacher when the VRLE is used and how does this differ from the earlier IE model? How can its effectiveness be improved?
2. Is the students' work supported by computer collaboration within the VRLE?
3. What elements of the IE course support the students generation of ideas?

4. How may the students' abilities to draw inside the VRLE be improved?

Table 6.7 below shows how the data answered the research question and enabled triangulation.

Section	Raw data	Data Sources	Q 1	Q 2	Q 3	Q4
A6.7.1	A6.3.1 - A6.3.2	Interviews with the teacher	x	x	x	x
A6.7.2	A6.3.3 - A6.3.5	Interviews with students group	x	x	x	x
A6.7.3	A6.3.6	Interviews with individual student	x	x	x	x
A6.7.4	A6.3.7 – A6.3.15	The teachers and researchers logbook	x	x	x	x
A6.7.5	A6.3.16	Data from the VRLE			x	
A6.7.6	A6.3.17	Students' drawings from tests in the classroom.				x
A6.7.7	A6.3.18	Video recordings in the classroom	x	x	x	

Table 6.7: Shows how the data collection methods enabled the research questions to be answered.

6.9.1 Question One: What Characterises the Role of the Teacher when the VRLE is used and how does this differ from the Earlier IE Model? How can its Effectiveness be Improved?

The teacher's role, in terms of the new IE-VRLE context, is different from his role in the earlier model (pre-VRLE). Some of these differences are outlined in this section and are contrasted in table 6.8. This will be further discussed in the overall discussion of the enquiry (see chapter 10.0).

Old conventional model	**Later IE/VRLE classroom model**
The teachers role in conventional IE	Teachers role in IE using the VRLE
- Fundamental training on IE - Teach the IE process to class - Organise the course - Preparation for the course - Instructor and facilitator - Conducting brainstorming - Engage parents in homework - Discuss problems, needs and solutions - Assist students inside a classroom - Use textbooks - Teach fundamental skill and knowledge	- Fundamental training in IE, ICT/VRLE -Teach the IE process inside the VRLE - Organise the course - Prepare for the course - Solve technical problems - Instructor and facilitator - Engage parents in homework - Conduct brainstorming and refocus students (partly in VRLE) - Discuss problems, needs and solutions - Assist students inside the VRLE - Support students self-reliance - Teach fundamental skills and knowledge

Table 6.8: Shows the differences between the teacher's role in the two IE models.

Using the VRLE had an impact upon the teacher's role, in many ways (Thorsteinsson & Denton 2003), and the research highlighted the importance of the teacher as a facilitator and intermediary: this required new knowledge and skills from the teacher, both in IE and ICT. The VRLE was structured around the innovation process, with incorporated tutorials, and thus the VRLE had the capability to enable and guide the students' work and, to some extent, took over part of the teacher's role, relative to the earlier model of IE: this also maximised the opportunity for developing students' self-reliance and autonomy. The teacher supported this, as he often stood back when the students were working inside the VRLE. Such a step back may have been intentional, in order to avoid conflict between his roles of instructor and student assistant (this would require further follow-up). Furthermore, when the students were alone, they supported each other in seeking help (an example of collaboration). The VRLE could possibly be used by the students at home, without a teacher physically present, within the context of open and distance learning: this is clearly an area for further research.

The teacher's role was identified as sophisticated, based on the use of various teaching methods and the ability to make professional decisions on the appropriateness of such methods, in terms of using the VRLE for IE. It should also be noted that the teacher had not previously taught IE or used a VRLE, although he was an experienced computer user. The teacher occasionally had to adopt the role of instructor; however, he also needed to be able to support student self-reliance and capability, in terms of independent usage of the VRLE for IE. He also had to teach fundamental (didactic) skills, yet had to adopt the role of facilitator, supporting the students with discussion and advice. He underpinned their self-reliance by giving them time for independent experience in using the VRLE. It was important that the teacher encouraged the students to become engaged in their work inside the VRLE during lessons and he had to support them without distracting them from their idea generation.

Interviews with the teacher, data from his logbook and author observations indicated that the teacher lacked confidence in teaching IE and in the use of the VRLE and it is reasonable to infer that this would have affected his performance and approach. In addition, being observed by the author would have increased any pressure on the teacher. The interviews showed that the teacher still lacked confidence after receiving basic training in IE and in the use of the VRLE: such training should have enabled him to be better prepared and more confident in using the equipment and software before lessons began. Again, this may indicate that the research period was too short to enable the teacher to build up the required confidence.

Another aspect of the teacher's role was informing and engaging with parents: two aspects of this were to enable parents to support their children with their homework and to help them to encourage their own child. In this case, none of the parents had experienced IE or the VRLE when they were at school and thus the teacher provided them with a relatively detailed course plan prior to the start of the course (see section A6.0.5). The parents in case study series two were less directly supportive of their child's work, but were indirectly supportive. The small numbers involved prevented hard conclusions from being drawn and these may have been variations that appear in small groups.

Part of the teacher's role was to plan and prepare for the course (see section 6.8.1). An effective lesson plan and efficient pace setting supports students in undertaking their tasks and thus makes them more productive. A teacher has to be able to solve technical problems and assist students when working inside the VRLE; they must have a good basic understanding of IE and must introduce the innovation process well. This enables students to get started in using the VRLE and ensures increased self-sufficiency. Similarly, as in the earlier model (see section 1.6), the teacher must understand the meaning of the students' homework and encourage its exploitation, in terms of the students' idea generation inside the VRLE. He must place an emphasis on the students' identification of needs/problems during the course and must support the students' idea generation by brainstorming with them at the beginning of lessons, based on their homework. The teacher also has to be able to value the efficiency of students' idea generation and focus during the lesson: he also must be ready to support them through the use of short brainstorming sessions (in order to refresh them and encourage them to generate more solutions).

The original pedagogical model of the IE innovation process (see chapter 1.0) was developed by a number of collaborators, prior to the introduction of the VRLE, and the model has been useful in enabling the discussion of pedagogical characteristics. The model is illustrated below (based on a series of steps, iterations and relationships).

Ideation skills are employed at all stages of the IE innovation process and innovation relates to the usefulness of ideas and/or how they can be implemented as solutions to many problems encountered in everyday life. Students learn through the cycles of the innovation process, supported by the collaboration amongst individuals, as a group, and by the teacher. The overall framework is managed by the teacher. Ideation is at the core of IE pedagogy and the IE innovation process is iterative, with the overlying direction leading from 'finding needs' to 'the presentation of solutions' (see diagram below, which featured in chapter 1.0 and has been relisted here to assist the reader).

To enrich the understanding of the emerging pedagogy, in terms of the VRLE, the model below was designed: this demonstrates the pedagogy of IE as it appeared during the research. Figure 6.9 shows how students learn through idea generation and how learners' interactions between home, the classroom and the VRLE are fundamental to this process. Both individual and social events are important in the process of idea generation and the teacher plays a fundamental role in both training and the facilitation of learning.

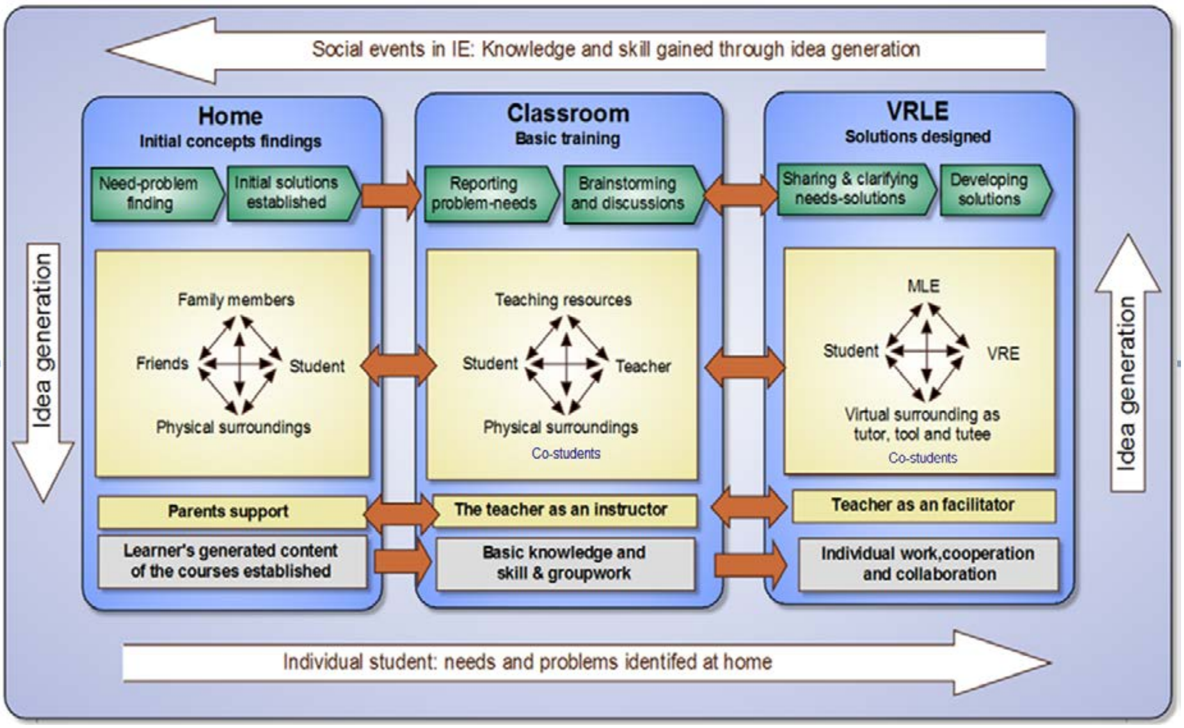

Figure 6.9: The model shows IE pedagogy as it appeared during the research.

6.9.2 Question Two: Is the Students' Work Supported by Computer Collaboration within the VRLE?

Students' work inside the VRLE was supported by computer collaboration. The VRLE enabled multimodal possibilities for communications, as an addition to face to face communication in the classroom and this supported the idea generation of students. The students were able to speak face to face, write to each other, speak through the headset and use avatar gestures. Furthermore, the VRLE helped the students to communicate and share needs and ideas inside the VRLE and thus made them more productive. The students were communicative and collaborative: this was identified on video clips from lesson four, when the students were working inside the VRLE, and in the interviews with the teacher. It was also apparent in comparing the data from the VRLE with these video clips (see section A6.7.5.1). The VRLE database showed that half of the students shared their solutions with each other. This was supported by the teacher, who asked the students to help each other and communicate, using headsets, inside the VRLE during the lesson.

Students worked independently, but supported each other during conversations, both online and face-to-face, and their collaboration helped them to become self-sufficient in using the VRLE. The level of student communication also increased when the teacher was not present (see section A6.7.7.1). The VRE was the most challenging part of the VRLE for the students, but it was difficult to use for collaborative work and they found it more interesting in playing games; i.e., an off-task exploration, permitted by the teacher, prior to the start of the lesson. This probably made them more self-reliant and independent in using the VRLE in lessons. In lesson three, the teacher asked them to develop a solution together inside the VRE, in a group of four students. As in a similar lesson in the pilot study, the students found it difficult to collaborate, specifically in drawing together on the virtual whiteboard and interacting as avatars. The smaller the group, the better the students worked together.

6.9.3 Question Three: What Elements of the IE Course Support the Students' Ideas Generation?

Various data highlighted issues that affected the students' idea generation, including brainstorming, homework, collaboration, drawing methods and time pressures. Pre-training the students in using the VRLE, giving them basic IE knowledge and their own experiences were beneficial in supporting their idea generation. It was part of the teacher's role to help them to understand IE and to teach them how to partake in the innovation process inside the VRLE. Similarly, as in the pilot study, the students quickly understood the innovation process and were able to identify needs and problems in their own environment. Thus, they identified ideas easily.

The students' identification of needs/problems at home was important, in terms of their idea generation. The IN enabled them to record needs, problems and solutions and they then used it in school, as a basis for their idea generation. Subsequently, the teacher and the students used the IN as a source for beginning idea generation in school. The IN was also used when the students lacked ideas when working inside the VRLE during lessons. Brainstorming was identified as an important method in triggering idea generation inside the VRLE; furthermore, short brainstorming sessions during the lesson strengthened the students' staying power when they were working inside the VRLE. It also affected their ability to generate more ideas and thus supported their idea generation. Time pressures also enhanced idea generation: this was identified in short brainstorming sessions during lessons (such sessions had a positive impact on the students' attention and refocused them. Furthermore, it was noted that the students worked better early in the day, within the school's regular time schedule, rather than after-school lessons (they were more physically capable of partaking in lessons earlier on in the day).

In contrast to the pilot study, fewer ideas were related to the students' families and more solutions were based on input from the teacher. Furthermore, most of the solutions were identified at school, when the students were working inside the VRLE. 60% of the ideas were based on needs obtained at school and 40% at home. Upgraded software, the increased skill of the teacher and self-confidence applied to the educational context and thus improved the students' school work. The VRLE also supported the students' idea generation, as it was structured around the innovation process. Working together inside the VRLE enabled the students to communicate ideas and to share needs and ideas online and their collaboration in the classroom and in the VRLE triggered and enhanced their idea generation.

The students used different digital pen tablets for drawing and the quality of these drawings were influenced by the time it took to draw them and the productivity of idea generation (6.9.4). The students' positive mood on the IE course further enhanced their idea generation; research has shown how good humour increases idea productivity (Runco, 2007; Cayirdaga & Acarb; 2010).

6.9.4 Question Four: How May the Students' Abilities to Draw Inside the VRLE be Improved?

Drawing exercises increased the students' skills and the quality of their drawings. The students undertook a simple drawing test in the first case study lessons, which showed that they had to be taught how to use the cad programme with digital pen tablets and how to draw three dimensionally. In the collaborative work inside the VRE, the students drew together; however, it was concluded that individual drawing was easier.

Skills and advanced drawing technology are two important issues concerning the students' ability to draw inside the VRLE and training students in the use of the appropriate media should be part of a longer IE course. Three different drawing tools and cad packages were tested in lesson two: a) the computer mouse, with the software *Paint*, b) digital pens (number 1), with the cad inside the VRLE and c) wireless digital *Pegasus* pens (number 2), which were ink pens with specific complementary software. The tests showed that the students were better at using conventional pencils than the digital pen tablets. However, they were used to the pencil and further training in the use of the digital tablets would probably have improved their drawing. The initial digital pen tablets (number 1) produced a better image quality than the *Pegasus* tablets, except in terms of accuracy. However, the *Pegasus* tablets were not part of the test (they were only used in the assessment) and thus it was difficult to compare concepts such as 3D skill, clarity and realism.

As in the earlier course, the students were able to learn to use the different tools, based on own experiences and without specific training. The students used the mouse more than the initial digital drawing tablets, as they were not flexible enough and slowed down their work. However, the students were most pleased with the digital pens, which used ink, as they could draw directly on paper and see what they were drawing (the image appeared on the computer screen at the same time). Their drawings got better during the course, as a result of the students' increased experience and improved drawing tablets (Pegasus). It was better for the students to use the digital ink pen, as this enabled them to see their drawings appear on paper, under the pen. With the non-ink digital pens, the students had to study the computer screen when drawing: this is closer to the natural way of drawing.

6.10 Feed Forward to Next Phase

One of the conclusions was the students' interest in the VRE element of the VRLE. This was one reason for looking closer at the context of computer supportive collaborative learning and how the VRE affects the development of students' ideation skills, within the pedagogical context. Further work needs to be done, in order to establish a greater understanding of the pedagogical context of using the VRE for IE. As the research context was the same and the research questions were similar, it was appropriate to use the same methodology.

Case study series two was based on the evidence from the pilot study and it was designed to develop a further understanding of the identified pedagogical issues.

From the data gained and the conclusions drawn, it was decided to design a third case study series, which would look more closely at five specific areas:

1. The teacher's role and preparation
2. Drawing
3. Idea generation within the VRE
4. Use of the VRE and collaboration
5. The school's attitude to the research and the value of the new context.

In addition to this, it was also considered necessary to examine the school's attitude to the research and the value of the new context. The headmaster and the teacher's colleagues both supported and encouraged the teacher and this may have affected the novelty of the research. It was also decided to make changes in the collection of data and it was decided that this would be done by considering a set of three related case studies, incorporating an action research element. The aim was to gain further experience and an understanding of the pedagogy of using the VRE within the VRLE for collaborative ideation, within an IE school context.

This case study series has highlighted many issues in need of further observation: the data from the pilot study revealed both pedagogical and practical issues that are worthy of further examination. As before, the author had to decide which areas of research identified in the pilot study to take forward to case study series two. However, it would have been too much work for the author to deal with all such areas of research. Thus, he had choose what he thought were the most relevant areas for case study series three, in the light of the earlier study, in order to contribute to answering the overall research question 'how does the use of the VRLE affect the teacher's pedagogy and the students' work in conventional Innovation Education in Iceland?' The author's decision was largely based on the overall discussions and conclusions in chapter six (see section 6.8).

6.10.1 Focal Points in the View of the Earlier Studies

The following paragraphs contrast the five areas with the earlier study and highlight these areas:

6.10.1.1 Teacher's Role and Preparation

The pilot study identified a conflict in roles, in terms of the teacher being both administrator and tutor. Part of this problem was related to the fact that the teacher was badly prepared and disorganised (see section 5.8.1). In order to improve the teacher's ability to fulfil his role, better preparation became part of the research plan and the teacher was asked to take full responsibility for the running of the lessons. This would give him better 'ownership' and he would have a close knowledge of how IE lessons operate.

The conflict in roles was not raised again, probably due to the fact that the teacher was gaining experience of using the VRLE. However, the teacher's limited preparation for lessons became an issue and he did not use the help page set up for him inside the VRLE. In case study three, the teacher was asked to prepare the lesson and to gain personal IE experience from using the VRLE, in order to improve his insight and understanding and, consequently, to assist the students.

In case study series two, the teacher was given further training and was asked to prepare the lessons. In this course, he will also be asked to test the computer hardware before the lessons. The relevant help pages for case study series three will be improved, particularly with regards to the use of the VRE. This will include further instructions, such as:

- How to upgrade the build for the VRE
- How to manage student groups inside the system
- How to use the VRE
- How to communicate with the students inside the VRE
- How to access and operate the VRE
- How to use the *Pegasus* digital pen tablets
- How to use the virtual whiteboards.

Small bugs in the software, identified in case study two, will be repaired, in order to prevent further technical problems. Furthermore, the teacher will be encouraged to spend time developing his own experience of using the VRE for IE, mirroring the work the students will be required to do. As in the earlier study, the teacher will be given full responsibility for organising and running the course and the observer will just focus on his observations: this will further improve the recording of interactions inside the classroom and the VRE. Attempts will be made to organise the lessons within the school's schedule, as it was identified that the students were more capable then than after-school.

The teacher's introduction in case study series two, before the course began, was important and will be further developed. It was observed in this case study that, while the students reported problems/solutions during brainstorming sessions, the reflection element was limited. Brainstorming sessions will be undertaken during lessons, both at the beginning and after. However, in accordance with the experience from this case study, the teacher will be asked to motivate the students and give them more time to reflect, both on needs and problems. This might improve the students' contributions and prepare them for collaboration inside the VRE. The brainstorming sessions will be incorporated within lesson plans, in order to ensure enough time for such brainstorming. However, the teacher will apply time pressures in the sessions and in lessons, as this was identified as an important element in getting the students focused.

Using the VRLE at home and before lessons began helped the students to become familiar with the VRLE. In future, the students will be asked to use the VRLE at home before the course begins and to play inside the VRE, in order to improve their skill and familiarity with the VRLE.

6.10.1.2 Drawing

In both the pilot study and case study series two, the students quickly learned to use the CAD programme inside the VRLE and the drawing tablets, even though they were not formally taught how to use the software or tablets, but their drawings were relatively inaccurate. However, in case study series three, these drawings will be further improved through the use of the new *Pegasus* pen tablets (see section 6.8.4).

The students found it difficult to use the VRE CAD and the reason for this was they misconstrued the element of collaboration and were drawing on each other's virtual whiteboard, distracting them. Further tests will be undertaken in the VRE, in order to observe the possibility of improving the method of using the virtual whiteboard, both individually and in a group. A pre-test will be carried out before the course, in order to assess the students' general drawing skills inside the VRE.

6.10.1.3 Idea Generation inside the VRE

The possibilities for using the VRE for collaborative idea generation work will be explored further. In both the pilot study and case study series two, the teacher requested that the students undertake group work in idea generation, inside the VRE (in lesson three). However, in both studies, this slowed down idea generation, as the students were collaboratively focusing on developing one solution. The collaborative work was also time-consuming, as the students tended to get distracted and strayed from their work.

To enable the collaborative work, the teacher will give the students detailed instructions and will instruct that they work in two groups of four. The students will not be allowed to spend time playing together, except prior to lessons, as this distracted them from the ideation work in case study two. The teacher will ask them to develop a solution together, based on one of their needs identified at home. The group work inside the VRE may also be supported by training the students to make common decisions during brainstorming sessions, by directing their discussion. The students will have to be able to agree on this as, in case study series two, the teacher had to suggest a solution and this was not in accordance with the pedagogical foundation of IE.

6.10.1.4 Use of the VRE and Collaboration

In both the pilot study and case study series two, the students found it difficult to collaborate inside the VRE, especially when drawing together on the virtual whiteboard and interacting as avatars in the virtual world. The possibilities of such collaboration will be examined further, in order to highlight the difficulties and observe the possibilities of improving such collaboration. Specific training in the use of the avatars will be conducted, in an attempt to improve the students' performance, and data will be collected, in the form of screen captured videos. Furthermore, a normal video will be recorded in the classroom, when the students are working together inside the VRE. Interviews will be conducted with the students and the teacher, in order to uncover how students communicate together inside of the VRE. How do they manage to generate solutions as a group? How do they manage to draw together inside the VRE?

As with earlier studies, the teacher will ask students, in groups of four, to develop solutions together inside the VRE. The students will be asked to meet inside the VRE at home, before lessons, in order to improve their skills.

6.10.1.5 The School's Attitude to the Research and the Value of the New Context

The school's interest and positive attitude may have enhanced the novelty factor and put pressure on the teacher, in improving his teaching. In case study series three, this area will be examined through observation and interviews with the head teacher and class teacher.

6.10.2 Changes in the Data Collection Methods

In the pilot study and case study series two, both the author and the teacher were present. In study three, the author will not contribute to the teaching; rather, he will focus on observations and the subsequent gathering of data. The author will use two computers to collect screen captured video data of the students working inside the VRE, in order to observe how they manage to design together and draw on the virtual whiteboard.

The author will focus on the students' idea generation inside the VRE. Video recordings will be made of the group in the classroom and data will be collected, regarding the students' collaboration and communication when they use the VRLE. A broader lens will be used for the normal video recordings inside the classroom, so that a larger area of the classroom is viewed: this should improve the capture of communication between the students and the teacher.

The teacher will be present in the interviews, which will be conducted after each lesson. He was present in the pilot study interviews, but did not attend interviews in case study series two. It was noted that the students were less open and less communicative in his absence.

Chapter 7. Case Study Series Three

7.0 Chapter Summary

The chapter reports the third case study series (CSS3). The IE course content and preparation is outlined, as are the overall aims, objectives and research questions. Furthermore, the specific data collection methods are discussed, in addition to the categories generated and the conclusions drawn. Such conclusions are used to shape the final stage of the gathering of data (see chapter 8.0).

7.1 Introduction

The CSS3 was undertaken in May 2004 and evidence from the earlier studies (see chapters 4.0, 5.0 & 6.0) highlighted five specific areas that required closer investigation:

a. The teacher's role and preparation
b. Drawing, using the VRE CAD
c. More reflective brainstorming sessions
d. Co-operative idea generation in the VRE
e. The use of the VRE to support collaboration, in order to enable individual idea generation inside the MLE.

The series aimed to explore the issues concerning the teacher's management of a conventional innovation class that incorporated the use of the VRE. The teacher took full responsibility for running the sessions, as he was now better prepared and his experience of using the VRLE had grown (see sections 7.8.1 and 7.8.5). Developments included brainstorming sessions at the start and the end of lessons, which increased students' awareness of identifying problem-needs at home. Students were given time for reflection, in order to prepare for collaborative idea generation within the VRE. Time pressures were applied, in order to keep the students focused. The students' ability to use digital pen tablets in idea generation was also examined further and a pre-test was conducted, in order to ascertain the students' general drawing skills within the VRE. The Pegasus pen tablet was tested further and the VRE CAD whiteboards were used, both inside the VRE and the MLE (see section 7.8.3).

CSS3 examined the students' abilities to work co-operatively on solutions inside the VRE; it also examined the use of the VRE in enabling collaboration supporting individual idea generation inside the MLE. The innovation process undertaken in the MLE and VRE was subsequently explored (see section 7.8.5). Initially, the plan was to observe a typical class over a number of weeks; however, the author's professional commitments meant that this was not possible within the available timeframe. The course, featuring four students, was run in the first few days of the summer holiday, over three lessons. While this was a small sample, the research was building on the previous case study work and, to improve reliability, the evidence base was triangulated through the use of nine data collection methods.

7.2 Preparation for Case Study Series Three

A new course plan (see 7.5) was designed, based on the conclusions from case study series two, with the parents, the teacher and the headmaster giving their permission to use the data collected for research purposes (see sections A7.0.1-A7.0.3). The teacher sent a letter to parents before the course, outlining the project and the course plan and requesting the support of parents.

Four girls and four boys from class 7 volunteered for the research: all had attended one of the earlier courses. The teacher set up email accounts for these students and registered them to the VRLE; he also took digital photographs, which the students used to personalise their VRLE workshops. The teacher was the same as in the earlier studies and was familiar with IE and VRLE. Prior to this course, he had also received further training in the use of the VRE for IE work. The computer facilities in the classroom were tested before the activity started; this was based on evidence discovered in series two, where the teacher had stated that he needed further training, in order to be better prepared (see section 6.8.1).

7.3 Setting up the Classroom

The author split the classroom: one half contained the VRLE computers, while the other half was used for instruction and brainstorming sessions.

7.4 Research Aims, Objectives and Questions

The aim of case study series three was to develop a further understanding of the pedagogical issues identified in CSS2.

The objectives were:

a) To observe the effectiveness of the teacher's preparation and teaching
b) To observe the innovation process (including brainstorming), with regards to collaborative idea generation inside the MLE and co-operative idea generation inside the VRE (see definition in section 2.13.2)
c) To gather data on the use of more advanced drawing technologies
d) To develop further experience of case study methodology and to review the methods employed

The research questions for case study three were:

1. How can the VRE be used for idea generation inside the VRLE?
2. How does collaboration relate to teaching and learning within lessons?
3. How do communications during the lesson support students' work?
4. What is the value of using the VRLE for IE, within the context of school?

7.5 The IE Course Plan and Lesson Synopses

The course plan (see section A7.0.4) was based on a similar structure as used in case study two. Prior to the course, a 90 minute IE and VRLE introduction was conducted by the teacher and the subsequent course was based on two 90-minute lessons/case studies. These were conducted in the holidays, during what would have been normal school hours (the dates were 03.05.04 and 12.05.04).

7.5.1 Introductory Lesson

The teacher introduced the students to the IE course and gave them letters to give to their parents, which outlined the course content. He introduced the digital pen tablets and the VRLE workshops and the students gained some experience of these. The students were then registered to the VRLE database and given a copy of *The Inventors Notebook;* they were also briefed on the identification of needs and problems for the next lesson.

7.5.2 Lesson One

The teacher recorded the needs the students had identified at home on the blackboard; he then asked the students to work together in a group. Firstly, he trained the students how to use the VRE CAD programme and conducted some drawing tests: the tests aimed to gain an idea of the students' capabilities and provide them with experience in the use of both the VRE and the CAD programme. The students subsequently had to choose one need from the blackboard, brainstorm, with regards to the need, and cooperatively work out a solution inside the VRE. One student was chosen to direct the design work, with the teacher selecting a student who he thought was most likely to be able to manage the task. Finally, the students saved their drawing to their database, with a description. Before the students went home, the teacher informed them of the next lesson and briefed them on using the inventor's notebook at home.

7.5.3 Lesson Two

This lesson began with a short introduction on the intended activity. All students had brought their INs with them, but none had actually done the homework (possibly due to it being the holidays). Nevertheless, the teacher wrote up any needs and problems the students put forward and this was followed by a short brainstorming session. The students then worked individually within the VRLE, registering new needs to their workshop. Using the CAD programme, they drew solutions inside the VRE and saved them to the VRLE.

7.6 The Measuring Instruments

A range of data instruments (see section 3.9) were selected, in order to enable effective triangulation and improve reliability. In terms of analysing the data, the qualitative and inductive methodology developed by Glaser and Strauss (1967) was used. The specific instruments used are listed against the research questions in table 7.1 below.

Section	Raw data	Data Sources	Q 1	Q 2	Q 3	Q4
A7.7.1	A7.3.3 – A7.3.4	Interviews with the teacher	x	x	x	x
A7.7.2	A7.3.1 – A7.3.2	Interviews with the group of students	x	x	x	x
A7.7.3	A7.3.5 – A7.3.6	The teacher's logbook	x	x	x	x
A7.7.3	A7.3.7 – A7.3.8	The author's logbook	x	x	x	x
A7.7.4	A7.3.9	Data from the VRE	x	x	x	
A7.7.5	A7.3.10	Students' drawings from tests conducted in the VRE.	x	x	x	
A7.7.6	A7.3.11	Video recordings in the classroom from lessons two	x	x	x	
A7.7.7	A7.3.13	Interview with the headmaster				x
A7.7.8	A7.3.12	Screen captured videos	x	x	x	

Table 7.1: Data collection methods used in the case study.

7.6.1 Interviews with the Teacher

Two interviews were held (one after each lesson) and the author used a semi-structured interview schedule. The teacher was open to discussion and was constructively critical.

7.6.2 Interviews with the Group of Students

Interviews with the group of students were conducted after each lesson and occurred in the teacher's workshop. The teacher was present and contributed to the interviews (unlike in case study two). The students were relaxed, but not very communicative. In these interviews, the author adhered to a semi-structured schedule and used a digital recorder.

7.6.3 The Teacher's and the Author's Logbooks

Logbooks were written up after each lesson, when occurrences were fresh in the minds of both the teacher and the author. The logbooks were a combination of observations and reflections and were based on the following structure:

- Use of the VRE and the MLE
- Students' collaboration
- Students' motivation and condition
- Teaching methods
- Preparation
- IE and idea generation
- Other issues.

7.6.4 Data from the VRLE

The author had administrator rights, in terms of the VRLE, and was thus able to access student work inside its database.

7.6.5 Drawing Tests inside the VRE

The data from the drawing tests was collected with Camtasia 3.0, as a screen captured video. Snapshots of the drawings were taken and analysed and the use of the CAD programme inside the VRE was identified as an important aspect of the students' ability to work together. Furthermore, it had an impact on both the time it took to generate solutions and the quality of the work; this is the reason why the drawing tests were conducted in lesson one. The aim was to examine the students' ability to draw with the initial digital pen tablets inside the VRE CAD programme, using the virtual whiteboard. Also, the tests were appropriate training for collaborative work inside the VRE, as the students used the virtual whiteboards together.

The tests were based on three stages, as below. The students were:

a. trained how to use the VRE CAD programme, by drawing forms
b. asked to draw illustrative drawings and
c. asked to design various bottle openers individually, but on the same virtual whiteboard inside the VRE.

7.6.6 Video Recordings in the Classroom

During the second lesson, the author conducted video recordings inside the classroom. The students were working on their ideas within the MLE, using the CAD inside the VRE at the same time. This data was collected in order to enable a greater understanding of collaboration within the classroom.

The author used a digital video camera with a larger angle than before, in order to cover the required area. Unfortunately, the resolution of the video was low and it was sometimes difficult to grasp what was being said. However, the quality was sufficient enough to enable the author to detect sentences and make meaning of conversations.

7.6.7 An Interview with the Headmaster

The interview was conducted in the headmaster's office and the aim of the interview was to examine the headmaster's background, school policies and any ideas the headmaster had, in terms of using IE within school. In this interview, the author employed a semi-structured interview schedule.

7.6.8 Screen Captured Videos

A screen captured video was formulated using *Camtasia 3.0,* focusing on the collaborative work inside the VRE. There was no sound, but text and graphics were highlighted. The fact there was no sound was not an issue, as the students did not discuss their work inside the VRE.

7.7 Data Collection and Analysis (A7.7)

The data collection methods employed for case study series two are shown in table 7.1 above and the process of analysis was outlined in chapter 3.0. The summaries of findings are in appendices in section A7.7 and the categories developed from the summaries are described and discussed below (see method in section 3.11.2).

7.8 Established Categories, Discussion and Conclusions

The main pedagogical categories that appeared in the data were:

1. Teacher's role and teaching handling;
2. Motivation;
3. Drawing;
4. Ideation and innovation education;
5. Use of the VRLE;
6. Collaboration;
7. Value;
8. Homework;
9. Computer literacy.

7.8.1 Teacher's Role and Handling of Teaching

Discussion

During the course, the teacher did not mention any technical difficulties or problems in managing the software or the hardware: he had probably improved his skills and knowledge enough to manage both. Nevertheless, as in case study series two, lesson preparation was an issue for him; he felt badly prepared, both for the course and the lessons. Furthermore, he was not confident with the plan he had set up for the course; however, he had become skilled in using the VRLE and was familiar with conducting an IE lesson. He had also prepared for lessons and his negativity was most likely due to his general mindset as a teacher and his lack of confidence.

In terms of the IE course, the teacher's role was certainly different from his normal teaching role; it was possibly more difficult and complex. However, the teacher's workload reduced during the course, as school had finished. Thus, the teacher had time to apply the advice already given and prepare for the course. It is likely that he was unable to estimate the quality of his teaching, as the VRLE and IE were relatively new to him. The teacher's lack of confidence might also have been related to the presence of the author, as he was his former student (the author was a teacher trainer and a specialist in IE). His lessons were also part of the data and perhaps this made him nervous. Nevertheless, the teacher was happy with the results from both lessons.

The students had declined the teacher's offer of formal training in the use of the CAD programme; however, the informal training he gave them, in the form of the drawing tests, had a positive influence on their drawings. Thus, training in the use of the CAD programme and the digital pens may be identified as an important part of the IE course plan. The teacher employed different teaching methods, such as direct and written instruction, and, as in the earlier courses, he supported the students' work with discussions and advice. However, when the students began to work inside the VRLE, the teacher frequently left the students during the lesson. At his follow-up interview in chapter 9, the teacher indicated that he used this deliberate technique in order to give the students space and increase their responsibility. Subsequently, symbiosis between the students also appeared to increase. As in the earlier courses, this showed him to be more a facilitator than an instructor.

The teacher's method of facilitation might have been appropriate, as a tutorial was included in the VRLE and it was desirable for the students to access this software-based support. Furthermore, the VRLE was based on the conventional framework for idea generation (see section 1.6), with the VRLE most likely guiding the students. This was probably why the headmaster had mentioned using the VRLE in IE: it enabled the students to become autonomous learners.

Conclusion

The teacher improved his skills and knowledge, in terms of managing the VRLE as an administrator, through the teaching of earlier courses of IE. However, it was difficult for the teacher to evaluate his teaching, as there was no tradition of using a VRLE in IE. Furthermore, his mindset was probably due, in part, to a lack of confidence.

The teacher used different teaching methods, including direct instruction, written instruction and short brainstorming sessions. His introduction and the informal training of students (during the drawing tests) had a positive influence on their drawing skills.

The teacher's method of teaching reflected the school's policy in supporting autonomous learning and enabling individual-based education. He thus attempted to increase the students' self-reliance by teaching them fundamental skills and allowing them to learn from their own experiences. Moreover, the teacher's tendency towards the role of facilitator was probably due to his method of teaching: he supported each student by examining their work and assisting them, although they did not always ask for his help**.** The teacher's approach of leaving the classroom occasionally encouraged the students to collaborate and thus become more self-reliant.

Allowing students to play in the VRE may distract them from their work; however, it may be important in developing their collaboration and team spirit (Rieber, 2001; O'Quin & Derks, 1997).

7.8.2 Motivation

Discussion

Running the research project after school had finished probably reduced the students' motivation and performance, even though they had volunteered to participate in the project. The novelty of taking part in an IE course might also have diminished for these students; almost certainly, the students' participation was more dependent on their relationship with the teacher than their interest in the course. The students were no longer as interested in the Young Inventors Competition, as the teacher expected. The author suggested the giving of awards, in an attempt to motivate the students into finishing the course, and, subsequently, the teacher invited them to make a mobile sensor, once they had finished their tasks. In practice, once they were in school, they performed well and the reward was perhaps not needed. The teacher was concerned, as he felt the group was not fully committed; however, the video recordings showed the students relaxed and working. As in the second course, this was probably due to their ability to use the VRE for playing. The students were probably not in a hurry to begin idea generation in the first lesson, but they did become more focused in lesson two.

Students' text messages inside the VRE demonstrated a light hearted, collaborative spirit, including comments and emotional expressions: this indicated that the students were motivated and happy. Perhaps for them, work inside the VRE was equivalent to play. However, compared to the earlier course, they became more focused and a possible reason for this may have been that they were working collaboratively. The VRE was obviously interesting for them and enabled them to socialise: this may indicate possibilities in using the VRE for idea generation, through game-based learning.

Conclusion

Running the research project in the summer holidays caused issues, with regards to the fact that students demonstrated little motivation to participate. Indeed, the participation of students was probably more dependent on their relationship with the teacher, rather than their interest in the course. Running the course when students were less motivated affected the teacher's confidence.

The students were relaxed, happy and active in lessons. However, their interest in the *Young Inventors Competition* had diminished. The novelty factor associated with using the VRLE for IE had also waned.

The students were focused when working together inside the VRE. Thus, using the VRE for idea generation, through game-based learning, may be useful in IE. The students enjoyed playing inside the VRE and this may have helped to facilitate their motivation and collaboration. VRE text messages were used by students to express their light-hearted spirit and thus enabled collaboration.

7.8.3 Drawing

Discussion

In the earlier courses, the CAD programme inside the VRLE was only accessible from the VRE and thus the students found it difficult to use. The reason for this appeared to be that they were drawing together on one virtual whiteboard and were disturbing each other. In case study three, the CAD was accessible from both the VRE and the MLE and so the students could draw individually, undisturbed. Nevertheless, the students were asked to use the CAD programme inside the VRE, in order to enable collaboration during their work in the MLE. It would probably have been easier for them to use the CAD programme directly from the MLE, as they would not have been dependant on the use of the avatars, which made their work more complicated. However, the influence of the avatar communication would then have gone unnoticed.

Students had no prior experience of using CAD, other than its use in the earlier courses (see section 7.2). However, unlike in the earlier courses, they found it easy to use the CAD programme, as they were familiar with the VRLE and the CAD inside the VRE. During the course, however, the students had to recover and improve their skills in using the CAD programme, through their own experiences. Subsequently, they became more skilled in using the virtual whiteboard. The students began to draw quickly, but the teacher noted their limited skills in using the VRE CAD, which was a drawback in their idea generation work. Thus, the students were informally trained in this by the teacher, through the drawing tests (see section 3.9.6). Furthermore, the teacher demonstrated how they could draw their solutions and he offered to teach the students how to use the CAD, but they told him it was not necessary. It is likely, however, that this would have improved their work, both in terms of quality and productivity.

The students were probably overconfident, as they did not listen to the teacher's instructions pertaining to the use of the VRE CAD. They also stated that they knew how to use the digital pens and the VRE CAD. Like the students in the earlier study, they used the VRE CAD programme in conjunction with the mouse, as the batteries in the Pegasus pens were flat and the initial digital pens were not flexible enough. However, these technical problems should have been prevented by the teacher, as he should have been familiar with these problems from the earlier study.

The teacher believed that teaching the students to use CAD was important and would yield better results; for example, he stated that saving drawings in the right format and uploading them to the VRLE should be taught at the beginning of each course. Nevertheless, the students appeared to be better at CAD than in the earlier courses: they had probably improved their skills and knowledge through experience. It was also noted that their skill had improved during the drawing tests, probably because they were, effectively, a form of informal training. This was confirmed by the teacher, who estimated the drawings as relatively good for this age range, and their solutions appeared to be more advanced than in earlier courses. Drawings were more accurate than before and students were able to design individually inside the VRE, with regards to the test.

It was noted that, when the students were working together inside the VRE, they were interested in the aesthetics of their drawing; they used colourful flowers and green grass to decorate their work. It was also noted that being able to decorate their drawings made the collaborative work inside the VRE more interesting for students: this may indicate the importance of aesthetics, as part of the course task, in supporting collaboration. Female student three was the most active in decorating the solution and this possibly indicates a difference between the sexes; however, the numbers are too low for generalisation.

The teacher felt that the students were unable to collaborate easily, when drawing together inside the VRE. He probably came to this conclusion as they were not speaking together outside of the computer, during their work. However, it was identified they were able to collaborate by mainly communicating through their drawings and text messages. The students were able to draw together, but found it difficult; nevertheless, they managed to draw a basic solution. This was not detailed and was limited by their basic drawing skills. The students' solution was in ten different parts, which were drawn in a logical order: these were mostly drawn individually, but within the context of collaboration. The exercise was based on the students' initiative and was not planned by the teacher. This information may be useful in formulating a framework to enable students to collaborate within the VRE.

Conclusion

When students were working inside the MLE, the use of the CAD programme inside the VRE enabled communication. They were also able to use the CAD programme inside the VRE for individual designing and individual drawing appeared easier than collaborative drawing. Students drew better than in previous case studies and they found it easier to use the VRE CAD, due to their past experiences. They also improved their skills throughout the course, as a result of their experiences. Drawing tests also increased the students' skills and the quality of their drawings.

Students based their collaborative drawings on their communication through drawings and text messages, rather than verbal communication in the real world/classroom. They collaborated, in a logical order, on the virtual whiteboard. Their interest in the aesthetics (decorative aspect) of their drawings improved their collaboration. The students' drawings had limited accuracy, as one would expect at their age, but did demonstrate basic solutions. The case study also highlighted their limited skills in using a computer mouse.

The teacher noted how the students' limited drawing skills were a problem, in terms of their idea generation inside the MLE. However, expectations for 12 year olds need to be realistic. Extensive evidence has demonstrated the need to train students on the IE course in drawing and in the use of the CAD programme. Formal teaching may have improved the quality of the students' work and may have made them more productive.

It is important the teacher is familiar with drawings and is able to use digital output devices. They should be skilled enough to prevent any technical problems pertaining to the use of the Pegasus pen tablets.

7.8.4 Using the VRLE

Discussion

The students used the VRLE without difficulty, as they were familiar with it from earlier courses. The VRLE was also designed to support the teacher's work during the course, as it was based on the IE process. The VRLE had been improved, as a result of feedback from the earlier courses. However, both the students and the teacher had concerns about its value and suggested other methods of enabling their work, such as using mobile technology and blogs. Mobile phones could be used for sending any PNs identified at home directly to the VRLE, in the form of blogs.

The students thought the VRLE was not a 'clever' system and stated that it had not improved their work. In contrast with the students' and teachers' concerns, the author identified the activities inside the VRE as supportive of individual-based idea generation: this was probably due to the multi-modal possibilities for communication and collaboration within the VRLE. However, as in the earlier courses, the students were less productive when they used the VRE CAD programme for their work inside the MLE (see table 6.5 in section A6.7.5.1). The students believed they could master the VRE through experience and it should be remembered that they had prior experience, via the previous course; however, they subsequently did not access it again until case study series 3.

The students were probably less productive because they had used the VRE for playing together. Their collaborative work was time-consuming and thus fewer ideas were generated than when they worked individually. However, there is the argument that this play could have value, in terms of developing experience and collaboration skills; it enabled the students to relax from their work and communicate any ideas. It probably also made the students more self-reliant and quicker, in terms of using the VRLE.

Conclusion

The VRLE supported the students' and teacher's work, as it was structured around the IE process. Students used it without difficulty, as they were familiar with it from earlier courses. Playing inside the VRE also made the students increasingly skilled in using the VRLE, in addition to enabling them to become more self-reliant; thus, they did not consider that further training would improve their work inside the VRLE. The VRLE also operated better, as the software had been upgraded. Students found it useful to be able to access the VRLE from various locations.

The students and the teacher considered that the blog would be easier and 'cleverer' to use than mobile phones, in terms of sending images to the VRLE. The teacher also felt that a blog would be more useful than digital drawing. The students, however, found it easier to use the IN, rather than the VRLE.

Activity inside the VRE supported individual-based idea generation, as a result of the students' familiarity with it from earlier experiences. The more skilled students became in using the VRLE, the more it supported their idea generation.

Playing inside the VRE allowed the students to relax from their work and communicate their ideas. However, using the VRE for co-operative idea generation decreased students' productivity, as it was more complex, time consuming and enabled play, which was distracting.

7.8.5 Ideation and Innovation Education

Discussion

All of the students in CSS3 were familiar with the basic innovation process and the use of the VRLE; they were also more self-reliant and independent. However, probably as a result of the summer vacation, they had not done any homework. They did, however, sometimes refer to the needs and problems in their INs, which they had identified at home during the earlier course, as the basis for their work. This supported the students' work, as the brainstorming sessions in the classroom were not as productive as they might have been, due to the fact that the students had not brought ideas in from home.

The students' idea generation during their co-operative work in lesson one was dependant on their drawing skills, their ability to co-operate and their initiative. Individual ability to contribute to the work was, therefore, varied. Male student one had the strongest initiative, as he started the drawing and was mostly overseeing the technical part of the work. There were also differences between the sexes: the male students were more active in the technical part of the design, while the female students were more active in the aesthetic (decorative) element of the drawings. However, the number of students is too low to make a general judgement.

It was noted, as in case study series two, that student collaboration probably triggered idea generation. The students were happy working inside the VRE and were often light hearted: this may have improved their idea generation, as research has shown that humour increases the amount of generated ideas (Runco, 2007; Cayirdag & Acar, 2010). The students' tendency to decorate and colour their collaborative drawing inside the VRE also positively affected their ideation, as it increased their humour.

More ideas were generated inside the MLE than in the VRE; the students generated just one idea during their collaboration inside the VRE. Probably as a result of this, the teacher considered group ideation a difficult task; however, the students design together with ease. The students' solution was formulated from many different drawings by different students.

Conclusion

Students had not used the innovation process, their INs or thought about IE since they had taken part in one of the earlier courses. However, their familiarity with the innovation process was beneficial for idea generation. Thus, they were more skilled, self-reliant and independent than when they were beginners.

During their collaborative work in lesson one, the students' generation of ideas was dependant on both their drawing skills and their ability to collaborate. As before, the brainstorming sessions at the beginning of lessons were useful in triggering idea generation and helped students in using the VRLE. Occasionally, the students retrieved needs and problems from their INs when they lacked ideas in school and the teacher thus considered it important that students carry their INs with them, in order to enhance their idea generation. Subsequently, students established most of their ideas within school. Further ideas were generated inside the MLE, rather than in the VRE. Nevertheless, student collaboration inside the VRE also appeared to support idea generation (the students' collaborative work was based on a problem identified at home).

Students stated that it was easy to design together. They quickly came up with a basic drawing inside the VRE and this was most likely as a result of their familiarity with the VRE and the CAD programme, which they had experienced in earlier courses. Male students were more technical, while the female students were more interested in the aesthetics of the drawing (however, the small sample restricts the reliability of this assertion). The students' tendency to decorate and colour their joint drawing probably positively affected their ideation, as it made them happier.

The students' upbeat mood throughout the IE course and their collaboration in the classroom enhanced their idea generation. However, they doubted this course had increased their understanding of design and inventions (see section A7.7.2).

7.8.6 Collaboration

Discussion

The students worked independently, but collaborated through different modes of communication. In the classroom, they were able to send text messages, show their drawings to each other, use avatar gestures and speak through the headset or face-to-face. When working inside the VRE, their collaboration was the basis for idea generation: the students brainstormed needs and ideas, both inside the classroom and the VRLE, as two parallel worlds. Their work was supported by computer-mediated collaboration

According to the interview with the headmaster, students were used to working closely in small groups and undergoing personal communication with teachers. This may explain how the students had the skills to work together when the teacher left the class. Unlike case study series two, the teacher knew that the students would benefit from discussing both needs and solutions before working inside the VRLE; thus, he gave them the flexibility to make mutual decisions, with regards to their work. Furthermore, playing together inside the VRE, at the beginning of lessons and throughout the course of their work, helped the students to establish any collaboration; it also promoted communication and illustrates the fact that the total attention of students, in terms of a task, is very difficult to achieve in any lesson. In this case, off-task communication occurred within the VRLE and will have helped, to some extent, to develop the students' ability to communicate and share ideas in this 'alternate reality'.

The teacher reported that the students did not appear to be operating as a team in the VRE. Rather, he stated that the students were working together randomly, in an individual manner. However, the teacher may not have been in a good position to recognise teamwork, as there was no apparent face-to-face communication within the classroom. The data highlighted that the students were indeed collaborating. The teacher believed that structuring the students' work would make them more skilled in using the VRE for idea generation; however, the author noticed that collaborative work had taken place, as stated in his diary, which noted: 'the collaboration inside the VRE was successful, as it appeared to be relatively easy for the students to work out a solution together (see section A7.7.3.1)'. The low number of students probably made collaboration easier, as in case study two, which indicated that small numbers of participating students enabled collaboration. The smaller the group, the better the students worked together.

The students usually worked individually inside the VRE. The appointed group leader did not guide the work and none of the students were dominant: their collaboration was mostly based on communication through drawings and text messages. The students adopted different roles during the collaborative work inside the VRE in lesson one: male student one (not the appointed leader) appeared to be leading the work and spent the most time working. He worked most frequently with male student two, but sent fewer text messages than the other students. Female student four was least active, but most communicative; however, her text messages were usually not directly related to the work. The students often drew different parts individually, but worked relatively little together. They tended to collaborate in pairs and had difficulties in groups of three or four.

In lesson two, the students worked as individuals inside the MLE, but also used the VRE to communicate as avatars: this was done to enable collaboration. The VRE connected the students together during the lesson and enabled them to hear each other speaking. When students discussed their ideas, they asked for opinions and gave comments. It was noted the students supported each other during discussions in the classroom and inside the VRLE: they discussed daily matters and their own ideas and helped each other in this. In order to receive comments, the students frequently showed each other their work on the computer screen.

Conclusion

Students were communicative and collaborated well together .They communicated needs and ideas, viewing the classroom and the VRLE as parallel worlds. Their collaboration appeared to enhance idea generation, as it helped them to develop their own ideas, and the multimodal possibilities of communication within the VRLE (text messages, avatar gestures, drawing, talking face-to-face and through the headset) also enriched their collaboration. In lesson two, the students worked as individuals inside the MLE but were supported through communication, both inside the VRE and face-to-face. During brainstorming sessions, the teacher gave the students enough time and flexibility to agree on a mutual task.

Students were used to both working independently and in groups with others and using the VRE appeared to enrich both communication and collaboration. Students helped each other during their work by discussing their ideas: in order to receive comments, students frequently showed each other their work on the computer screen. They collaborated more in pairs than in threes and had difficulties working as a group of four. They adopted different roles during their work and leadership was informally adopted.

Students did not discuss multiple possibilities for solving their common needs inside the VRE, either before or during their work. They usually drew the various parts of the VRE solution individually.

Game-based learning might be an effective methodology, in terms of IE (Rieber, 2001; O'Quin & Derks, 1997), as students playing together inside the VRE at the beginning of lessons facilitated collaboration.

7.8.7 Benefits of IE for Education and Implementing IE in Schools

Discussion

The school had tried to follow theories of constructivism and the headmaster saw IE as a possible method of fulfilling this aim; thus, he wanted the teacher to continue with IE after the research (see interview with the headmaster in section A7.7.7). The teacher believed it better to run IE courses relating to other subjects, rather than as a specific subject, as this would give students the incentive to use IE in their daily lives. However, he believed that the adoption of IE in schools would depend on the teacher and the interest of the education authority.

The teacher thought that the VRLE would not improve the students' ideation skills, but he did believe that it would be useful in teaching idea generation. Nevertheless, the students saw little use for IE, in terms of solving problems in their daily lives. They were not sure if IE would make their lives easier and using the IN had not changed their way of thinking. Obviously, the students saw the IE course as merely another school project.

The headmaster believed that the school's community understood the benefits of IE, as the school had established associations with industry. The teacher believed that the relationship between IE and the economy would help the students to become more innovative in their daily lives, while the teacher and the headmaster also saw IE as a way of supporting students with learning problems, as it would build up their self-confidence. The headmaster also saw the use of the VRLE for IE as useful in increasing computer literacy and improving ICT skills for individually-based studies. The school policy enabled students to plan their studies by offering them many optional courses and work in small groups.

Conclusion

The headmaster and the teacher envisaged many possibilities, in terms of the use of IE within general education. For example, the headmaster saw IE as a way of following constructivist theories and supporting students with learning problems, by building up their self-confidence. He was interested in adopting the VRLE to increase computer literacy and ICT skills; however, he doubted the value of the use of VRE in education.

The teacher believed that the VRLE would not improve ideation skills, but did state that it would be useful in teaching idea generation. He considered it important to use the VRLE for other subjects, in order to help students to use IE in their daily lives. However, he doubted the value of IE as a future subject within school. The teacher considered that IE would increase the students' understanding of the economy and would help them to become more innovative in their daily lives. He believed that the adoption of IE in schools would be dependent on the interest and goodwill of educational authorities.

Students believed that the IE course would possibly improve their idea generation skills. However, they saw little use for IE, in terms of solving their daily problems.

7.8.8 Homework

Discussion

Students had not done any homework during the course and therefore had not identified any needs or problems at home. This was possibly because they were on summer vacation and were distracted by the excitement of the start of their holiday. Also, they had not discussed IE with their parents after they finished the last course. For parents, the IE course was just the same as any other school activity; thus, they were probably not supporting the students in further IE work, after their last course.

Conclusion

Students did not identify any needs or problems during the course and were not interested in spending time on schoolwork during their summer vacation. This is probably why they did not discuss their coursework, needs or ideas with their parents. Furthermore, parents did not support the students outside the school context.

7.8.9 Computer Literacy

Discussion

The headmaster saw possibilities in using IE and the VRLE to increase the computer literacy of students and teachers. However, most of his teachers lacked the skills to employ computers in their work; thus, only a few were able to teach IE using the VRLE.

The headmaster stated that the teaching of ICT was not very important, as the students were able to learn from their own experiences. He underlined the importance of students using computers as a tool, noting that many students in class seven had a good standard of ICT, due to the fact that 'many fathers' (sic) of these students had trained their children; however, one of the fathers had stated that computers were antisocial and physically dangerous (see section A7.7.7). The headmaster's beliefs probably mirror the novelty of using ICT in education on a daily basis and his interest in making progress in his school. Nevertheless, it also highlighted ignorance of IE within general education, as he did not speak about ideation; rather, he frequently mentioned the relationship between IE, the economy and ICT.

Conclusion

The headmaster saw IE and the VRLE as a means of progression within school. However, no teacher, other than the IE teacher, was using MLEs..The headmaster saw IE and the VRLE as a way of increasing students' and teachers' computer literacy and ICT skills: he stated that ICT studies were not as important, as students were able to learn from their own experiences.

The standard of ICT was good in class seven, as many fathers (sic) supported their children in this. Students generally used the Internet for collating information, but using it for IE presented further possibilities.

7.9 Answering the Research Questions

The research questions for CSS3 are revisited and subsequently answered in the following sections:

1. How can the VRE be used for idea generation inside the VRLE?
2. How does collaboration relate to teaching and learning within these lessons?

3. How do communications during the lesson support the students' work?
4. What is the value of using the VRLE for IE, within the school context?

Section	Raw data	Data Sources	Q 1	Q 2	Q 3	Q4
A7.7.1	A7.3.3 – A7.3.4	Interviews with the teacher	x	x	x	x
A7.7.2	A7.3.1 – A7.3.2	Interviews with the group of students	x	x	x	x
A7.7.3	A7.3.5 – A7.3.6	The teacher's logbook	x	x	x	x
A7.7.3	A7.3.7 – A7.3.8	The author's logbook	x	x	x	x
A7.7.4	A7.3.9	Data from the VRE	x	x	x	
A7.7.5	A7.3.10	Students' drawings from the VRE tests	x	x	x	
A7.7.6	A7.3.11	Video recordings in the classroom in lessons two	x	x	x	
A7.7.7	A7.3.13	Interview with the headmaster				x
A7.7.8	A7.3.12	Screen captured videos	x	x	x	

Table 7.2: Repeated to remind the reader of how the data answered the research questions and enabled triangulation.

7.9.1 Question One: How can the VRE be used for Idea Generation inside the VRLE?

Drawing inside the VRE was identified as beneficial for idea generation; however, training was required in this, in order to make the students self-reliant and independent. In lesson one, the students received training through drawing tests, prior to using the VRE for co-operative work. Furthermore, they gained greater experience by informally playing inside the VRE at the beginning of the lesson. Consequently, in the second lesson they were more experienced and used the VRE to support their work inside the MLE, via communication. However, more ideas were generated inside the MLE than in the VRE.

As in case study series two, collaboration inside the VRE appeared to support idea generation. Playing inside the VRE also gave students a rest from their work. Again, as in case study series two, the students were happy during their work inside the VRE and often displayed a light-hearted attitude. This may have positively affected their idea generation, as research has shown that humour increases the amount of ideas generated (Runco, 2007; Cayirdag & Acar; 2010; Isen et al.,1987).

During the research, the students used the VRE for idea generation, in various ways:

a. For co-operative work, using the same virtual whiteboard in the VRE;
b. For individual work, using separate virtual whiteboards in the VRE;
c. For enabling drawing and multimodal communication, during work inside the MLE.

7.9.1.1 Co-operative Work

In both the pilot study and case study series two, the students found it difficult to co-operate inside the VRE, specifically when drawing together on the virtual whiteboard and interacting as avatars in the virtual world. However, the students had stated that, in case study series two, they could possibly learn to work together inside the VRE. In CSS3, the students used the VRE without apparent difficulties, probably as a result of their prior experiences and informal training through the drawing tests. They had also been using it for playing and thus they became more familiar and skilled in its use.

The students' drawing inside the VRE in lesson two was based on co-operation. They had different roles in this, but used their initiative. During the work, the students communicated mostly through their drawings and text messages, but also face-to-face and through the headset. Their level of communication also varied, both on a personal level but, largely, on a work level. Figure 7.1 below shows how the students used the VRE for co-operative work (left side) and collaborative work (right side).

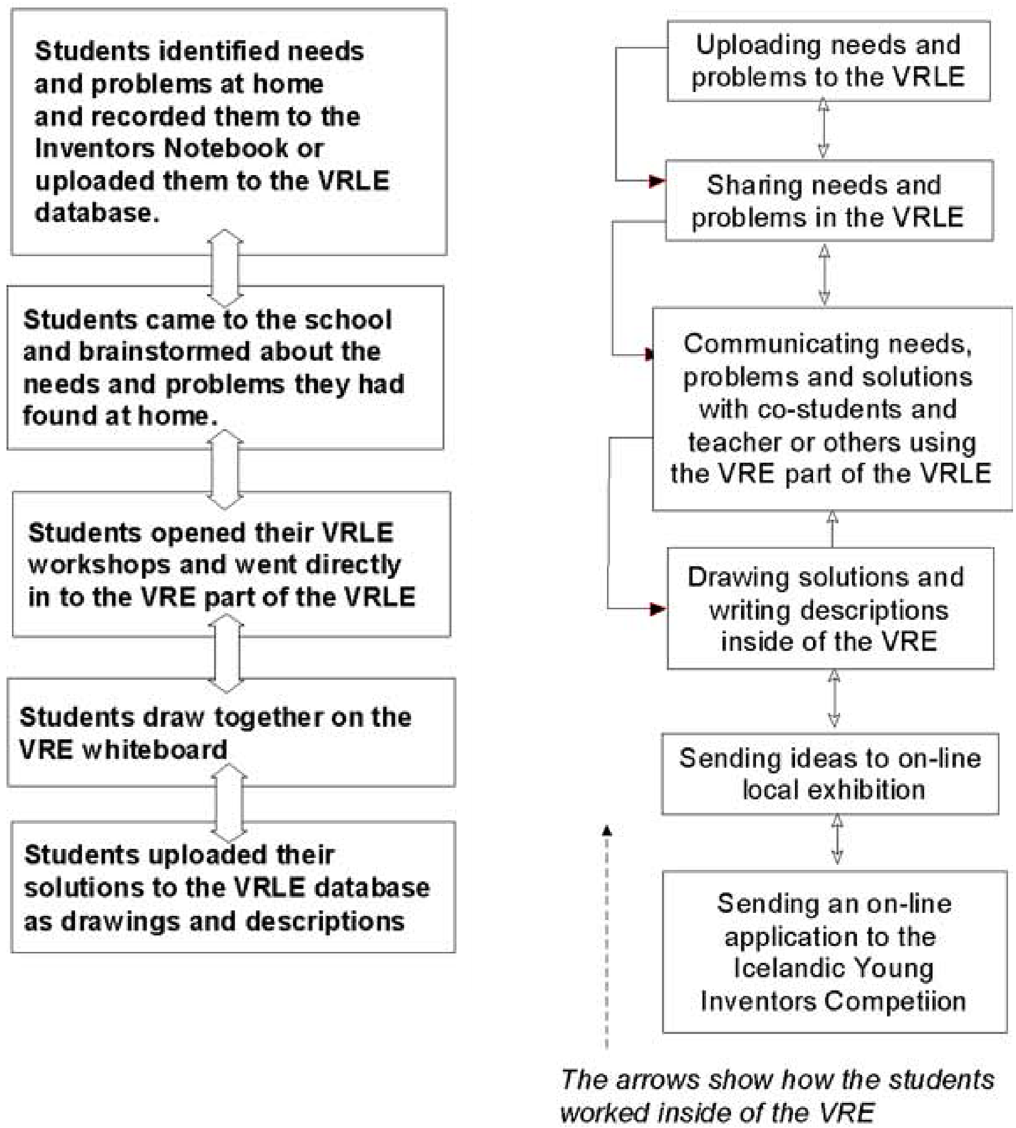

Figure 7.1: Demonstrates the way students worked together inside the VRE.

In lesson one, the students' idea generation was both dependent on their drawing skills and their ability to co-operate. Thus, contributions to the common solution were varied. Male student possessed the greatest initiative, as he started the drawing and mainly oversaw the technical part of the work.

7.9.1.2 Individual Work

Working and collaborating inside the VRE supported idea generation and the students' light-hearted spirit may have positively affected their idea generation (Runco, 2007; Cayirdag & Acar, 2010). There were big differences between the ability of individuals to draw and illustrate solutions on the virtual whiteboard. In his interview, the teacher noted that the students needed to be taught to draw in and use the CAD programme and this would have improved their skills and ability to use the VRE. The drawing test underlines the need for pre-training in the use of the CAD programme and the digital pen tablets, in terms of three-dimensional drawing. However, it was noted that the skills of students improved during the test.

7.9.1.3 Enabling Drawing and Multimodal Communication

In lesson two, the VRE was used for enabling drawing and multimodal communication, in order to support idea generation inside the MLE. Students used separate virtual whiteboards, but communicated their ideas inside the VRE and the classroom. In the earlier courses, the CAD programme within the VRLE was only accessible from the VRE and thus the students found it difficult to use. However, in CSS3, it had been upgraded and was accessible both from the VRE and the MLE. In this lesson, the students kept the VRE open and could thus communicate as avatars, employing text messages and speaking inside both the VRE and the classroom at the same time. This enabled the students to hear each other speaking and communicating, both virtually and physically; it also gave them the chance to brainstorm inside the VRE at the same time. Furthermore, being able to enter the VRE enabled the students to take a rest from their work, as they often entered the VRE to play.

7.9.1.4 Summary

Students used the VRE for idea generation, in various ways:

a. For co-operative idea generation inside the VRE, using the virtual whiteboard.
b. For individual work inside the VRE, using the virtual whiteboard.
c. To enable drawing and multimodal communication, during work inside the MLE.

7.9.2 Question Two: How does Collaboration Relate to Teaching and Learning within Lessons?

The IE activity inside the VRLE was supported by multi-channel learning opportunities. Such learning characteristics of the VRLE enabled the teacher to manage the IE material and supported the students' work. Both parts of the VRLE had value, in terms of IE activities. In lesson one, the students worked inside the VRE, while, in lesson two, they worked inside the MLE, but used the VRE to communicate as avatars. In relation to their work, they used the VRE as a place for working, socialisation and communication; it enabled them to communicate ideas and to take a rest from their work through play (i.e., off-task). The VRE part of the VRLE was thus a tool in the facilitation of computer supported collaborative learning (see further in chapter 2.0) and novel possibilities appeared, in terms of the teacher enhancing students' ideation work through online support (but inside the classroom). These multiple possibilities for collaboration learning promoted the learning experience of students.

According to the school's policy, the teacher was used to the context of collaborative group work: this may explain the way in which he communicated with students during their work. He gave them both the time to communicate and the space to activate their autonomy and self-reliance. However, using the VRLE to support students' work was a new experience for him and may have caused a conflict in roles, in terms of instruction and the capacity inherent in the software for tutoring students.

The teacher's role was based on the use of various teaching methods and the ability to make professional decisions on the appropriateness of these, when the VRLE was used for IE in school. As in the earlier case studies, it was identified through the video in lesson two that the teacher's tactic of leaving the students enabled collaborative learning, through increased symbiosis. This supported the students' capabilities and the independent use of the VRLE for IE. The teacher taught fundamental (didactic) skills, but also adopted the role of facilitator, supporting students with discussion and advice. Furthermore, he had to underpin student self-reliance by giving them time for independent experiences in using the VRLE. It was important that the teacher got the students engaged in their work inside the VRLE during lessons and he had to support them without distracting them from their idea generation.

In earlier case studies, students used their INs to discuss their ideas with family members and such collaboration, with ideation, was important preparation for the course. In the beginning, the teacher always asked the students to report their homework and brainstorm solutions. The brainstorming sessions were also undertaken collaboratively and helped the students to get started. In his first interview, the teacher had stated that discussion enriched collaborative work. During the brainstorming sessions, the teacher had to be very active in extracting ideas from students. However, he also gave the students the flexibility to generate ideas and make joint decisions.

Students worked independently, but supported each other during conversations, both online and face-to-face: this collaboration helped them to become self-sufficient in using the VRLE. The level of student communication increased when the teacher was not present; however, the teacher did give individual students frequent help, both when they asked for it and when he monitored the students' work during lessons. As everyone was connected thought the VRLE, all were aware of the conversation and could both benefit from and contribute to any discussions. Off-task activity inside the VRE was interesting for the students and thus they were in no hurry to begin idea generation. This may have made them more skilled in using the VRE and thus may have established their collaboration.

Due to their earlier experiences, it was relatively easy for the students to work out a solution together: this made them more skilled in drawing and enabled their joint work in idea generation. Students frequently helped each other and provided comments by turning the screen to each other (they used text messages to comment on each other's work). These text messages appeared on everyone's screen and demonstrated a light-hearted collaborative spirit, incorporating the use of comments and emotional expression. This may have, in turn, promoted idea generation (Runco, 2007; Cayirdag & Acar, 2010).

The VRLE helped the students to communicate and share needs and ideas inside the VRLE and thus made them more productive. The students were communicative and collaborative and, in case study series two, the VRLE database showed that half of the students shared their solutions with each other (see also table 6.4 and figure 6.7 in section A6.7.5.1 in the appendices): this promoted idea generation. Furthermore, it was supported by the teacher, who asked the students to help each other by speaking through the headsets, when inside the VRLE, during lessons.

7.9.2.1 Summary

The IE activity inside the VRLE classroom was supported by multi-channel learning opportunities. The teacher's method of communicating with the students and his way of teaching was identified as an important element in supporting the students' symbiosis. Collaborative activities within the IE course affected the context of teaching and learning and included:

1. Students' collaboration with families, through their homework;
2. Brainstorming sessions at the beginning of and during lessons;
3. Collaborative drawing sessions;
4. Students helping each other during the lesson, though face-to-face and online communication. This enabled the teacher to become a facilitator, rather than instructor.
5. Teacher advice and reflections, in terms of the multi-channel context of communication;
6. Students playing informally (off-task activity) inside the VRE;
7. Students communicating ideas inside the VRE;
8. Students sharing needs and problems inside the VRLE.

7.9.3 Question Three: How do Communications During Lessons Support Student Work?

The students' ability to communicate in both the conventional classroom and the VRLE, via multi-modal communications, appeared to support their work. It is intended that this would lead them to create more meaningful solutions than in a formal classroom (Gunnarsdottir, 2001a). However, due to the limited data available, the author cannot yet claim that this has been established.

The headmaster stated that the school supported personal communications between teachers and students: this may have created a relaxed working atmosphere in the classroom and also affected the way the teacher communicated, as a facilitator. The teacher noted how the discussion enriched the students' collaborative work; for example, they could work inside the MLE and use the VRE to communicate (as avatars) at the same time. Also, the students frequently spoke inside the VRLE and used text messages to comment on each other's work. In order to gain feedback during lessons, the students frequently showed their work to each other, directly viewing the screen; most students spoke face-to-face, rather than through the VRLE. The VRE connected the students together during the lesson and enabled them to hear the whole class speaking; it also enabled the students to share information, both formally and informally, and may have maintained the light-hearted spirit of the class. This in turn may have positively affected their idea generation (Runco, 2007; Cayirdag and Acar 2010), as was the intention of the learning experience.

The students communicated their ideas inside the VRE, using their drawings and text messages. The level of communication in the VRE varied between individuals, but was an important part of their collaboration. In lesson one, when the students were using the VRE for co-operative ideation, the most active student used fewer text messages than the other students.

It was noted that, at the beginning of lesson one, the group discussed how solutions could be introduced in the VRLE. However, they did not discuss their work before they started: the teacher considered it preferable for the students to discuss common needs and solutions before entering the VRE, but the students did not discuss multiple possibilities for solving their common need. Thus, the teacher suggested the work inside the VRE would be framed, in order to guide students through the innovation process inside the VRE.

The earlier case studies highlighted the inventor's notebook as a tool that supported communication with parents and as a medium with which to transport work to school. It also enabled discussions and reflections on ideas in the classroom during brainstorming sessions, as it showed something concrete that had originated in the student's home environment. In CSS3, however, the students did not do any homework. They did take their INs into school and used any needs and problems they had identified during the earlier course. Once again, this indicates the value of the IN as a tool in the enhancing of ideation.

7.9.3.1 Summary

Communication was an important aspect of the IE course: it supported idea generation and the teacher, as facilitator. Students could employ multiple methods of communication and could contact society outside the classroom. The students were able to communicate in various ways, both inside the VRLE and in the classroom, at the same time: this made them aware of others' work and possibly promoted the flow of information. Students collaborated by communicating their ideas through drawings and text messages and these communications may have promoted a light-hearted sprit inside the classroom, which in turn may have supported idea generation. The IN was identified as a tool in enabling communication with the students' families and a fundamental source of idea generation during lessons.

7.9.4 Question Four: What is the Value of Using the VRLE for IE within the Context of the School?

The teacher believed it was better to integrate IE and the VRLE with existing subjects, rather than establishing it as a new subject, and he noted the importance of the teacher's and school's interest in this. The teacher believed IE would increase student understanding of the value of innovation, in terms of the economy, and its impact on society, and both he and the students believed that the VRLE would help them to become more innovative in their daily lives. The teacher and the headmaster also believed that IE would help students with learning difficulties, by building up their self-confidence.

Interviews with the students showed that they viewed the course as a general school project and that this had not significantly changed their way of thinking. However, the teacher noted how his experience of the IN had been informative for him as a teacher (see chapter 8.0). It is thus hypothesised that a more extended programme of the use of the VRLE for IE may significantly lead to an improvement in the way in which students approach idea generation. The headmaster underlined the importance of using computers as tools for individual-based studies and he noted that IE would be useful in helping the school to instruct on the theories of constructivism.

7.9.4.1 Summary

The teacher and headmaster both positively reacted to the potential for IE in education. Indeed, IE may:

1. Increase the understanding of the value of innovation for the economy;
2. Increase the understanding of the potential impact of innovation on society;
3. Help students to become more innovative in their daily lives;
4. Help students with learning difficulties;
5. Support the position of boys within school;
6. Enable individual-based education;
7. Follow the theories of constructivism.

7.10 Feed Forward

The case studies have explored the use of the VRLE in supporting the development of ideation skills within the innovation process, within the context of the pedagogy of Innovation Education. Data has been collected, in order to answer the specific questions within three case study series, relating to the overall question below:

'How does the use of the VRLE affect the teacher's pedagogy and students' work, in terms of conventional Innovation Education in Iceland?'

It is difficult to estimate if the work undertaken is sufficient to answer this question. Many new issues and questions have arisen and the research has also indicated many possibilities for the use of the VRLE, both within IE and general education. However, due to time limitations, the fieldwork had to stop at this point, in order to enable sufficient time to reflect on the data gained and to relate this data to the literature.

During the whole case study series, the dominant emerging issues appeared to relate to the role of the teacher. Some of these issues concerned the teacher's mindset, while others related to his role as a teacher and the practical issues of teaching. It thus became necessary to clarify these issues by revisiting the teacher: this will improve the triangulation of data and clarify the understanding of these emerging issues. Such issues and the methodology employed are outlined in the following chapter.

Chapter 8. A Follow up: the Teacher's Review of the IE Courses

8.0 Chapter Summary

This chapter presents the data from a set of interviews with the teacher involved in the case studies. These interviews were designed to answer the specific points that emerged from the initial analysis of the case studies. A semi-structured interview schedule was designed and used, in order to enhance the possibility of the emergence of relevant points.

8.1 Introduction

The purpose of this follow-up was to clarify various issues that had emerged during the fieldwork and this was undertaken through two face-to-face, semi-structured interviews (this method allowed the author to react flexibly as points emerged). The interviews were also an opportunity for the author to check that he had understood the prior data correctly.

The interviews were conducted in October 2008, in Iceland, and the pedagogical issues identified by the author, with regards to the teacher's role, were used to formulate both a pre-interview briefing paper and a semi-structured schedule for each interview. The teacher received the briefing paper ten days prior to the first interview, in order to enable him to recover his memory and reflect on the content before the interview. The normal reassurances were offered to participants, with regards to the confidentiality of any data arising from the interview. The data from the first interview was analysed and, in the two weeks between interviews, the teacher and the author reflected further. The second interview clarified specific points from the first interview.

8.2. Issues Requiring Clarification

Several issues were identified during the data analysis of chapters 5, 6 & 7. These were related to the issue of the teacher as a participant in the case studies and required clarification. The data generated enabled the following categories to be developed further:

1. Teacher's role and handling of teaching;
2. Motivation;

3. Drawings;
4. Ideation and Innovation Education;
5. Collaboration;
6. Values.

8.3 Interview Schedule

The author planned the interview schedule by going through the overall categories and discussions from chapters 4.0 to 7.0 and identifying the issues that required clarification from the teacher. The same schedule of issues was used to guide the second interview (see section A8.2.1).

8.4 Interviews with the Teacher

Two interviews were conducted in the teacher's workshop in Iceland and the atmosphere was relaxed and open. The teacher was well prepared, as he had reflected on the pre-questionnaire he had received ten days before. The author used a digital recorder in the interview, with the teacher's permission.

8.5 Summary of Findings from the Interviews

The schedule was used as a flexible base for questioning and the data generated was analysed and re-grouped into categories representing the issues. All were written from the perspective of the teacher and his comments.

8.5.1. Limited Computer Literacy and Administrator's Right

The teacher noted that he, the students and the author were not great at handling the computer facilities at the beginning of the research. Furthermore, the facilities had not been set up properly. It thus took time for the teacher and author to establish their skills and understanding of the ICT equipment. This caused a conflict in roles for the teacher, in terms of him being both teacher and administrator (see chapter 5.0). These issues lessened after the first course, probably due to increased experience (also see c below).

The teacher's administrative rights and ICT skills were important, as he was able to set up and repair the software and equipment (although this did take time). He noted that it would have been difficult to do this without administrative rights and that most teachers would have required extra support. The VRLE was found to be unstable: upgrades were required and software problems occurred. Furthermore, the teacher noted that, if this becomes an issue, students tend to lose interest. However, the teacher also added that part of the research was to develop the software and learn from such developments.

8.5.2 Preparation for the IE Course

The teacher considered that he had underestimated his preparation and thought more time was needed for lesson preparation. Part of this might have been due to experimental effects, as the teacher was a participant in the research, while the author was an observer (Cohen et al., 2005). The teacher's difficulties appear to be related to his insecurity in undertaking new courses; indeed, the students found the courses both easy and enjoyable. The teacher believed that a 2-3 day starter course in the use of the VRLE would have been beneficial; furthermore, he believed that his work would have improved if he himself had accessed the VRLE prior to the courses and gained better experience.

8.5.3 Teacher's Role Difficulties

The teacher noted that he was responsible for both enabling the research and conducting the lessons at the same time. This made his work more difficult than his regular teaching; the action research element also made the teacher's role more difficult and caused him confusion in the beginning. He had to learn about IE and the VRLE, manage the technology, develop the course plan in co-operation with the author and develop the teaching methods; he also felt responsible for the research. In the second course, these difficulties were less evident, as the majority of technical difficulties had been solved through experience. In the third case study, the students had experienced IE before and were focused, thus reducing the teacher's workload. The teacher noted that this underlined the importance of prior experience, in terms of the students.

8.5.4 The Novelty Impact of the VRLE

The teacher noted that the novelty factor of the VRLE had affected the research, particularly with regards to the students' initial lack of familiarity with the VRLE. However, for the teacher, the research was an opportunity to discover something new. He stated that the VRLE was considered 'exotic' at that time, but would be considered normal today, due to the students' familiarity with computer literacy and similar software. He considered that the difficulties that had occurred would not arise today and, as a result of the novel technology, the teacher felt particularly responsible for keeping the VRLE running. He was also using new computers at the time, which required management. Partly as a result of these factors, the teacher initially lacked confidence and was insecure at first. The teacher believed that the VRLE was a novelty for students at this time and was also new and exciting to them, as it was specific and uncommon. Today, the basis of IE would be the same, but the educational value of the technology may be increased, due to technological evolution.

8.5.5 The Participants' Lack of Familiarity with IE and the VRLE

The teacher and the students were often confused during the research, particularly at the beginning. Initially, the students were not familiar with the VRLE or the IE process. The teacher noted that the requirement for innovative ideas may have caused the students some difficulties. They also appeared to believe that their ideas had to be complex and these factors may have caused the students some stress.

8.5.6 The Author's Impact on Students' Motivation

The teacher noted that the author's introduction to IE was useful in his planning. It facilitated the students' interest in participation, especially when the author demonstrated prototypes from earlier IE students and the Young Inventors' Competition.

8.5.7 Disadvantageous Time Schedule

The author noted that, in the first two courses, the students entered the classroom before the lesson began. However, in course three, the teacher had difficulty motivating the students to join the course. He explained that this was because school had ended and the summer vacation was underway, stating: 'the timing was too late and was inappropriate'.

The teacher asserted that the courses should have been implemented on a day within the school's regular schedule, as this would have offered more flexibility. The teacher believed longer sessions would have given better results and he stated that this would have given both him and the students more freedom and fewer disturbances. He also noted that lessons run during the day would have given him more flexibility and would have posed the opportunity for all types of experiments.

8.5.8 The Teacher's Workload and the Impact of the School Context

The courses meant a substantial extra workload for the teacher, as an after school activity. The teacher himself asserted that his colleagues and the school's expectations also put pressure on him; however, he did acknowledge that the new undertakings were part of the nature of his profession and that this demanded time. Furthermore, he noted that the only way forward was to build on past experiences.

8.5.9 Expectations of the School

The teacher was convinced that the school was more open than other schools in supporting the research. He was aware of the expectations of his co-teachers and the headmaster, who was both encouraging and supportive; nevertheless, such expectations were stressful for the teacher.

8.5.10 The Author's Support for the Teacher

The teacher was unsure as to whether the author could have supported him differently before the lessons had begun, as they were both developing their skills and understanding of teaching IE through the VRLE. The teacher recognised that the object of the course was to develop and examine the pedagogy of using the VRLE for IE and stated that both he and the author were innovative during the research: the lessons were not totally pre-defined. However, a detailed manuscript would have made him feel more confident.

8.5.11 Opportunities for Trying New Teaching Methods

The teacher saw the courses as different from his normal work, as they encouraged him to try out new teaching methods. He began the lessons with the usual instructions and discussions, but, subsequently, the lessons were flexible (this may not have been clear at the beginning of lessons). The teacher thus viewed these lessons as more dynamic and he agreed with the author that it would have been better to run the courses over longer periods, in order to enable the development of the teaching methods.

8.5.12 Impact of the Research, in Terms of the Educational Context

The teacher noted that parts of the activities were concerned with the research context and the identifying of appropriate teaching methods. However, this made his work more difficult. Precise tutorials, guidance and instructions in conducting the lessons would have simplified his work. The teacher further noted that the course plan could have been stricter, outlining a specific aim for each day: this would have enabled a review of activities.

8.5.13 Multiple Teaching Methods

The teaching methods were a combination of the methods the teacher employed on a daily basis and he defined his methods of teaching as *Inquiry Based Learning*. The teacher taught directly from printed documents and also by defining needs through discussion with students and searching for solutions. The VRLE offered students various functions and enabled them to find something 'new'; however, the teacher also noted that students could get 'lost' in their speculations and considerations. He stated that part of this method was to get the students to understand that there was no wrong or right answer and he had to allow them to generate their own ideas and work from there. The teacher noted that this part of the course was also novel.

The teacher believed that he was a key element in such undertakings and that background and security were important in this. He noted he had to find his own ways of working and employed multiple teaching methods, rather than gaining support from textbooks. He felt that the IE approach of identifying needs and solutions and designing from them was more difficult and stated that a textbook-focused approach to IE would have affected the characteristics of the IE work. The students' work came from within themselves and the teacher felt that more experience, with regards to himself, would probably have made him more skilled and would have enabled him to better formulate his approach to teaching.

8.5.14 The Teacher's Background

The teacher was a classroom teacher, who taught ICT and Design & Craft. He noted that his background enabled him to switch between instructor and facilitator and considered that this made the students more independent. Furthermore, he believed that the VRLE supported individual-based studies; for example, in the MLE workshops, the students had the freedom to be creative and worked on individually-based ideas.

The teacher described his role in design and craft as that of facilitator and, in IE, as in design and craft lessons, he issued short instructions at the beginning of lessons and conducted brainstorming sessions, in order to enable idea generation. Students learned through working with their own ideas and the teacher felt that his teaching method was difficult, due to the fact that every student was working on their own ideas. The teacher allowed flexibility, in order to support student collaboration.

The teacher was familiar with the innovation process, as a result of making prototypes of student ideas for the *Young Inventor's Competition, and* this had enabled his understanding and formulated his expectations. However, he referred to the case studies as a 'chaotic system'. Such studies had initially caused him to feel insecure, as he was unable to assess the situation, due to a lack of experience. Furthermore, he could not seek help from anyone, as such research had not been undertaken before. However, the development and assessment included in the research helped him gain direction. He noted that his role in the case studies was different from that of a normal teacher, as he had to motivate the group from the beginning using brainstorming, rather than textbooks.

8.5.15 The Relationship between the Teacher and the Students

The teacher noted that he had to be the student's companion, father, mother and friend; however, he also had to be their boss. A certain closeness should develop between the teacher and the student, but the teacher has to be able to keep the students at a distance, if required. The teacher noted that being too close to the students was not good, as it made them stressed. He also believed that the students would pretend that they were active if he was always stood over them. However, he noted that, if a student was working alone, their initiative and creative process could be activated by the attention of the teacher. However, the teacher believed that being too closely involved with the students' work may affect their collaboration. He noted that a teacher's interventions can be a hindrance, as it limits the students' self-development. He also asserted that the teacher's expectations may stress students, referring to this as the '*time clock'* syndrome.

8.5.16 Software Upgrades During the Course

The teacher mentioned that new upgrades had been introduced for the software used during the course and that he and the author had to spend time experimenting with this, causing the teacher to feel insecure. He further noted that he and the author may have got further with the research if they had understood the software better.

8.5.17 Selection of Students and Timing of Courses

The teacher invited students that he trusted to participate in the course and those who he thought would be interested in IE. These students were mostly from his class, as they were at hand, and thus they were used to working together. In the third course, the students were from various classes, but co-operated well: working with new ideas and technology was interesting for them.

The timing of the courses was established in conjunction with the teacher's availability and the teacher noted how the season in which the course was held influenced the students. For example, in the autumn, students were full of tension, the Christmas period was characterised by expectancy and, during the spring/summer seasons, students were influenced by the improved weather.

8.5.18 Participation in the Research and its Impact on the School

The teacher wanted to experience the innovation process and noted that he found the research exciting, but different from teaching. However, he stated that the after school timing of the courses had affected the research and also the students' commitment to other activities that occurred at the same time. The students' interest was triggered by the author's introduction to IE, former students' prototypes and the young inventors' competition. One parent was working for an innovation fund and encouraged the research.

The school has attempted to be innovative in various subjects since the research, by employing IE in subjects such as ICT and multimedia. The teacher considered that none of the former students had continued with IE, as they lacked the support to do so. Nevertheless, the school had participated in the young inventor's competition, with one student receiving an award. Media attention had a positive influence on any interest in IE.

8.5.19 Pre-Training Students in Drawing with Digital Output Devices

The teacher felt that the students needed to be trained to draw with the digital output devices prior to the start of the courses. He felt that such training should have been a part of the course, as the use of such equipment was new to the students. He added that there would be more advanced equipment available today and the students would still require pre-training in the use of this equipment.

8.5.20 Brainstorming Sessions and the Inventor's Notebook

The teacher noted that the brainstorming sessions were useful in triggering students' IE work; they also helped him gain direction in lessons, reducing any insecurities he may have had. He further noted that the IN was a useful tool, as students were able to sketch any ideas they identified between lessons in the notebook. Students used the IN, in different contexts, for a long period of time after the research.

8.5.21 VRLE in Supporting Idea Generation

The teacher noted that using the VRLE for IE was different from the old model, as it was closer to the student mindset, with regards to the daily use of ICT and games. Students quickly learned to access the VRLE through experience, while the teacher believed that the VRLE workshops were useful and productive. He also noted that the VRE supported student collaboration, as they could look at and compare each others' work. It also enabled the teacher to employ multiple teaching methods.

The teacher believed that idea generation was randomly different between groups. However, he stated that the students' relationships in school during the research may have influenced the results. Furthermore, he noted that the students may have shared information and stated that they had been increasingly discussing ideas during the courses (evident from his day to day contact with students in normal lessons). The teacher saw the VRLE as an additional learning tool and believed that ODL studies would be possible, but difficult, as there would be a lack of support for the students in this.

8.5.22 Students' Collaboration inside the VRE

The teacher felt that the students found collaboration inside the VRE exciting and interesting. The students already knew each other from the teacher's class and were used to group work; thus, they found any collaboration easy. The teacher stated that students at this age were generally interested in communication and collaboration.

8.5.23 Game Based Learning

The teacher noted how playing independently (i.e., not directed activity) inside the VRLE increased the students' skills; any fear of using the VRLE and unfamiliarity quickly disappeared. He further noted that the children were not afraid of new experiences on the computers; thus, the students discovered many other possibilities through the use of the VRLE. This made them arrive earlier for classes, which the teacher found interesting: youngsters of this age did not usually spend any more time than required in school.

The VRLE helped students in their idea generation, as they were able to find a solution and then express it. The teacher was convinced that the avatars had no meaning for the students, other than the entertainment value.

8.5.24 The Impact of the Undertakings on the Teacher

The teacher stated that the research increased his interested in IE. He noted that, in the subject of design and craft, the teacher does not always have a specific product intention and his assessment is always subjective. In this sense, the teacher did not feel insecure; however, he considered that a normal, classroom-based teacher would not be interested in running such courses because they were too open and the results were not definable in advance, stating that this may make teachers insecure.

8.5.25 Running the Activities with a Whole Class, as Part of the School Curriculum

The teacher believed that implementing IE activities once a week, over a year, would ensure that students viewed IE as any other subject. However, he believed that it would minimise the novelty of IE and could possibly lessen the creativity of students. It would thus be better to run such activities over several short periods, condensing the content. Assessment would be important, as subjects without any assessment commanded less respect, especially in a full class of students (30).

The teacher believed that IE/VRLE activities would work with a whole class, if undertaken over a whole term; however, he noted that only part of the class would be active in an obligatory subject. He also noted that he would require textbooks (note the apparent conflict with his statements above) and he believed that it would be possible to implement individually-based education, but this would be more work for the teacher, as they would have to meet students' individual needs.

8.5.26 Value of Using IE

The teacher stated that IE and the young inventors' competition had had a positive influence on Icelandic education and it had also influenced other subject areas. The teacher described IE as multiple methods of teaching and learning; IE was able to meet the different needs of students at various levels, as it gave them the freedom to work with whatever they were interested in. It also enabled students to show the results of their work in a different manner than exams.

8.6 Feed Forward

The follow-up interviews with the teacher provided the author with more data, with regards to a further understanding of the pedagogical issues identified from the case studies. The analysis of the data will be used for further development, clarification and extension of the issues that emerged from previous chapters. The outcomes will be fed into the summaries of the overall findings in chapter 9.0 and will be discussed in chapter 10.0. Any outcome may belong to more than one category.

Chapter 9. Summary of Overall Findings

9.0 Chapter Summary

Chapter nine reports the overall findings of the research, based on the three case studies that were developed iteratively during 2003-2004. The data was analysed into categories, in accordance with the principles of grounded theory.

9.1 Introduction

The purpose of this chapter is to give the reader an overview of the overall findings, by reviewing a series of summaries of the case studies and the final interview with the teacher (the full data from each case study is available in the appendices). The analysis of the data supports the further development, clarification and extension of the categories emerging from previous chapters and the findings are fed forward to the overall discussion in chapter 10.

9.2 Summaries of Overall Findings

The following sections report the main findings from the following categories, established during the enquiry (see sections 3.11.2 and 3.11.5). These initially appeared in the pilot study and were refined through the case study series

1. The teacher and his approach to his work;
2. Homework;
3. Use of the VRLE;
4. Innovation Education and idea generation;
5. Drawing;
6. The perceived value of IE within school.

9.2.1 The Teacher and His Approach to His Work (A10.0.1)

The specific role of the teacher was to guide and help students to develop their ideation skills, supported by the VRLE. However, this was identified as complicated, in terms of managing the VRLE technology and the students depending largely on the teacher's ability to administer such technology. In overseeing the ideation process, as the framework for IE courses, the teacher had to adopt multiple roles, including:

- The organising of courses;
- Lesson preparation;
- Identifying appropriate teaching methods and applying these in various contexts;
- Solving any technical problems, in terms of both in hardware and software;
- Teaching fundamental skills and training students in IE and the use of the VRLE;
- Teaching the IE process inside the VRLE;
- Employing appropriate teaching methods during lessons;
- Being both instructor and facilitator;
- Engaging parents in helping students with their homework;

The novelty and complications of running lessons within the framework of blended IE learning also caused a conflict in roles for the teacher, which appeared to increase his insecurities and made him more self-critical. The teacher lacked confidence, in terms of the course plans he had developed in conjunction with the researcher; he also lacked confidence in the teaching of IE and in using the VRLE. In the first case study, the teacher experienced a conflict in roles, in terms of administrative work and tutoring; thus, his administrator rights and ICT skills were important in the use of the VRLE. These difficulties were mostly caused by his limited skills and knowledge, but were also the result of limited preparation time and limited practice for lessons. The teacher considered that the research constituted a substantial amount of extra work and thus he felt it would be better to run the IE course within the school's regular curriculum, within regular school hours: this would ensure that he was better able to manage his teaching and administration duties.

Reflective self-criticism is part of the general mindset of a teacher and, in this case, the teacher appeared to display a lack of confidence, possibly due to the context of the research. After the pilot study and case study series two, the teacher was given general training, in terms of IE lessons that incorporated the use of the VRLE. He was also encouraged to spend time developing his own experience of using the VRLE for IE, mirroring the work the students were required to do. Later, the teacher did note that the only way forward in teaching IE was to build on experience and he argued a detailed instruction booklet and further training would make him feel more confident. He also considered that his approach would have been much easier today, as computer literacy has improved and technology has progressed.

Better preparation, on the part of the teacher, thus became part of the research plan for case study series two and three; in addition, help pages were set up inside the VRLE. However, the teacher did not access the help pages, probably because his workload was high and his preparation time was often limited. Nevertheless, during the last case study, the teacher did not mention any technical difficulties or any problems in managing the hardware and software: by this time, he had become skilled in using the VRLE and was familiar with hosting IE lessons. He was also more thoroughly prepared for lessons. The teacher established his own method of working, rather than relying on the tutorials offered by the author. He had the confidence to act flexibly, in terms of the IE course plan, and the teaching methods employed were a mixture of conventional IE learning, using the VRLE, the use of media and tools within the classroom and the VRLE and various didactic methods of teaching.

The VRLE was designed to enhance both collaboration and co-operation, via the additional modes of communication it provides, and the teacher was able to use different teaching methods throughout the research, such as direct instruction, training, groupwork and individually-based sessions inside the VRLE. As a result, he developed the following basic structure:

- introduction;
- basic training;
- students reporting needs and problems;
- brainstorming sessions;
- students developing solutions inside the VRLE, both as individuals and in groups;
- summary and preparing students for the next lesson.

Homework, the introduction and pre-training gave students basic knowledge and an understanding of the innovation process prior to lessons and pre-trained them, in terms of the use of the VRLE. The teacher also allowed students to ‘play’ inside the VRLE, further increasing their experience of the software. This had a positive influence on their skills and motivation and subsequently reduced the teacher’s workload and the aspect of play appears to be an important factor, in terms of subsequent learning.

At the beginning of lessons, the teacher introduced the plans for the lesson and, at the end, he discussed the next lesson. Observations by the author indicated that this process focused the class. The teacher underlined the value of identifying needs and problems at home, prior to the start of the course, and he understood the purpose of the homework, which was to prepare for idea generation inside the VRLE.

The teacher switched teaching roles during lessons; for example, he began by instructing and then switched to discussion. He sometimes taught directly from the printed documents, but also helped the students in defining needs and solutions themselves. He noted that this fostered the development of autonomy and met the needs of different individuals. The teacher's background enabled him to change the mode of his teaching, from instructor to facilitator, in accordance with the circumstances; he had the confidence to act flexibly, with regards to the course plan. Furthermore, he noted that he had to find his own method of teaching, instead of relying on textbooks and stated that any pre-experience, in terms of the VRLE, would have reduced his workload.

The teacher employed the role of instructor in the introductory sessions, conducting basic training in the use of the software and brainstorming sessions. It was important to link the students' homework with their activities inside the VRLE and, at the start of lessons, students reported any problems and needs they had identified and discussed them when the teacher conducted group brainstorming sessions. After this, they could work independently. The brainstorming sessions appear to have aided the teacher in establishing a plan for the running of lessons and thus reduced his insecurities. Students brainstormed, both during sessions with the teacher and informally, during their work inside the VRLE.

The teacher viewed his lesson plans and control of the pace in lessons as important, referring to the technique of applying time pressures. The teacher felt that, if he were not in control, the students might have been distracted from their idea generation work. However, in CS2, he considered that he had applied too much pressure, in terms of time, and this limited the students' ability to reflect on their work. Thus, in case study series three, more time was given for reflection, in terms of both needs and problems.

It was noted that the teacher employed a specific teaching technique during lessons, whereby he would leave the class for short periods. The teacher asserted that his intention in this was to give students a degree of autonomy and to establish mutual trust; he also argued the VRLE enhanced this autonomy and collaboration. In order to increase students' self-reliance in collaborative work, the teacher gave them detailed instructions before they began to work inside the VRLE. He also supported the students, sometimes individually and sometimes in pairs, although they did not always ask for his help.

9.2.2 Homework (A10.0.6)

Homework was important, as it formed the basis of innovation and learning, both in the classroom and in the VRLE, and the inventor's notebook played an important role in connecting the three elements together. The homework was based on the finding of problems and needs, the use of the inventor's notebook and communication with families. The IN appeared to have increased the students' interest in identifying ideas and appeared to be a simple but effective motivator; this was the starting point of the IE innovation process and activated students' ideation. The teacher placed emphasis on the identification of needs and problems during the course and supported idea generation by brainstorming with students, referring to their homework, during lessons. The students also used the VRLE as a virtual IN at home, recording needs, problems, ideas and solutions inside the MLE. However, few needs and problems were uploaded to the VRLE from home during the research and the paper IN was particularly useful and popular with the students.

Another element of the homework was supporting the teacher's role in informing and engaging parents. He had to encourage parents to support their children, in terms of homework, and none of the parents had experienced IE or the VRLE before. Thus, the teacher provided the parents with a significantly detailed course plan, prior to the course. In the later studies, he also wrote a letter to parents, outlining the importance of parental support for students, with regards to the initial phase of the innovation process. Almost all the parents gave their children some support; however, none discussed needs or problems with their children, only ideas. This may be an example of how they approached craftwork when they were students themselves.

9.2.3 Use of the VRLE (A10.0.4)

Throughout the research, the VRLE generally worked well; it was stable and the students were able to register without any problems. However, dealing with the VRLE technology might have been more difficult for teachers who do not possess competent information technology skills. The teacher also considered the VRLE as ‘exotic’ at the time of the case studies (2004), but noted that it would be considered normal today. Probably as a result of their good computer literacy, students learned to use the VRLE through direct experience. Using the VRLE network inside the classroom also meant that students could assist each other in learning, both face-to-face and online (they also received some instruction from the teacher).

The students quickly became self-reliant, but the teacher felt that they would benefit from more didactic learning materials and a traditional instructional phase. In particular, he considered that the students required training in the use of the VRE for idea generation, as it was new to them, and he believed it was difficult for them to design together inside the VRE, as avatars. Thus, the students were given the opportunity to play in the VRE, prior to the start of lessons and during breaks from their work in the MLE, during lessons. The students felt it was important to be able to personalise the interface of their virtual workshops and this appeared to have a positive impact on their motivation, in terms of learning. The VRLE was connected to the internet and was password protected; however, the teacher had to be aware of the possibility of outsiders breaching the security system of the VRE.

9.2.4 Innovation Education and Idea Generation (A10.0.5)

The teacher’s role was to help students foster an understanding of IE and the innovation process and instructing them via the VRLE was beneficial, in terms of their idea generation. Usually, students quickly understood the innovation process and were able to identify needs and problems in their own environment. The inventor’s notebook played a significant role in the first stages of the innovation process, which took place at home (see section 9.2.2): this was intended to trigger idea generation in lessons and help students to generate the content of the course, making them self-directing and thus giving their work personal meaning. Students usually voiced their findings spontaneously and tended to record solutions in the IN, rather than needs and problems. However, the teacher was able to help the students define needs (rather than solutions) through discussion, while they worked inside the VRLE, without imposing his own value judgements.

Brainstorming appeared to be useful in establishing the students' idea generation; they submitted the majority of their ideas to the VRLE database after the brainstorming session. Normal time pressures imposed by the teacher increased productivity during brainstorming but, as this pressure grew, it reached a point where the number of ideas appeared to decrease. The students' ability to identify needs increased slowly at the beginning of lessons, after the first brainstorming session. As they became tired, as the lesson progressed, the teacher implemented further, short brainstorming sessions, aiming to trigger further idea generation and refresh and refocus the students.

The VRLE directed students' idea generation, as it was structured around the innovation process. Students were generally self-reliant and often worked individually inside the MLE part of the VRLE; they tended to collaborate within the VRE and such collaboration appeared to further supported idea generation. The VRLE facility for sharing needs and solutions and brainstorming were identified as beneficial. Students frequently shared needs and problems with each other, both face-to-face and online. They usually came up with many ideas, when working inside the MLE, but typically worked collaboratively on one idea inside the VRE. However, working inside the MLE, the VRE and face-to-face at the same time appeared to further trigger their ideas. Being able to play inside the VRE, when taking a break from working in the MLE, also supported any collaboration. There was a balance between needs identified at home and at school; however, most ideas were generated when students were working collaboratively inside the VRLE.

Students' collaboration inside the VRE, employing the VRE CAD programme, supported individual-based idea generation, but students were less productive and fewer ideas were generated when they worked inside the MLE than in lessons. Furthermore, the light-hearted spirit in lessons increased the students' motivation and engagement with idea generation work.

The students' main activities were collaborative work inside the MLE, but they were co-operative inside the VRE, when working on a shared task. The students usually worked alone or in pairs on the virtual whiteboard inside the VRE; they found it difficult to collaborate inside the VRE, especially in terms of drawing together on the virtual whiteboard and interacting as avatars. This may have been due to a lack of social skills and training or a lack of experience in working together inside the VRE.

9.2.5 **Drawing** (A10.0.3)

Drawing, whether in the IN or through the use of the VRLE CAD programme, enabled students to record and develop solutions*;* it also enabled idea generation and the ability to communicate and develop solutions. Students' drawings, when using digital input devices, were generally inaccurate, but demonstrated basic solutions to identified problems and needs and were therefore usable, in terms of IE. Effective drawing equipment and the CAD programme enabled students' work, as demonstrated by the better quality tablet input devices used in the later case study. The students' drawing skills appeared to improve with training, as one would expect.

Students were better at using pencils, rather than the digital pen tablets; however, these tablets were faster than computer mice and generated better quality drawings. The initial digital drawing tablets were not flexible enough and slowed down the students' work. However, the designs formulated with the initial digital drawing tablets appeared to be more advanced than those drawn with the more technologically-advanced Pegasus tablets (except in terms of accuracy). The CAD programme inside the VRE enabled students to draw together, as avatars, on virtual whiteboards, but they found this difficult. In CSS3, the CAD programme was accessible from the MLE, in order to enable individual drawing without having to be inside the VRE. However, the CAD programme appeared to be a useful tool in the collaboration of students, during their individual work inside the MLE.

9.2.6 **The Perceived Value of IE in School** (A10.0.9)

This category arose as a result of interviews with the teacher, his students and the headmaster. However, it is only vaguely triangulated and requires more research for validation. The headmaster believed that using the VRLE would increase students' computer literacy, increase their motivation for learning and improve their ICT skills, on an individual basis. He also saw IE as a way of basing school activities on constructivist theories and collaborative group work in a democratic fashion.

The teacher argued that IE was able to meet the various needs of individual students at various academic levels, as it gave them the freedom to work with their interests. He further considered that IE would enable students to change their ways of learning and argued that integrating IE within existing subjects would give students a reason to incorporate IE within their daily lives. Using the VRLE would also help students to become more innovative. However, the students asserted that IE had not had a great impact on their methods of thinking: this may be due to the relatively short exposure to IE in the case studies.

9.3 Feed Forward to Chapter 10.0 Discussion

The interviews have provided the author with more data, in terms of supporting an understanding of the issues identified from the case studies, and this data relates to the overall research question:

‘How does the use of the VRLE affect the teacher’s pedagogy and the students’ work, in conventional Innovation Education in Iceland?’

These findings will be employed in the discussion chapter, in order to strengthen triangulation.

Chapter 10. Discussion

10.0 Chapter Summary

Chapter ten brings together the findings from chapters 5.0 to 8.0 and discusses them, in terms of the literature. The discussion centres around the central research question: 'How does the use of the VRLE affect the teacher's pedagogy and students' work, in terms of conventional Innovation Education in Iceland?'

10.1 Introduction

Three case study series were developed iteratively during 2003-2004 and the data from each was collected, summarised and analysed into categories. The results were discussed and conclusions drawn, which were then used to establish the next case study. The data was obtained within a complex naturalistic context and analysed in accordance with the principles of grounded theory. The process attempted to understand and interpret the learning experience of students within this context, in addition to understanding the pedagogy employed by the teacher.

In this chapter, the categories are further defined and then discussed, in accordance with the literature. Blended learning was employed as a framework for illustrating the educational activities in this enquiry and the value of using the two different parts of the VRLE (the MLE and the VRE), both separately and together, is discussed and contrasted. Finally, any relationships with educational theories are discussed, in order to enhance the understanding of the emerging pedagogy of using the VRLE for IE.

10.2 Discussion of the Categories and Issues Arising from the Enquiry

The main categories established during the enquiry (see chapter 5.0; 6.0 and 7.0) will be discussed, as below:

1. The teacher and his approach to his work;
2. Homework;
3. Use of the VRLE;
4. Innovation Education and ideation;
5. Drawing;
6. Values.

These are the significant categories identified from the data generated during the research: the initial categories appeared in the pilot study (see section 5.8) and were subsequently refined through the case study series. The categories are discussed as subsections, but it should be noted that they are so closely related that the discussion often overlaps.

10.2.1 The Teacher and His Approach to His Work

The teacher's role was identified as a fundamental category and this section discusses any issues relating to this category; furthermore, it attempts to project the degree to which findings may be significant onto a broader teaching population.

The teacher's role refers to teachers' responsibilities, in terms of managing and enabling the contexts of teaching and learning, and it is often described in terms of certain pedagogical theories. *The Oxford Dictionary* (2008) defined a teacher as 'one who or that which teaches or instructs; an instructor; one whose function is to give instruction' (p. 687-689); however, this definition is instructionally orientated, rather than being related to pedagogical theory or classroom activity. The research highlighted how the teacher's role in the IE/VRLE context consisted of various dimensions, including technician, planner of instructional contexts, provider of information and facilitator.

Jonsdottir‘s research (2005; see 2.6.2) aimed to identify the factors that influenced the implementation of conventional Innovation Education in Iceland. In common with the author of this research, Jonsdottir asserted how the teacher's role in IE is significant in creating the circumstances that support the progress of students. She also identified the teacher's mindset as an important factor (see 10.2.2), especially within the contexts of their social or cultural values. Thus, the teacher's training in IE is important and facilitates their access to information and IE teaching materials. However, in this research project, the teacher's role is more complex than in Jonsdottir's research, as a result of the inclusion of the VRLE. It also incorporates the teacher as both technician and computer administrator. Also, the teacher had to consider appropriate teaching methods, due to the fact that the VRLE was a new concept.

In common with Jonsdottir's research, Gunnarsdottir (2001a; also see 2.6.1) highlighted the significance of the teacher´s role in conventional IE classes. Jonsdottir stated how a teacher's relationship with their students is important, in terms of their learning. Similarly, Gunnarsdottir (2005) applied Vygotsky's theories to describe this context: If teachers are able to support students in their 'zones of proximal development' (Vygotsky, 1978), they consequently facilitate their ideation. The teacher may undertake several roles (simultaneously and sequentially) that are often interconnected and closely related one to another. Gunnarsdottir (2005) underlined the importance of the teacher becoming a facilitator in the classroom, when students are working (see further in 10.2.3.4), in order to enable their ideation.

Part of the research was to examine and discover the new roles of the IE teacher within a blended learning context: this had not been defined prior to this research, which may have created pedagogical and technological problems for the teacher and caused him to feel insecure in his work. Similar issues were examined in Kiryat Malachi's one-year pilot study, which researched online English courses in nine upper schools in Israel, within the context of blended learning (Graham, 2006). However, unlike this study, the teacher's role had been defined prior to the research and the teachers were not requested to find their own methods of teaching. Malachi's study suggested that, in order for blended learning solutions to be successful, teachers should be fully trained and familiar with the relevant computer programmes and their role in the course should be clearly defined (Graham, 2006). This was important, as the teachers were not used to this context and had not previously accessed such computer programmes. They were also unfamiliar with the role of being a teacher within a blended learning class.

It was identified in this research that the use of the VRLE is largely dependent on the teacher's ability to manage it (see chapter 5.0; 6.0; 7.0 and 8.0). However, the teacher also had to manage many other roles at the same time. Bonk et al.'s (2002) research similarly indicated that teachers have to co-ordinate many roles and responsibilities within the context of blended learning, in order to achieve e-learning success. A delicate and informed balance between these roles is vital to the success of e-learning (Bonk et al., 2002).

The ideation process provided the framework for the IE course and, in managing this, the teacher had to develop his roles. Some of these roles, relating to the use of the VRLE, were more demanding than conventional teaching. For example, the teacher had to:

- Organise the courses;
- Prepare for lessons;
- Identify the appropriate teaching methods and apply them in various contexts;
- Solve both hardware and software technical problems;
- Teach fundamental skills and train students in IE and the use of the VRLE;
- Teach the IE process inside the VRLE;
- Identify appropriate teaching methods during lessons:
- Be both instructor and facilitator;
- Engage parents in homework;
- Conduct brainstorming sessions and refocus students (partly in the VRLE);
- Support the ideation process by discussing problems, needs and solutions.

The novelty associated with and the complications of the teacher running lessons within the framework of blended IE learning appeared to cause a conflict of roles for the teacher; there was evidence of increased insecurity and he became more self-critical. He was working through the process of identifying and establishing his teaching methods and faced many problems in this, largely caused by the novelty of the new technology. He also had to assist students inside the classroom and the VRLE and encourage their self-reliance. Nevertheless, he had experience as an ICT teacher and was probably more capable than a classroom teacher, in terms of hosting the lessons; he was also the administrator for the school computers. In terms of curriculum development, it is important to be aware of these stresses, as some teachers may be unable or unwilling to confront them. Kennedy (1996) recognised this in his research on curriculum changes. His study concluded that the transferring of responsibilities to teachers, in terms of the designing and teaching of new courses, will only work if the teachers in question possess the necessary knowledge and skills, and are given time to evaluate the thinking behind the new developments. Kennedy stated: ‘teachers then can be powerful positive forces for change, but only if they are given the resources and support which will enable them to carry this out; otherwise, the change is more like to cause stress and disaffection...‘ (p.87). Similarly, in this study, the teacher frequently asked for more guidance from the author and also for text materials. However, unlike the Kennedy study, the pedagogy in this research was not defined beforehand, as the VRLE had not been used within the context of IE before. Therefore, the main aim of the research became to *explicate the pedagogy of using the Virtual Reality Learning Environment (VRLE) in supporting conventional*

Innovation Education within Icelandic schools. The teacher had to build up his own experience, identifying the preferred methods of teaching throughout the course.

10.2.2 The Teacher's Mindset and Responsibilities

The Oxford English Dictionary Online (2011) defined the term *mindset* as: *'*an established set of attitudes, especially regarded as typical of a particular group's social or cultural values; the outlook, philosophy or values of a person; (now also more generally) frame of mind, attitude and disposition*'.* The data from this research indicated (see chapter 5.0; 6.0; 7.0 and 8.0) that the following elements influenced the teacher's mindset:

1. Conflict between the roles of teacher and administrator;
2. Preparation for the course;
3. His reactions to being observed;
4. Workload;
5. School pressures;
6. Teaching.

The term *mindset* indicates 'set' or 'fixed'; however, it is readily apparent that an individual's mindset can develop, but this may be a slow process and thus may cause stress. In this research, the teacher's background (including his education, his social status, attributed social value, his life experience in general and his role as an educator) was the basis of his mindset and his reflection on the development of his roles, in terms of IE and the VRLE, enabled him to interpret the IE activities he was undertaking in a manner acceptable to him. The teacher's work was complex and his multiple roles and responsibilities were not pre-defined. As the project featured an inherent action research element, the teacher was confronted with new circumstances and with improving his professional endeavours; in addition, he was part of the data. He was also responsible for the maintenance of the school's hardware and software and such issues affected his mindset, lesson preparation, the selection of teaching methods and his ability to make professional decisions, in terms of the appropriateness of when to use the VRLE for IE.

Walker (2000) and Witfelt (2000) noted how, in non-traditional classrooms, such as the open/global classroom, the roles and responsibilities of the teacher have changed. For example, the teacher, as an agent, has to constantly update information and technology, in order to ensure learning is authentic and relevant. In blended learning, the instructor combines two or more teaching methods (Worthington, 2008) and the teacher in this research had to base his choices on the IE innovation process and fulfil the aim of training students in idea generation.

At the beginning of the fieldwork, the teacher's specific role was described as guiding and helping students to develop their ideation skills, supported by the VRLE (see chapter 5.0). In this, his administrator rights and ICT skills were important in using the VRLE in a conventional context, as he was able to set up the software and equipment; he was also able to repair it, if so required. However, during the research, the teacher's role was identified as complicated, in terms of managing the VRLE technology in a conventional classroom. It was noted in the first case study that the teacher experienced a conflict in roles, in terms of his administrator role and tutoring: this was largely caused by his limited skills in and minimal knowledge of the use of the VRLE and limited preparation time. The teacher stated that he needed more time to prepare and practice for lessons.

Hennessey and Deaney (2004) informed that the confidence of teachers plays an important role in influencing their use of information technology and multimedia within their programmes. It was also noted in this research that the teacher lacked confidence in the course plan he had developed in conjunction with the researcher. Furthermore, interviews with the teacher, the data from his logbook and author observations indicated that the teacher lacked confidence, in terms of teaching IE and using the VRLE. The teacher considered that the action research element of the course was making his role difficult and thus causing him confusion (see section A8.5). He noted how he and the author had to be innovative during the research, conducting the lessons in a flexible manner (see section A8.5), and he probably felt responsible for identifying appropriate teaching methods. The teacher played a significant role in the enquiry and part of the data referred to the teacher's reflections on his work, which was an important part of the action research element (Kemmis, 1988; Bassey, 1999; Reason & Bradbury, 2001; McNiff, 2002).

The teacher considered that the research was a substantial extra workload for him, as an after school activity, and he believed that it would be better to run the IE course within regular school hours. Running the course for a whole day, while intense, would probably have offered more flexibility. Nevertheless, the teacher managed to organise some of the case study lessons inside the school schedule. In these lessons, however, he was disturbed by other teachers seeking his help because he was the school's computer administrator; they were also likely to be curious about the research. In this respect, conducting lessons after school may be more appropriate, in terms of allowing the class to work in peace.

It takes time for both the instructor and students to adapt to the relatively new instructional concept of blended learning (Worthington, 2008). Furthermore, students' lack of technical literacy can also mean the teacher adopts the role of assisting students with computer skills and encouraging them to become independent learners (Worthington, 2008). Part of the research was to develop the VRLE and learn from it and thus software upgrades were required. The teacher noted that this would have been difficult for a non-specialist teacher and he himself did not have significant experience in dealing with the new software upgrades and he felt insecure in this. Consequently, it took time for both the teacher and the students to establish their ability to handle the computer facilities, in terms of both hardware and software.

According to Bradley and Russell (1997), frequent technical problems and the expectation of faults during lessons are likely to reduce teachers' confidence and a lack of available technical support is also likely to lead to teachers avoiding ICT, due to a fear of faults contributing to unsuccessful lessons (Cuban, 1999; Preston et al., 2000). This research indicated that the teacher lacked confidence, in terms of knowledge and skill in ICT; however, he was capable of solving the majority of problems during the research, due to his background as an ICT teacher. In one of the follow-up interviews, the teacher stated that this would have been too much for a teacher without such a background (see further in chapter 9).

According to Glick (2008), prior to implementing blended learning, a school's local material computer components should be analysed and customised. Graham (2006) also underlined the need to provide professional development for instructors, in terms of both online and face-to-face instruction. However, the teacher in this research had a special role as a pathfinder, in using the VRLE in IE. He was unable to get help from other teachers who had used the VRLE before and the only way forward in teaching IE was to build on his past experiences (see section A8.5), developing his approach from scratch (see chapter 5.0 and 6.0). During the research, the teacher informed that instruction books would have helped him to feel more secure in his instruction but, as he was the pathfinder, this was not possible.

Manternach-Wigans (1999) noted how teachers are often unable to make full use of ICT facilities as they lack time for lesson preparation and similar results have been found in other studies (Fabry & Higgs, 1997; Preston et al., 2000). During this research, the teacher had a large workload and undertook the courses as an after school activity. The author thus tried to give him adequate support, in order to ease his workload. After the pilot study and case study series two, the teacher was given general training for lessons, with regards to the use of the VRLE and teaching IE. Better preparation became part of the research plan for case study series two and three and help pages were set up inside the VRLE. However, the teacher did not access the help pages, probably because his workload was high and his preparation time was often limited. Teachers must have diverse experiences, in order to enter the classroom with a comprehensive ability and an associated positive belief system necessary in the use of technology (Russell et al., 2003). The teacher had both experience of being a class teacher and an ICT teacher. However, during the research, the teacher was also encouraged to spend time developing his own experience of using the VRLE for IE, mirroring the work the students were required to do.

The conflict of roles experienced by the teacher appeared to reduce after the first case study, as his experience grew; however, the teacher faced many unexpected administrative and technical difficulties throughout the research. Thus, he noted how, without administrative rights, a regular teacher would have required extra support. Then, in the follow up interview, the teacher mentioned that the associated technology and the computer literacy of students had increased enormously and thus such teaching would be much easier today (2008), both for teachers and students. The teacher considered (see section A8.5) the VRLE as ‘exotic’ at the time of the case studies (2004), but noted that it would be seen as normal today. More advanced computers with faster internet connections are available in schools today and these facilities may have aided the teacher´s work as an administrator and the students’ access to the VRE from home; they may also have allowed the VRLE to be developed further. Smartphones are now commonplace and may be integrated into schoolwork: this might have helped the students in this research, as they could have used such phones as a tool for the identification of problems and needs (rather than having to use the inventor’s notebook). However, some parents may not be able to provide such new and expensive technology and this would place some students at a disadvantage. Nevertheless, implementing a new technology is not just a question of parents buying expensive equipment. The teacher always has to be able to implement a relevant learning context and identify a suitable method of teaching.

Dewey asserted that, if a teacher teaches today as he was taught yesterday, he will rob his students of tomorrow (Turkmen, 2006). Thus, the use of technology can help teachers relate to today’s students, who are very media aware, prompt new approaches to the curriculum and encourage developments in teaching skills (Schwarz, 2000). However, teachers have to be up to date with their skills and knowledge if they are to meet the students’ needs in the use of such technology. During the last case study, the teacher did not mention any technical difficulties or problems in managing the software or the hardware; this was probably because he had significantly improved his skills and knowledge and was able to manage both. Nevertheless, as with the other case study series, lesson preparation was still an issue for him: he felt badly prepared, both for the courses and the lessons; in addition, he was not confident with the course plan he had implemented. However, this time he was more skilled in using the VRLE and was familiar with conducting an IE lesson; he had also prepared for lessons.

Future in-service teacher training, in terms of IE and the use of the VRLE, may well be based on the VRLE. The MLE could be used for individual training and an online discussion facility, inside the VRE, would enable teachers to share their experiences and offer advice to others (with a mentor checking postings). This would ensure that schools could train teachers inside normal working hours, although time for this would have to be made available. Further research could explore how long such training would take, in terms of an experienced IE teacher learning to use the VRLE and a teacher new to IE learning about both the IE and the VRLE.

Self-criticism was, most likely, a part of the teacher’s general mindset and this may have incorporated a lack of confidence and self-efficacy (see section A8.5): self-efficacy is the belief that one is capable of performing in a certain manner, in order to attain certain goals (Ormrod, 2006). According to Bandura (1995, p2), self-efficacy is ‘the belief in one’s capabilities to organise and execute the courses of action required to manage prospective situations’. Self-efficacy affects how people feel and low self-efficacy is associated with depression, anxiety and helplessness (Ozdemir, 2007). However, the author provided the teacher with social support, via after-lesson discussions. He was also always readily available, as he was responsible for collecting data during the research. However, he did not want to interfere in the research and thus kept a low profile. His closeness to the teacher did mean that the author was a source of support for the teacher and the teacher could always discuss any problems that may have occurred during lessons (in the after-lesson discussions). Several researchers have concluded that people who have social support available to them (i.e., a listening ear and emotional support) are less likely to experience burnout (Ozdemir, 2007; Gil-Monte et al., 1997). Similarly, regular teachers without social support would probably have given up, in terms of this research. Running a long-term IE class, incorporating the use of the VRLE, within the school's normal schedule is a totally different context and requires further, more extensive research. A teacher running such a class would be better trained and supported with educational material, based upon experiences such as in this research.

10.2.3 Identifying a Learning and Teaching Strategy for Using the VRLE for IE

Part of the research concerned the teacher's role in identifying appropriate teaching methods to support student idea generation and the approach selected was a mixture of face-to-face teaching and computer-mediated teaching (an opportunity offered by the research) (see figure 10.1). This approach reflected blended learning, where the teacher's role is based on multiple teaching methods, both old and new. Bonk and Graham (2006) stated that blended learning 'is the combination of instruction from two historically separate models of teaching and learning: traditional learning systems and distributed learning systems' (p5). Graham (2006) further defined blended learning as: '...an approach in blending different learning methods, techniques and resources and applying and delivering them in an interactive, meaningful learning environment. Learners should have easy access to different learning resources, in order to apply the knowledge and skills they learn under the supervision and support of the teacher inside and/or outside the classroom. Such an approach may apply face-to-face instruction with computer-mediated instruction......learners and teachers can work together to improve the quality of learning and teaching' (p3-21).

The research employed blended learning, focusing on the use of the innovation process inside the VRLE. This context of blending learning required the use of different teaching methods and a revision of the teacher's role, in order to improve the value of learning and teaching. During the research, the teacher employed both roles of instructor and facilitator; he had to understand the learners' needs, in order to support their work. He also realised that he had to provide the students with specific training and a basic knowledge of a given situation. This meets one of key findings in Donovan et al.'s (1999) research, which asserted that students come to the classroom with preconceptions of how the world works and, if their initial understandings are not engaged, they may fail to grasp the new concepts and information that are taught. However, the teacher in this research, as a facilitator, had to support the students' autonomy and self-reliance during their work, in order to enable them to work with the course content that they had generated themselves.

Two learning environments were used together: the conventional classroom and the interactive VRLE: this enabled the students to employ different learning resources during idea generation, such as the internet, tutorials inside the VRLE, written material provided by the teacher and teacher guidance within the classroom. Blended learning also enabled the students to communicate in various ways, both face-to-face and online, and thus provided them with both individual and group learning support (Hough, et al., 2004; Loiselle et al., 1998; Schrum & Berenfeld, 1997); for example, the knowledge of the whole group could be used in developing solutions. In this sense, the students also learned from each other and they were able to collaborate face-to-face, both in the classroom and inside the VRLE, supported by multi-modal communication via computer-supported media. However, the nature of students' communication varied: they sometimes played together but, at other times, they supported each other's work by contributing to each other's solutions. Although collaboration between students is desirable in educational contexts, for many reasons, research in the area of online communications has focused on how deep and substantial the conversations are from the viewpoint of the teacher or the researcher, with a focus on cognitive engagement (Garrison and Cleveland-Innes 2005; Gilbert and Dabbagh, 2005; Wallace 2003; Zhu 2006). The results of these studies have often shown that students engage in superficial rather than deep cognitive levels, in terms of online discussions. Practitioners continue to enquire as to how best to integrate discussions into online environments, in order to meet learning goals.

Figure 10.1 below highlights the context of blended learning in this enquiry, as a combination of learning through the VRLE and face-to-face learning.

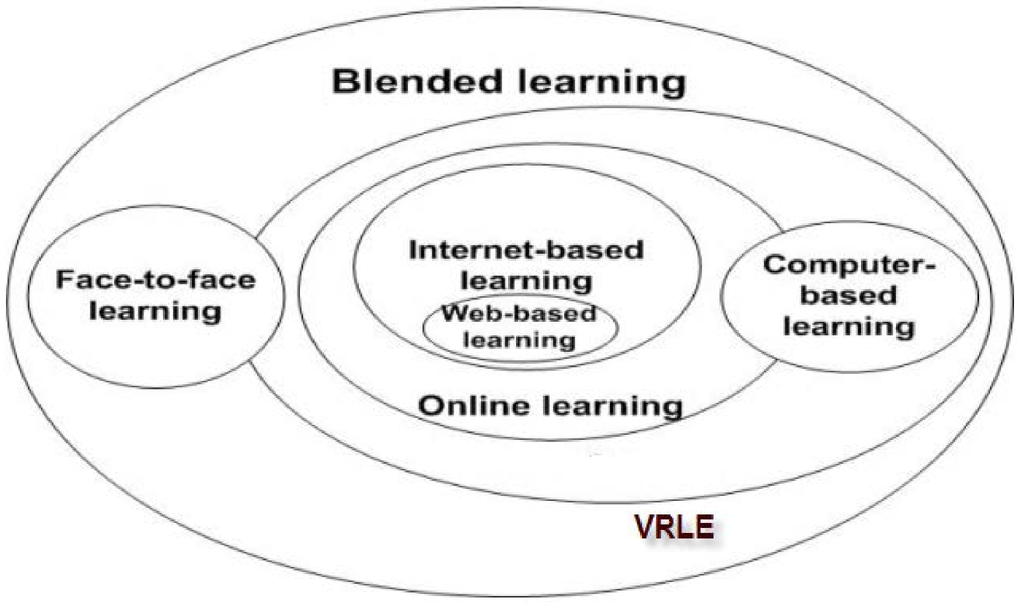

Figure 10.1: The Components of blended learning (developed from Bonk and Graham's diagram of blended learning (2006, p5).

10.2.3.1 Teacher's Background

The teacher was a general subject classroom teacher, who taught ICT and design & craft; he was also the school's ICT administrator. He had experience of IE and the innovation process via helping students make prototypes for the *Young Inventors Competition*; thus, his background meant this teacher was suitable, in terms of undertaking IE courses. According to the social constructivist approach (see section 2.13.1.3), teachers have to adapt to the role of facilitator, rather than instructor (Bauersfeld, 1995), yet the teacher noted that his background in design and craft had enabled him to change his teaching mode from instructor to facilitator (see section A8.5). He argued that design & craft teachers usually dealt with individual student projects and thus were familiar with motivating and supporting individuals in a flexible manner. However, it should be noted that the teacher also used more formal instructional teaching methods within the case studies. He reported how he had to find his own methods of working, instead of relying on textbooks. Furthermore, he had the confidence to act flexibly, in terms of his course plan.

10.2.3.2 Teaching Methods Employed in the Case Studies

The teaching methods used in the first case study were based on professional discussion between the author and the teacher and, from then on, the teacher used his professional skills and autonomy to reflect on each case and develop the teaching methods. The teacher was also an active participant in the research, providing an independent perspective and helping to minimise observer bias.

The teacher developed the following basic structure:

- Introduction;
- basic training;
- students' reporting of needs and problems;
- brainstorming sessions;
- students developing solutions inside the VRLE, both as individuals and in groups;
- summary and preparing students for the next lesson.

At the end of the lesson, the group gathered in front of the blackboard: their progress was discussed and then the teacher introduced the next lesson and gave the students homework (see chapter 5.0; 6.0 and 7.0).

Building on the work of Whitelock and Jelfs (2003) and Kerres and De Witt (2003), teaching in the case studies was built on a combination of:

1. Conventional IE learning, using the VRLE approach;
2. The media and tools employed in the classroom and the VRLE;
3. The various didactic learning methods and delivery formats.

The students learned through the IE process, working with solutions to the problems and needs they had identified in their environment (see chapter 1.0). Their homework and personal experience was thus important, as the students used this as a source for their idea generation. This is in harmony with the basic idea of Constructivism, which states that the learner is stimulated to construct his knowledge independently (Bischoff et al., 2002).

The students' work was individually-based (see chapter 1.0), but collaborative activity was employed at key points, in order to provide support. Collaboration between students is an important factor, in terms of facilitating their learning (for the definition of blended learning, see Heinze and Procter (2005) and 2.13) and, in this enquiry, the

MLE was used to support individual idea generation, with students collaborating inside the VRE. Furthermore, the VRE was used in group idea generation (see chapter 7.0). The values of the VRLE collaboration are in-line with social constructivist beliefs, such as the Zone of Proximal Development (ZPD) (Vygotsky, 1962; see section 2.13.1.2). As a result of the VRLE's ability to enhance both collaboration and co-operation, the teacher was able to employ various teaching methods during the enquiry, such as direct instruction, training, group work and individual-based sessions inside the VRLE.

The teacher decided to introduce the students to the VRLE before the lessons began and the author noticed that the teacher's introduction and training had a positive influence on the students; sometimes, the teacher allowed them to 'play' inside the VRLE, in order to enable them to become familiar with it, and he considered that this reduced the teacher's subsequent workload. It was noted that the students had experienced virtual reality previously, through playing computer games at home, and their strong motivation for playing inside the VRE was also noted (see chapter 5.0; 6.0 and 7.0). There is empirical evidence that games can be an effective tool in enhancing learning and in the understanding of complex subject matter (Prensky, 2001; Turgut & Irgin, 2009; Ricci et al., 1996; Cordova & Lepper, 1996). Prensky (2001), for example, argued that computer-based or digital games are essential in addressing the learning requirements of the modern 'digital' generation: this suggests that one alternative, in terms of continuing this research, would be to investigate and exploit the game playing aspects of the VRLE, in order to identify any aspects of this that might be transferrable (in pedagogical terms) to teaching (Connolly et al., 2004). It would be highly desirable to harness the appropriate properties of computer games to enhance learning and improve student performance, in terms of IE.

10.2.3.3 Basic Training and Establishing the Content of the Course

Homework, the introduction and pre-training were identified as important in all the IE courses. These gave students a basic knowledge and understanding of the innovation process prior to the lessons and pre-trained them in using the VRLE. The students were asked to access the VRLE from home, as this should have helped them use the VRLE. The teacher was effectively taking a social constructivist approach, in that he ensured that IE was an active process based on social interaction in the home, the classroom and the VRLE (Vygotsky, 1978; von der Glasersfeld, 1992; Thorsteinsson and Denton, 2007).

At the beginning of lessons, the teacher introduced the plan and, at the end, he discussed the following lesson. Observations indicated that this process focused the class (see chapter 5.0; 6.0 and 7.0). The teacher underlined the value of the identification of needs and problems at home prior to the course starting, and he understood the purpose of the homework, which was to prepare for idea generation inside the VRLE, through personal experiences. Von der Glasersfeld (1989) noted how an individual's knowledge of the world is bound to personal experiences and is mediated through interaction with others.

It was important to link the students' homework with their activities inside the VRLE; after this, the students could work independently (Thorsteinsson & Denton, 2006). At the start of lessons, students reported any problems and needs they had identified and discussed them in brainstorming sessions conducted by the teacher (see chapter 5.0; 6.0 and 7.0): this helped students to better understand the innovation process. Students brainstormed both formally, in face-to-face sessions with the teacher, and informally, during their work inside the VRLE. The teacher assisted students inside the classroom, facilitating their work inside the VRLE (see chapter 5.0; 6.0 and 7.0), but could possibly have undertaken brainstorming sessions inside the VRE.

Brainstorming sessions enabled students to find solutions and start the idea generation process inside the VRLE. It also helped the teacher to gain direction for lessons and reduced his insecurities. Part of his insecurity referred to the fact that lessons were based on the students' own ideas (see chapter 8.0); thus, he underlined the importance of the identification of needs and problems during the course, in order to enable the learner generated context (LGC). Luckin et al. (2007, p91) defined the LGC as 'a context created by people interacting together with a common, self-defined learning goal. The key aspect of learner generated contexts is that they are generated through the enterprise of those who would previously have been consumers in a context created for them'.

In the literature, the LGC is usually based on the premise that learning and teaching should not take on new supportive technologies without contextualising the learning first (Luckin et al., 2007). In learner generated contexts, technology is seen to offer new dimensions for active participation and innovation in learning. LGC within IE relates to the constructivist learning theory, which states that students learn best when they are allowed to construct a personal understanding based on experiencing things and reflecting on those experiences (Jonassen, 1999; Tam, 2000).

10.2.3.4 The Teacher as Instructor and Facilitator

IE courses can be interpreted as learner-centred (e.g., LGC) and any activities can be described as constructivist and socio-cultural (Gunnardottir, 2001a, Bonk & Cunningham, 1998). The VRLE can also be seen as an interactive, collaborative, learning tool, which supports idea generation (Thorsteinsson & Denton, 2007), and the addition of the VRLE altered the teacher's role (Thorsteinsson, 1998; Thorsteinsson & Denton, 2003). However, it is noted that the aim of this enquiry was to explore the extension of the initial IE pedagogy model, rather than to re-interpret it, in terms of constructivist and socio-cultural practices.

The traditional teacher-centred role in which knowledge is 'transmitted' from teacher to learner has been criticised and replaced by alternative models (Heinze, 2008; Bonk & Cunningham, 1998) and the emphasis is now on guiding and supporting students as they learn to construct their understanding of their culture (Laurillard, 2002; Brown et al., 1993; Brown, Collins & Duguid, 1989; Cobb, 1994; Collins, 1990; Duffy & Cunningham, 1996; Pea, 1993b). The research, however, identified the importance of the IE teacher, in both the roles of traditional instructor and facilitator. The VRLE guides students, featuring interactive instructions and help pages, and this context requires new skills and knowledge. In terms of IE and the use of the VRLE, the teacher's background enabled him to change his mode of teaching in accordance with happenings in the classroom. Bonk et al.'s (2002) study addressed e-learning from the perspectives of the course learners, the course advisor and the instructors. Although there were differences in the perceptions of the overall learning environment, the students largely viewed the teacher as facilitator rather than instructor. A key role of the on-line instructors was to provide direction and guidance, which facilitated learning.

The teacher undertook the role of instructor in his introductory sessions; he also provided students with basic training in the use of the software and conducted brainstorming sessions: these sessions were useful in preparing students for collaborative activities inside the VRLE. This reflects the work of Gunnarsdottir (2001a, see also 2.15.3), which identified the role of the IE teacher as creating the circumstances that support or scaffold students' idea generation and a source of information that facilitates the activities of the students (Vygotsky, 1978). Nevertheless, it should be noted that the teacher switched roles during these lessons; for example, he began with instruction and then switched to discussion (see chapter 5.0; 6.0; 7.0 and 8.0). He sometimes taught directly from printed documents, but also assisted students in defining needs and solutions themselves.

The teacher had to help the students when they began to use VRLE: he was required to solve any technical problems and assisted students when they worked inside the VRLE. However, he tried to improve the self-reliance of the students by acting as a facilitator, rather than an instructor. The teacher supported the students with discussion and advice; this helped develop autonomy and met the individual needs of each student. Autonomous learners take responsibility for their own learning and for any group learning. Little (1991) described autonomous learning as '…the capacity for detachment, critical reflection, decision-making and independent action'. (1991, p4), while Schwienhorst (1998) asserted that the concept … 'contains the idea that learning essentially arises from supported performance' (p18). Dam (1990, p17) emphasised the 'socially responsible' nature of the autonomous learner.

It was noted that the teacher in this research employed a specific teaching technique, whereby he would leave the class for short periods of time (see chapter 7.0). In debriefing sessions, he informed that his intention in this was to give the students a degree of autonomy and to establish trust. In the case studies the teacher again used this technique and noted an increase in symbiosis; furthermore, he considered that the VRLE enhanced this autonomy and collaboration. The teacher felt that teacher intervention can be a hindrance and may limit students' opportunities, in terms of autonomy. He further noted how the teacher's expectations can cause students stress and reduce their effort; thus, too much interference was not a good thing, as it caused the students to feel stressed. To give the students space, the teacher would often move to the other end of the room, in order to facilitate a degree of autonomy. Furthermore, when the students were alone, they began to seek help and supported each other in this, which is an example of collaboration and autonomy. This reflects the work of Gunnarsdottir (2001a, see also 2.15.3), who highlighted the importance of the teacher's role as facilitator. She also noted the danger of overwhelming students who, she considered, would stop co-operating in innovative work.

The structure of the VRLE emphasises both individual and collaborative work and social interaction is identified as an element of knowledge construction (Thorsteinsson and Denton, 2008). This mirrors Bricken, (1991) and Bricken & Byrne (1993), who concluded, via their research, that VRLE technology offers benefits that derive from the capacity to support computer-based collaborative supportive learning and constructivist-learning activities. The VRLE can support autonomous learning through the communicating of ideas and information, the sharing of information and documents and the providing of feedback, in terms of problem-solving activities (Crook, 1994). A major principle of autonomous learning is that students should take responsibility for their own learning (see further in Boud, 1988a; Dearn, 1998; Stanton, 1988; Higgs, 1988; Long, 1990; Benson & Voller, 1997; Breen & Mann, 1997; Little, 1997; Littlewood, 1997; Sheerin, 1997; Voller, 1997; Champagne et al., 2001; Cotterall, 2003).

In order to increase self-reliance in collaborative work, the teacher gave students detailed instructions before work began inside the VRLE. According to Gunnarsdottir (2001a), the role of the IE teacher is to create circumstances that support or scaffold the learning of students and to be a source of information that facilitates the activity of the students. The teacher supported the students, sometimes individually and sometimes in pairs, although they did not always ask for his help.

10.2.3.5 Time Issues

The teacher viewed his lesson plans and control of the pace and timing of lessons as important. He felt that, if he were not in control, the students might get distracted from their idea generation work. In relation to pace and time, two important aspects emerged: the teacher noted that the students worked better early in the morning, rather than after school lesson; he also stated that he referred to the technique of applying time pressures. For example, he ensured that there was always plenty for the students to do and kept reminding students of the time left to do tasks. He stated that this appeared to be beneficial, in terms of keeping the students on-task. Applying time limits and pacing lessons appeared to promote student focus.

It was identified in CSS1P that time pressures appeared to enhance students' idea generation and short brainstorming sessions refreshed and refocused them. This was thus repeated in the later case study series. In CSS2 and CSS3, students were also asked to sit at their computers during presentations, so that they were not disturbed by having to move. It is difficult to differentiate between the effects of the brainstorming sessions and the deliberate manipulation of pace, in terms of the refocusing and output of ideas. It is assumed that both will have had some effect on students. Students' individual differences and social characteristics could also have influenced any effects and the various possible methods of communication, both in the classroom and within the VRLE. Earlier researches on time pressure are divided; for example, Andrews and Farris (1972) found a positive relationship between scientists' perceived time pressures, in terms of completing their work, and the 'innovativeness' of such work. However, Amabile and Gryskiewicz (1989) found no significant relationship between time pressure and the innovativeness of workers from five different social groups. The participants in both these studies, however, were adults and the effects may be very different with children (as in these case studies).

Too much pressure, in terms of time, can limit the students' ability to reflect on their work, due to less time being available and, possibly, the stresses associated with this. This was apparent in case study series two, when students reported problems and solutions during brainstorming sessions, the reflection element of this was limited. Furthermore, the students were unable to agree on which idea to work with. Thus, in case study series three, more time was given for reflection, in terms of both needs and problems. The brainstorming sessions were organised inside the lesson plan, in order to ensure that there was enough time for this. In lesson one of case study three, the additional time may have helped students to agree on an idea, in terms of co-operation. In this, the students did manage to agree on which idea to work with inside the VRE; however, the number of ideas was fewer than before. This might be explained by Yerkes and Dodson's hypothesis (Yerkes & Dodson, 1908), which suggested an empirical relationship between arousal and performance.

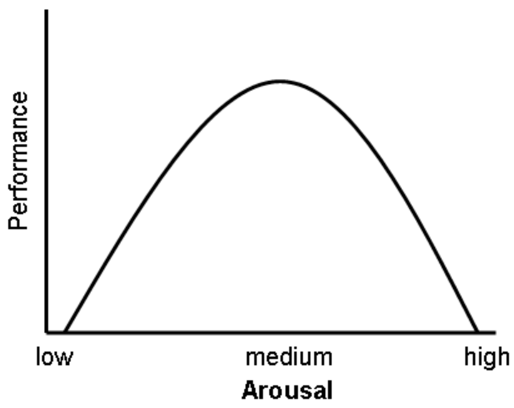

Figure 10.2: The Yerkes-Dodson hypothesis.

This hypothesis indicates that performance increases with physiological or mental arousal, but only up to a point: when levels of arousal become too high, performance decreases. Increased arousal leads to an increase in attention, resulting in better performance on the task, up to this optimal point. However, excessive arousal creates increased levels of stress and performance suffers. Thus, too much arousal decreases the level of performance, indicating that there is an optimal level. Other research has indicated that the correlation suggested by Yerkes and Dodson does exist (i.e., Broadhurst, 1957; Duffy, 1962; Anderson, 1988).

In lesson two, the teacher once again used time pressure and brainstorming to focus students, while they remained at their computers. Subsequently, students were more productive; however, this time they worked as individuals and so no discussion or agreements were required. Some research has indicated that individuals or groups which simply pool ideas perform, in terms of the number of ideas generated, better than groups with significant verbal interaction (Taylor et al., 1958; Paulus et al., 1995; Miller, 2009). The major reasons for this are blocking, social loafing and evaluation apprehension (Nijstad et al., 2003; Szymanski & Harkins, 1992; Gallupe et al., 1992).

10.2.4 Homework

Throughout the research, students' homework was seen as important, as it generated the course content. Homework was based on the identifying of problems and needs, the use of the inventor's notebook and communication with families. Similarly, as in the earlier model, the teacher had to understand the meaning of students' homework and enable its exploitation, in terms of idea generation inside the VRLE. Furthermore, homework also enabled social interaction inside and between the students' homes, the classroom and the VRLE, as indicated below.

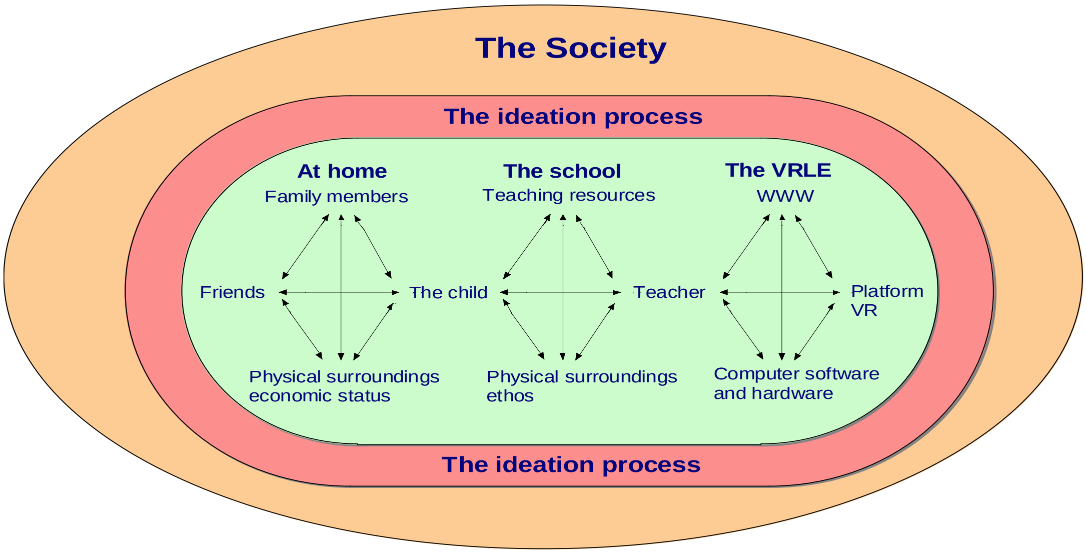

Figure 10.3: Shows the social interaction between the three elements of the IE course.

Wenger (2005) stated that school is no longer the centre of learning or the place where students come to acquire knowledge to use in the outside world. Learning takes place in life and the classroom is just one aspect of this. With regards to social constructivist theories, Gunnardottir (2001b) identified social interactions between the home and the classroom as vital. However, in the new model (see figure 10.3), the VRLE forms an additional element and also connects the three elements together, as it is both accessible to students both inside and outside of school. Social constructivists see the context in which learning takes place as central, including the social contexts that learners bring to their learning environment (Gredler, 1997; Jackson, et al. 2006). They emphasise the importance of culture and context in understanding what occurs in society and the construction of knowledge is based on this understanding (Jackson, et al. 2006; Derry, 1999; McMahon, 1997). According to Gredler (1997), knowledge, meaning and understanding of the world can be addressed in the classroom from both the view of the individual learner and the collective view of the entire class (Cobb, 1995; Gredler, 1997).

Students generated the problems and opportunities that were used in the IE courses at home, in the classroom and in the VRLE (see figure 10.3) and the inventor's notebook (IN) (see section A2.0.1) played an important role in connecting the three elements together (see figure 10.3). The teacher thus placed an emphasis on the students' identification of needs and problems during the course and supported their idea generation by brainstorming with them during lessons (using their homework). Students are part of the constructed environment and take part in constructing it (see chapter 2.0). In turn, the environment is one of the characteristics that shape students (Bredo, 1994; Gredler, 1997). When a student's mind in engaged, they are interacting with the environment. Therefore, if the environment and the social relationships of students change, the tasks of each student may also change (Bredo, 1994; Gredler, 1997; Jackson, et al. 2006). As a result, learning should not take place in isolation from the student's home.

According to the teacher observations in this research, the IN seemed to increase students' interest in identifying ideas and thus probably fostered their interest in IE. This was the initial state of the IE innovation process and thus activated students' ideation: the IN helped the students to remember, record and define identified needs and problems. According to Runco & Dow (1999), an essential step in solving problems is to firstly define them and the above authors also considered that, in training students to solve problems, such students also need to be able to handle ambiguous tasks, in order to foster clarification.

In Gunnarsdottir's research (2001a), the IN is a tool for communication, supporting social interaction, and is the initial state of the innovation process. The IN may also have made the IE context socially realistic for the students and these notebooks have been used by inventors, scientists and engineers such as Thomas A. Edison, Leonardo da Vinci, Thomas Jefferson and Albert Einstein (Grisson & Pressman, 2000). In CSC1 and CSC2, students also used the VRLE as a virtual IN at home., recording needs, problems, ideas and solutions inside the MLE. They also tried to enter the VRE; however, most of them lacked an appropriate graphics card and were unable to access the VRE. As a result, few solutions were uploaded to the VRLE from home and the physical IN was thus particularly useful.

Another element of the homework was the teacher's role in informing and engaging parents; he attempted to encourage them to support their children in their homework. None of the parents had experienced IE or the VRLE when they were at school and so the teacher provided them with a relatively detailed course plan, prior to the start of the course. In the later studies, the teacher also wrote a letter to parents, outlining how important it was for them to support their children in the initial state of the innovation process. Researchers have identified that parental involvement increase a child's educational achievement (see further in Cooper, Jackson, Nye, & Lindsay, 2001; Epstein, 1994; McCarthey, 2000; Snow, 1999) and have also indicated that parental interaction with students during the completion of homework is an important factor in improving parental involvement, thereby improving the home-school connection (see further in Barbour, 1998; Comer & Haynes, 1991; Cooper et al., 2001; Epstein, 1994; Hoover-Dempsey et al., 2001; McCarthey, 2000; Segel, 1990; Snow, 1999; Swick & Graves, 1993; Taylor & Dorsey-Gaines, 1988). Nearly all of the parents gave their child some support, but none of them talked about needs or problems, only about ideas. However, students often talked with someone in their family, in order to achieve more needs and problems. Three of the parents noted that ideation work could be reinforced by setting up a course for the parents and getting the students to collaborate with their friends more (see chapter 5.0). The small numbers of participants involved prevent hard conclusions being drawn, as the results may have been due to the variations that often arise in small groups.

During CSS1P and CSC2, the teacher suggested the use of mobile phones and blogs to send IE needs and images directly to the VRLE, instead of using the IN. The teacher informed that mobile phones connected to the VRLE could possibly have supported the innovation process, as a modern alternative to using the INs. Students tried to use the blog site at home and carried out a few trials, but they never did so at school. It could be assumed that further introduction and exercises may encourage greater use of the blog, if time were available to do this. Students, however, used the IN with ease, recording identified needs.

Prensky (2005) asserted that the following learning processes can be supported through the use of mobile phones: listening, observing, imitating, questioning, reflecting, trying, estimating, predicting, speculating and practising (traditional classroom environments often only support a portion of these). Mobile blogs could thus be employed as a tool in supporting the process of novel learning amongst IE students. However, a blog might be better used in the context of open and distance learning without physical communication inside school. More research in this area is required.

10.2.5 Use of the VRLE

The VRLE is a learning platform designed to facilitate idea generation within IE, support the teacher and the students' work and enable collaboration. Part of the research was to further develop this learning platform and to identify appropriate teaching methods. Throughout the research, the VRLE generally worked well: it remained stable and the students registered easily. A variety of issues associated with the use of the VRLE arose during the enquiry, such as technical difficulties and upgrade requirements. The teacher noted how having to deal with the VRLE technology would have been too difficult for a non-specialist teacher and considered that his experience of the equipment and software was important in overcoming any difficulties (see section 10.2.2). Studies (i.e., Mumtaz, 2000) have highlighted several reasons why teachers do not use computers in their teaching; for example:

- Lack of teaching experience, in terms of ICT;
- Lack of on-site technology support for teachers;
- Lack of help in supervising pupils, when on the computer;
- The existence of ICT specialist teachers, who teach students computer skills;
- Lack of computer availability.

Some teachers would probably be unwilling to work with the VRLE without appropriate training (Mumtaz, 2000) and it is noted that, in Iceland, the curriculum was changed in 1999. This focused on the use of ICT in general subjects, rather than it being viewed as a specialism. At the time of the fieldwork, these changes were only just being adjusted to. In the follow-up interview (2008), the teacher stated that such implementations would have been much easier today, as computer technology and the computer literacy of staff and students has progressed enormously. The novelty of using the software would therefore be different. As the technology improves and we learn more about how people learn by interacting with and within VRLEs, such technology will be seen more frequently in schools (Inoue, 2007).

Taylor (1980) and Blom and Monk (2003) classified the computers used in education as tutors, tools and trainees. They indicated that the use of computers as both tutors and tools can improve and enrich classroom learning and neither student or teacher are required to know much about computers. Blom and Monk (2003) further categorised the role of computers within an educational setting, as below:

1. *Tutor:* Often referred to as ‘drill and practice’ or ‘computer-aided instruction’. Learners are presented with information and are then usually quizzed on their subsequent knowledge.
2. *Tool:* Learners direct the learning process, rather than being directed by the computer. This approach sees learning as an active process of constructing knowledge through experience.
3. *Tutee:* Typically, learners use construction kits to help them reflect upon what they have learned through the innovation process.
4. *Enabling computer supported collaborative learning:* Learners use network based software to learn and communicate with members of the teaching team. Learners can also become involved in educational online communities with students from different geographical regions.

The VRLE was designed to support the both students’ and the teachers’ work in IE, and, as demonstrated in the above categories, the VRLE software offered multiple roles, depending on the student activities at any one time. The teacher considered that the VRLE both guided the students’ work and provided structure. This reflects the role of the computer as a tutor (see 1 above).

Students learned to use the VRLE through experience, but were also trained in this by the teacher. Thus, the students were able to use the VRLE as a tutor, tool, tutee and as a support in CSCL (see 1 to 4 above). Bruckman and Bandlow (2003) noted that most software tools for learning have been designed for one student working at a computer; however, learning is generally recognised as a social process. Accessing the VRLE network inside the classroom made it possible for students to learn from one another, both face-to-face and online (as in 4 above).

In case study series two, the VRLE was upgraded and a help page was set up within the VRLE, for both the students and the teacher. The students did not access this and the teacher stated that the VRLE needed to be more advanced and interactive, both for himself and the students. He believed that, if students had problems using the VRLE, they would just not use it and thus he suggested that a hard-copy material for using the VRLE. It was noted that the students appeared to learn easily through the direct use of the software, but the teacher requested more concrete learning material and a traditional instructional phase. Such requests may partly be due to his apparent conflict in roles and his insecurity, in terms of being both teacher (instructor) and facilitator. It could also have been the result of a lack of training and preparation. However, as a pathfinder, there was not the same training available to the teacher.

Observations indicated that the students felt it was important to be able to personalise the interface of their virtual workshops; for example, with a photograph of themselves. This, however, did distract them from their idea generation at the beginning of the first lesson; in future, it may be appropriate to make time for such familiarisation and individual personalisation. Blom and Monk (2003:193) defined personalisation as a process that changes the 'functionality, interface, information content or distinctiveness of a system, in order to increase its personal relevance to the individual'. However, the author also noted that, in personalising their interface, the students were effectively exploring and practicing using the interface, together with claiming ownership. Oulasvirta and Blom (2008) argued that the need for autonomy and self-determination is not met when personalisation is dictated by the software instead of the user.

Good computer literacy enabled the students' work and, during the research, they had no major problems in using the VRLE. In all the case studies, the students easily accessed the VRLE and quickly became self-reliant. Due to the small sample size, it was difficult to extrapolate the findings to normal teaching groups. However, the author's experience as a teacher in Iceland indicated that this cohort was reasonably representative. The teacher argued that using the VRLE for IE was different from the old model of IE, as it was closer to the students' mindsets, in terms of the daily use of ICT (see section A8.5 and Prenski, 2005). In addition, they were able to access it from home and learned by playing inside the VRLE before lessons began. The teacher considered that 'playing' inside the VRLE increased the students' skills and he was convinced that the use of avatars inside the VRE was just entertainment. However, playing games in the VRE made the students more skilled and confident in using the VRLE and made them more familiar with each other. This activity might be referred to as 'edutainment': a term that refers to describing computer software that both educates and entertains (The Oxford Dictionary, 2008). Educational researchers and psychologists have written extensively about the benefits of play as an integral part of children's learning. Hussain et al. (2003) argued that teachers have not fully understood the importance of edutainment and asserted that children's everyday play experiences could be employed as a tool for teaching. Many electronic games promote collaborative play and motivate students, in terms of spending time playing such games, solving problems and improving their skills (Hussain et al., 2003). To dismiss the use of the edutainment aspect of the VRLE in the classroom, just because students were having fun, would therefore have been unwise. When students are having fun, they are motivated in learning (Rieber, 2001) and, in the case studies, the students were given the opportunity to play in the VRE prior to the start of lessons and also during lessons, as a break from their work in the MLE.

The teacher considered that the students required training, in terms of using the VRE for idea generation. The VRE was new to the students and it was thus difficult for them to design together within the VRLE, as avatars. Working inside the VRE was tiring, but voice over IP helped students to co-operate. Being physically together and being able to speak to the teacher, both inside the classroom and the VRLE, appeared to assist their work. Any difficulties may partly have been the result of a lack of experience in the students working together in two worlds at the same time; however, the students asserted that they could get used to the VRE, probably as a result of the fact that students today have grown up using computer-based multimodal communications. Nevertheless, for the teacher, this may have seemed a difficult task, as he was not used to such technology. Social presence is an important aspect of the VRLE (Hauber et al., 2005) and refers to 'the degree of feeling, perception and reaction of being connected by computer-mediated communication to another person' (Tu and McIsaac, 2002:140). Hauber et al. (2005) interviewed students and ascertained that, in addition to the teacher acting as facilitator in a MLE, there is value in gathering all students in a common location. This could be useful in engaging students in co-operative or collaborative activities. During these activities, students noted that they were better able and more interested in communicating with other students. However, unlike this project, Hauber's VRLE did not incorporate a VR element and thus his students were unable to interact as avatars, face-to face in a virtual world. Nevertheless, being together inside the classroom might present similar values as being in a virtual world, but this requires further research, especially within the context of open and distance learning. It is thus vital that teachers use their skills to ensure that participants in a virtual learning environment develop a sense of being together inside the medium. VRLEs offer more than simply the exchanging of ideas and the transfer of knowledge; they offer a method of establishing a community of learners (Hamburg et al., 2003).

Hamburg et al. (2003) demonstrated that collaborative learning, when compared with individual and competitive learning scenarios, raises the achievement level of students, increases their problem-solving abilities, presents learners with cognitive advantages and positively influences the development of personality traits. These factors are beneficial for future learning, whether autonomous or co-operative and future working (Tozer et al., 1995). The single teacher's isolation in this research was readily apparent; he was unable to gain support from other teachers, as they had not experienced a similar situation. Thus, future research could perhaps involve more teachers; for example, they could either work together on a course or as a 'virtual' group of individuals from their respective schools, developing their approach at the same time via communication inside the VRLE. These two models would add an element of collaborative learning, lacking in this research, and would probably improve the teachers' confidence. The second model (i.e., a virtual group of teachers) would be particularly interesting, as it would mirror any further developments in IE and the use of the VRLE as a tool for distance-learning. This approach could be used to integrate students from different schools, countries and cultures, with regards to common IE tasks.

Preece (2000) defined a virtual learning community as consisting of:

1. people who interact socially, to satisfy needs, perform roles, etc;
2. a shared purpose, which provides a reason for a community;
3. policies that guide peoples' interactions;
4. virtual environments that support and mediate social interaction.

According to Preece, it is important that students feel comfortable inside a virtual learning environment and are able to contribute to each others' work.

The VRLE was internet connected and password protected; however, the teacher was aware of the possibility of unauthorised persons breaching the security of the VRE and he stated that it should be possible to close the VRLE´s connection to the WWW. This would have limited the VRLE connection to a local network, thus ensuring security. However, in being able to access the internet, the students were able to locate various sources of information that may have supported them in their work; it also enabled them to communicate with each other at home. With new technologies come new experiences and, also, new risks, which mean new responsibility for adults, in terms of children and young people's security (Byron, 2008). Just as we teach our children to be careful when crossing roads, we should also teach them to be aware of the security issues associated with the virtual world. In her report 'Children and New Technology' (commissioned by the British government), Byron (2008, p40) stated: *'*firstly, how integral these new technologies have become to the lives of young people and secondly, how important it is that we educate ourselves about the benefits and dangers they bring*?'* She further considered that parents should have the confidence and ability to enable their children to learn and grow, empowering them to undertake ownership of their behaviour online (safe and responsible digital behaviour.

10.2.6 Innovation Education and Idea Generation

Various elements were identified that appeared to affect the idea generation of students, including the use of the inventor's notebook, brainstorming, motivation, homework, collaboration and cooperation, drawing methods, time schedule and time pressures, computer literacy and group spirit. It was part of the teacher's role to help the students understand IE and the innovation process, both within and outside of the VRLE, and the teacher argued that the VRLE helped students with idea generation and the identification and expression of solutions. He considered IE a difficult approach and students were stressed because they believed that their ideas had to be complex, new and individually-based.

Gunnardottir (2001a) noted that IE students learn through their idea generation, supported by their collaboration. Collaboration played an important role at home, in the classroom and inside the VRLE, in terms of the facilitation of idea generation. As seen from Vytgosky's theories (1978), the ZPD highlights the developing potential of the students during their idea generation work, whilst they are interacting with their peers and the teacher. The knowledge generated was thus the differences between the knowledge of the individual student, the co-student and the teacher.

10.2.6.1 Training Students in Idea Generation

Gunnarsdottir (2001a) reported that IE teachers understood their roles in teaching the innovation process and facilitating idea generation work. The author's work indicated that training students via the VRLE was beneficial, in terms of idea generation (see section 6.8.6 and A6.7.5.1). In this research, students were taught the basics of IE and idea generation and the terms related to idea generation, innovation and idea generation; they were also informed of the differences between invention and design. Students usually quickly understood the innovation process and were able to identify needs and problems in their own environment. The teacher believed that training students, providing them with knowledge (instructor role) and personal experience (facilitator role), was beneficial in idea generation. He also considered that students should learn to draw, in order to speed up their work.

The value of training students was identified in case study series three, when previous training and experience appeared to have improved the students' skills (the students had been on an earlier course). Even though they had not been active in IE for some time, these students were familiar with the innovation process and the VRLE. Thus, they were subsequently self-reliant and independent and the teacher was able to largely adopt the role of facilitator, rather than instructor (see section A8.5).

10.2.6.2 Identifying Problem and Needs and Using the Inventor's Notebook

The Inventor's Notebook played a significant role in the first stages of the innovation process (which took place at home) and had an impact on students' idea generation in lessons. During the enquiry, the inventor's notebook was used as a problems and needs finding tool, in order to activate ideation. Runco and Dow (1999) pointed out that an essential step in solving problems is to firstly define them and the IN helped students to remember, record and define identified needs and problems. However, the students often defined their findings and recorded outline solutions in the IN, rather than needs and problems. An issue in this was whether they had identified a need and were jumping immediately into a solution or whether they simply looked for solutions: this specific point requires further research. Runco and Dow (1999) also considered that students need to handle ambiguous tasks, in order to learn to clarify such tasks.

The teacher believed that the IN increased the students' interest in finding ideas and students did accept that the key to finding ideas was to identify needs and problems within their own environment. Gunnarsdottir's (2001a) research showed that the IN and the student´s idea generation work was based on discussions at home. The author's work also showed that ideas were connected to family members or based on personal problems. Guilford (1950) referred to problem finding as 'sensitivity to problems', which may imply that an emotional tendency is similar to a cognitive skill. Regarding the data from the VRLE, this tendency might be identified as the students' attempts to solve problems within their environment and their family context (see table 6.4). Furthermore, Gunnarsdottir's research identified that the personal social histories of the participants, students and parents influenced the way that Innovation Education was employed at home. In this research this mi

In Gunnarsdottir's work on IE (2001a; section 2.6.1), there is interaction between home and school. In her research, the IN is a tool for communication, supporting social interaction and initial thoughts in the innovation process. The knowledge and skills gained at school (in this case, inside the VRLE) and the needs and problems identified at home are two areas. Gunnarsdottir suggests that, if the teacher takes a dominant role, the students tend to stop recalling their experiences and thus little innovative work will occur. In addition, it appeared that an important factor in students interacting with each other was to stimulate the evolution of skills and knowledge within lessons. This balance and the central processes are explained in figure 10.4 (Gunnarsdottir, 2001a).

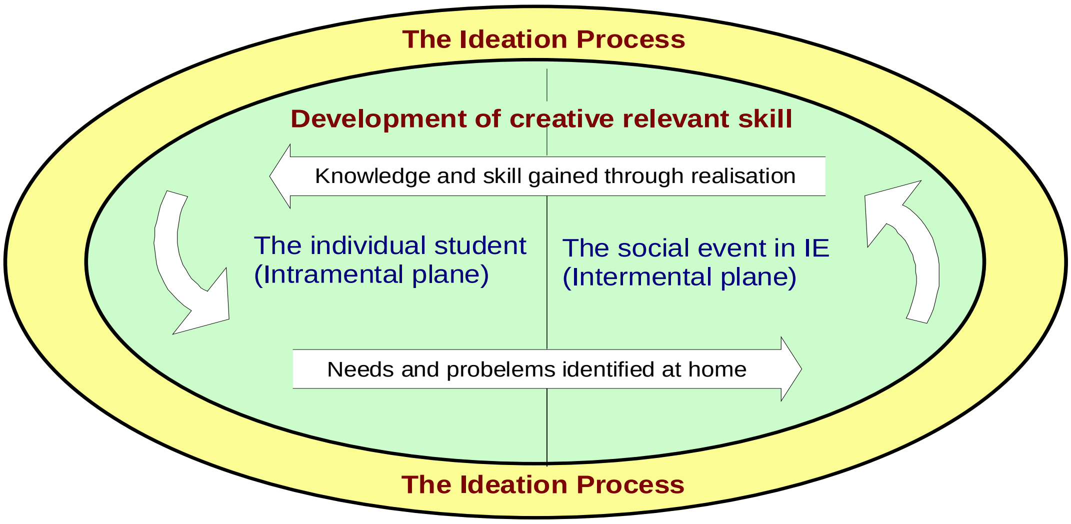

Figure 10.4: Pedagogical model for IE, developed from Gunnarsdottir (2001b).

The pedagogical model established during this research (see figure 10.4), however, shows interaction between home, the school and the VRLE and the IN still plays an important role in connecting these elements together. The students and the teacher considered that the IN was inspirational, in terms of finding new ideas: this relates to the constructivist theory, which states that students learn best when they are allowed to construct a personal understanding based on experiencing things and reflecting on those experiences (Jonassen, 1999; Jackson, et al., 2006). Students considered 'innovation' to mean 'create something new'. Their parents, however, were unsure about the novelty of their ideas. This highlights that what may be ‘ordinary’ in the adult world may be innovative to a child, hence the educational value.

10.2.6.3 Brainstorming and Idea Generation

Lessons began with students reporting the needs and problems they had identified at home. The teacher then ran brainstorming sessions, in order to generate ideas based on these needs and problems. The main aim was to trigger idea generation and to establish work inside the VRLE. Students submitted the majority of their ideas, after the brainstorming session, to the VRLE database and thus the value of these exercises is readily apparent. Osborn (1967) underlined the importance of training in brainstorming, in terms of idea generation and Mullen et al. (1991) also recognised training as having a positive effect on idea generation. Normal time pressures imposed by the teacher appeared to increase productivity during brainstorming, but, as the pressure grew, it could reach a point where the quantity of ideas decreased (Yerkes & Dodson, 1908).

The brainstorming sessions also aimed to facilitate collaboration during idea generation. Brainstorming in interactive groups, according to Greenberg & Folger (1983, cited in Paulus et al., 1993), promotes a sense of group ownership, in terms of shared problems and solutions. Furthermore, it increases the cohesiveness of the group and thus they are more likely to collaborate (Cartwright, 1968); this may also increase group productivity in general (Davies, 2004). The students in this research shared ideas inside the VRLE and such collaboration may have increased the cohesiveness of the group and the sense of the group ownership, in terms of the shared needs and solutions. Students reported that brainstorming, both inside the classroom and the VRLE, positively affected their idea generation. The VRLE offered the possibility of sharing needs and solutions and the opportunity for brainstorming sessions during any work and the VRLE database indicated that this was beneficial (see chapter 7.0). According to Parnes (1999), innovative ideas occur when new associations are made, with regards to existing information. Pauling, the recipient of two Nobel prizes, stated: ‘the best way to get a good idea is to get a lot of ideas’ (in Hecker and Birla, 2009: p.95).

Jessop (2002) asserted that the quality and quantity of brainstorming sessions may vary, according to the number of participants; for example, in terms of an individual, Jessop would consider that the ideas generated would not be very developed, because there is a limit to the depth of their knowledge. This relates to Vygotsky's (1978) ZPD for sharing knowledge during collaboration. In group brainstorming, Jessop would consider that these ideas would be further developed, as a result of the collective knowledge of the group. Dewey commented how '*a problem well-stated is a problem half-solved'.*(cited in Runco & Dow, 1999) and, during the case studies, the teacher taught the students to better define needs by having discussions as they worked inside the VRLE (see section A8.5) (without imposing his own value judgements). He clearly understood the principle of no idea being right or wrong (Osberg, 1993).

Students sometimes ran out of solutions in lessons (see chapters 5.0; 6.0 and 7.0), probably as a result of being tired, and it was observed that short brainstorming sessions triggered further idea generation and refreshed and refocused them (Thorsteinsson and Denton, 2006). In order to prevent disturbing the students and to save time, the teacher found it was better to undertake brainstorming sessions using the blackboard, with the students sat at their computers.

Denton (1994) examined the potential of using short periods of time to refocus students, at various points within lessons. He referred to these short periods of time, used to impart information and/or to focus pupil thinking, as 'critical point inputs'. His research showed that critical point inputs, implemented in a structured manner, can extend the learning potential within on-going project work lessons, whilst developing pupils' work rate and attention within these lessons. The act of stopping on-going work during this research and of implementing brainstorming sessions probably created 'critical points' during lessons, which improved recall and focus (Denton, 1994). However, such input needs to be self-contained and should stand out from a lesson (Denton, 1994). Buzan (1974) argued that, when issues are repeated, associated or unique in some way, they are more likely to be recalled: this gives the teacher the opportunity to refocus students by repeating such issues associated with a task.

10.2.6.4 Idea generation Inside the VRLE

The VRLE appeared to play multiple roles, depending on the activities at any one time This supports Taylor's (1980) and Blom's & Monk's (2003) classification of computers used in education as tutors, tools and trainees (see further in 10.2.5). The VRLE supported idea generation and, as it was structured upon the innovation process, students were generally self-reliant and often worked individually inside the MLE part of the VRLE; however, they also collaborated together inside the VRE (see section A7.7.8.1). Such collaboration apparently further supported idea generation (see table 6.5 and figure 6.4); students frequently shared needs and problems with each other, both face to face and online (see table 6.5). They usually put forward many ideas when working inside the MLE, but typically collaboratively worked with just one idea inside the VRE. However, when working inside the MLE, the teacher's observations and the VRLE database indicated that collaboration inside the VRE and face-to-face appeared to trigger the idea generation of students. Being able to play inside the VRE, when working in the MLE, also supported collaboration. This may also create an informal 'edutainment' context: when students are having fun, they are motivated to learn (Rieber, 2001). Cordova (1993) asserted that the creation of such environments, which stimulate learners to become absorbed in a fantasy world, may motivate and engage them in collaborative activities. His empirical research concluded that embedding material within a fantasy context can enhance learning more than a generic, decontextualized environment. However, within the context of this study, the value of 'edutainment' requires further research, in order to ascertain its impact on idea generation and student motivation.

The majority of students ideas were generated when they were working inside the VRLE (there was evidence of this in the VRLE database). The students stated that, when they entered the VRLE they began to think about ideas. Similarly, the teacher considered working with needs, problems and ideas and his co-operation with the students in this also positively affected the process of idea generation (Vygotsky, 1978). This may have been based on the social interaction of the learning context, both inside the VRLE and the classroom, although the novelty element would have also played a part, as a result of increased interest in the new technology (MERC, 2007). While the author uses the term 'novelty effects' in a research context (Cohen et al. 2005), a good teacher will also use such effects to gain and maintain student attention. Clark and Sugrue (1988) noted that increased attention sometimes results in increased effort or persistence, which yields gains in achievement. If this is the result of the novelty effect, these gains tend to diminish as the students become more familiar with the new medium.

The students stated that they were happy with the IE courses and they often demonstrated a light-hearted spirit in the classroom. The happy atmosphere in lessons may have had a positive impact on their motivation and their engagement with the generation of ideas; indeed, research has shown that humour increases the frequency of idea generation (O'Quin & Derks, 1999). Within the context of their research, O'Quin & Derks (1999) argued that, in common with other forms of ingenuity, the ability to generate humour requires divergent thinking, flexibility and the ability to generate multiple novel ideas in response to a given stimulus. These authors argued that humour has two related effects on thinking, in terms of idea generation: firstly, the mood associated with humour reduces tension and anxiety, which reduces the rigidity of students' responses to problem-solving situations. Secondly, it is considered that humour and the absurd can promote idea generation. During his research, Ziv (1983) found that 'the presence of laughter tends to open learners to divergent thinking previously suppressed by the critical, traditional self. New, often-unlikely and outrageous ideas emerge from this kind of environment, as the 'fun mood' increases creativity' (pp. 73-74). Humour and its impact on divergent thinking is an interesting area. However, within the context of this research, this area requires more research.

In CSC3, students collaborated inside the VRE, using the VRE CAD programme, when working inside the MLE. Contrary to earlier experiences, the author identified this as supportive in individually-based idea generation. However, the students were still less productive and fewer ideas were generated than in lessons where the VRE was not used when working inside the MLE: this was probably because they sometimes played inside the VRE and collaboration was time consuming. However, their play may have been valuable, in terms of developing experience and collaboration skills; it enabled the students to relax from their work and communicate their ideas. Furthermore, playing in the VRE probably also enabled the students to become quicker at using the VRLE and more self-reliant. In this context, play can be seen as an important part of the learning process (O'Quin & Derks, 1999).

10.3.6.5 Idea Generation within the Case Studies

As an administrator, the author could access the VRLE database and he was able to extract information about the work submitted. From this data, it was possible to examine the characteristics of students' work; for example, the ideas they were working with and the origins of such ideas. The data also revealed when the students were active inside the VRLE and whether they were working at school or at home. The following table lists the students' work from the three case study series: it highlights the nature and the origin of student solutions in numbers and percentages and behind each solution submitted to the database was a need, which was defined and uploaded to the VRLE database. The students recorded what was needed, why it was needed and who needed it. When the students designed solutions, they explained how ideas came about and described them.

CS1P	%	*CS2*	%	*CS3*	%
8 students and 12 ideas		8 students and 40 ideas		4 students and 6 ideas	
10 solutions generated from needs identified at home	83	16 solutions generated from needs identified at home	40	2 solutions generated from needs identified at home	33
2 solutions generated from needs identified at school	17	24 solutions generated from needs identified at school	60	4 solutions generated from needs identified at school	67
5 solutions for everybody	42	26 solutions for everybody	65	6 solutions for everybody	100
1 solution for the student him/herself	8	8 solutions for the students themselves	20	0 solutions for the students themselves	0
1 solution for teacher	8	1 solution for teacher	2	0 solution for teacher	0
5 solutions for student families	42	5 solutions for student families	13	0 solutions for student families	0
Most concern common problems in students' daily live	100	Most concern common problems in students' daily live	100	All concern general problems for everybody	100

Table 10.1: Summary of the origin of students' work.

Table 10.1 and figure 10.5 (below) highlight the differences between the three case study series. In CSS1P, students were most active at home: this might have been the result of the teacher frequently underlining the importance of working at home. Also, students often communicated with their families, in terms of needs and problems, which helped them considerably; the students thus generated most of their solutions with their families. Students in CSC2 were more self-reliant at home and did not ask others for help with needs and problems. Therefore, they probably generated more solutions at school than at home and these were for users beyond the students and their immediate families. Students in CSC3 did no homework, but based their solutions on the needs identified at home from earlier studies; the majority of ideas were thus established at school. In CSS3, the majority of solutions generated by the students suited everybody and this is probably because they did no homework and solutions were aimed at everybody, rather than themselves.

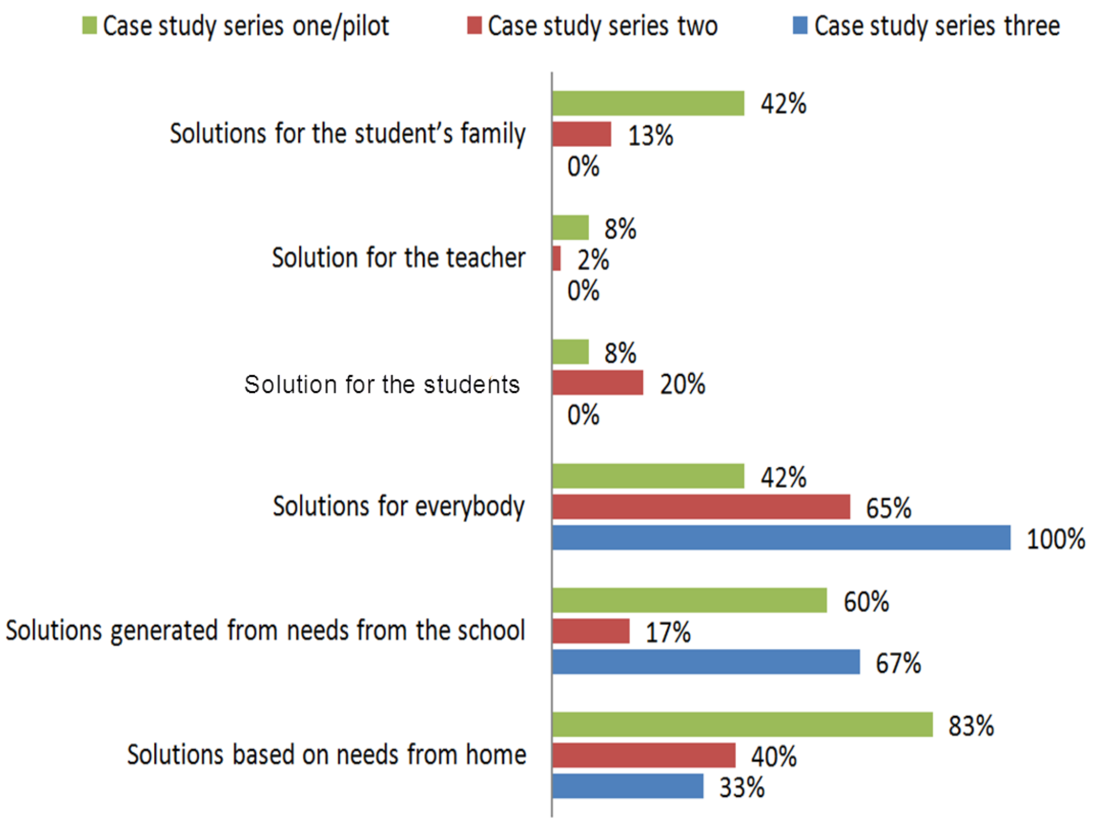

Figure 10.5: The origin of students' work and targets for ideas.

The differences between CSC1P and CSC2 are interesting: the numbers of participating students were the same, but the students were more effective in CSC2. (they generated 300% more solutions). In CSC2, 43% more ideas were generated from needs at school and 43% less at home and the origins of the solutions in both studies were common problems in the students' daily lives. There was congruency between the identified needs and solutions in both studies.

The author finds it difficult to identify the specific reasons for the differences listed above: this could have been a random occurrence, due to the small numbers of students in each case study series. However, it could also be the result of upgraded software, the teacher's increased experience, more frequent brainstorming sessions or students playing inside the VRLE before lessons, which ensured they were more skilled and comfortable in using the VRLE. Student productivity in lesson four of CSS2 also has to be considered. In this lesson, the students generated about 50% of all their solutions and were motivated in this by taking part in *The Young Inventors Competition*, under time pressures applied by the teacher. The improvement of the lesson plans, the software, the new tutorials and the teacher's improved preparation and self-confidence may also have contributed to the students generating more ideas in CSS2.

In the pilot study, the students' ideas related more to their families and more solutions were based on input from the teacher (see figure 10.5). This was further indicated in the group interviews and the interviews with individual students. In the pilot study, the students' families assisted them, yet this was not the case in CSS2: this appears to be a random effect, due to the small numbers in the groups. However, the students identified needs and problems themselves at home by examining their family lives and this was further confirmed with the data retrieved from the VRLE. In contrast to the pilot study, fewer ideas were related to the students' families and more solutions were established, based on input from the teacher. Furthermore, most of the solutions were identified at school, when working inside the VRL: 60% of ideas were based on needs obtained at school and 40% at home. The upgraded software and the increased skill and self-confidence of the teacher probably positively affected the educational context and thus improved the students' work at school.

Conducting IE within a small group is different from incorporating it within a whole class and each may yield different outcomes, in terms of idea generation. However, the teacher believed that the IE/VRLE activities would be effective with a whole class over a whole term. He considered that running the activities over a year, once a week, would make IE like any other subject. However, he believed that idea generation was randomly different between groups. The following table shows the total numbers of ideas generated (and their origin) throughout the total enquiry. The students (n=20) generated 58 ideas and all concerned general problems: 16.2 % of all solutions were based on needs identified at home, while 7.4 % were based on needs found at school (3% concerned the students themselves and 17% concerned their families). There was a balance between needs identified at home and at school and this could be explained by the impact of brainstorming during lessons and students sharing needs and problems inside the VRLE. This supports the students' assertion that brainstorming and their work, both inside the classroom and the VRLE, triggered their ideation. It would be interesting to compare IE classes, in terms of the two different IE models, as one of this enquiry's limitations was the small number of participants and the fact that this type of research has never been done before. It may illustrate the impact of using the VRLE for idea generation in IE.

Variants	Numbers and / or percentages
Total number of students	20
Total number of ideas	58
Ideas generated from needs found at home	28 / 48.3%
Ideas generated from needs found at school	30 / 51.7%
Ideas generated from needs from the teacher	2 / 3%
Solutions for everybody	37 / 64%
Solutions for students	9 / 16%
Solutions for the teacher	2 / 3%
Solutions for the student's family	10 / 17%
Solutions concerning general problems	100%

Table 10.2: Total activities during the enquiry.

10.2.6.6 Co-operative Idea Generation inside the VRE

The students' main activity was collaborative work inside the MLE; however, in CSC1P, CSS2 and CSC3, the teacher requested that the students undertake co-operative work inside the VRE by working on a shared task. Co-operative learning is generally defined as a teaching arrangement in which small, heterogeneous groups of students work together to achieve a common goal (Kagan, 1994; section 2.13.2), with each student having a specific responsibility within the group. In CSC1P and CSC2, the students found it difficult to collaborate inside the VRE, particularly with regards to drawing together on the virtual whiteboard and interacting as avatars. However, in CSC3, the students had attended one of the earlier courses and thus they were more skilled and the group size was smaller.

In CSC3, four students decided to design a device to help them to wake up in the mornings (see figure 10.6). They designed together, on the virtual whiteboard, for 18 minutes.

Figure 10.6: The group solution.

Advocates believe that co-operative learning enables students to acquire both knowledge and social skills and that such students try harder because they are members of a team; they also contend that students have more opportunities to ask questions and clarify any confusion than they do in a whole-class setting (Kagan, 1994; Slavin, 1991). In co-operative learning groups, students learn how to interact with their peers, thus increasing their participation within the school community (McInnerney, 2002). Co-operative learning, although outcome-based, can be considered an inward-looking, individual centred team process, whereby the primary goal of the process is the learning of each and every member of the team (Olivares, 2005).

In figure 10.9, the solution was created from many parts drawn by different students at different points in time and the main parts were drawn in sequence. However, each part was visited more than once, by different students and, each time, more detail and. Sometimes more colours were added. Usually, a single student drew each part, although, occasionally, more than one student drew different parts at the same time; furthermore, on a few occasions, more than one student drew a part together. Students had different skill levels, but everyone was able to contribute to the co-operative drawing activity (they adopted different roles, in terms of the technical and aesthetic elements of the design and demonstrated different levels of initiative and communication). The avatars used by the students within the VRE did not appear to aid communication, but students employed text and drawings to communicate. One topic of interest is the role of the 'shared visual context' in communication (Karsenty, 1999); in terms of design, this can be used to form relative suggestions (van der Lugt, 2005). In addition to providing a shared visual context, Scrivener and Clark (1994, p114) suggested a second role, in terms of sketching a co-operative design: a notational device that helps the innovator to reason in a complex and changing mental structure.

Figure 10.10 below shows how active students were when they worked individually and in groups of two, three or four (data retrieved from screen captured video). The blue line signifies the total time students spent drawing and the red line outlines how often they were active. The figures show that, the majority of the time, one individual was drawing, closely followed by students drawing as a pair. There was a significant drop, in terms of 3 or 4 students drawing together, and this may have been due to a lack of social skills and training, with regards to co-operative work inside the VRE. Johnson and Johnson (1991) suggested that the development of social skills is a key element of co-operative learning. However, further research is required, as individual personality effects would be significant in the small group in this study.

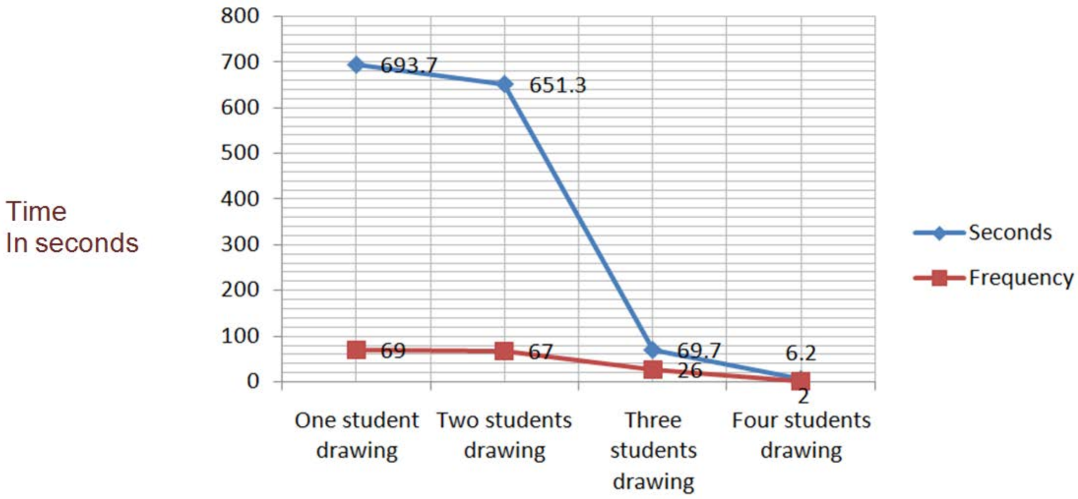

Figure 10.7: Shows the frequency of student collaboration inside the VRE

Figure 10.11 below shows the matrix of co-operation (i.e., how often the four students worked alone and together, in groups of two, three and four). The colour blue represents the males, while the buff colour represents females. On each figure, the frequency of that individual working alone is written and the arrows between the figures indicate the frequency of co-operation. The small central cluster informs when all four collaborated, with 2 as the frequency.

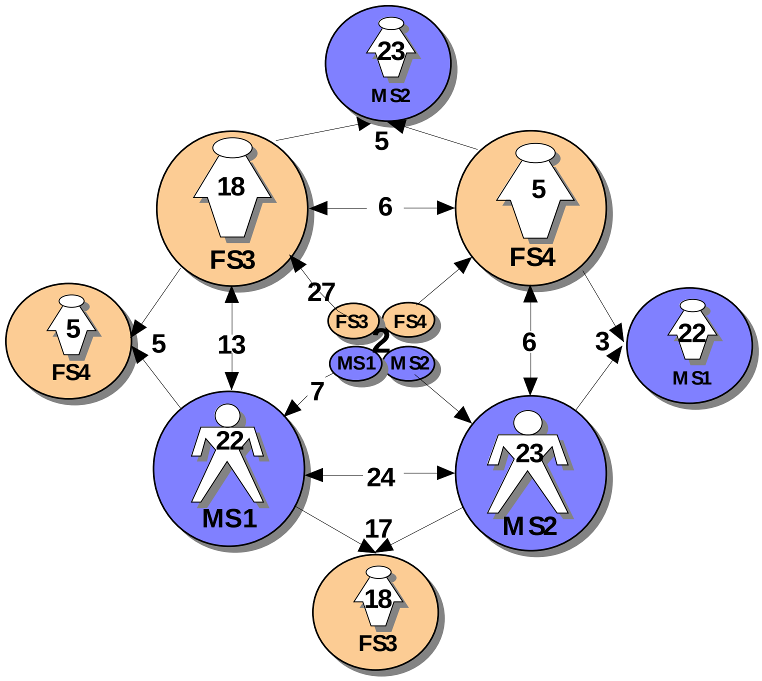

Figure 10.8: Shows student activity, in terms of collaborating inside the VRE. MS1 (1) Represents male one, MS2 (2) = male two, FS3 (3) = female three and FS4 (4) = female four.

The students worked mostly alone or in pairs on the virtual whiteboard inside the VRE (figure 10.13) and the time they spent drawing, their different roles, their communication with others and the initiatives they developed were all different, as one may expect. One of the students led the technical part of the design, while another presided over the aesthetics element of the drawing. Central to co-operative learning is the development of social skills, whereby group members learn to work together, so that all members of the group are successful. Johnson et al. (1998) defined co-operative learning as the instructional use of small groups, so that students may work together to maximise their own and each other's learning. Vygotskian theory (1978) indicates that, for complex cognitive tasks, learners benefit from interactions with more competent peers, like those interactions in co-operative learning.

10.2.7 Drawing

As a category in this research, drawing is associated with the productivity of idea generation, the quality of students' drawings and their ability to communicate their solutions. Drawing was identified as an important part of idea generation, as it enabled students to record and develop solutions. Purcell and Gero (1998) asserted that sketches are a core capability of the designer, in terms of idea generation. Purcell and Gero´s (1998) study of design sketches and their impact on idea generation and cognition noted that sketches play a key role in re-interpretation within the design process and that this leads to new knowledge and further re-interpretation. The authors asserted that interaction with the sketches established as a result of idea generation enhanced ingenuity, when forming solutions.

Ferguson (1992) identified three types of sketches employed during idea generation:

1. Thinking sketches, which refer to idea generators making use of the drawing surface, in support of their individual thinking processes.
2. Talking sketches, which refer to idea generators making use of the (shared) drawing surface, in support of group discussion.
3. Prescriptive sketches, which refer to idea generators communicating design decisions to persons that are outside of the design/innovation process.

Students' drawings incorporating the INs could be defined as thinking sketching (see 1 above) and were usually based on individual thinking at home. However, inside the VRLE, students used thinking sketches (1 above) when working as individuals inside the MLE and talking sketches (2 above) when working co-operatively as a group inside VRE. Prescriptive sketches (3 above) were employed when students sent their drawings to the young inventor's competition and to the web exhibition in CSC1P.

Effective drawing equipment and the CAD programme were also important in enabling students' work and training appeared to improve their skills. Nevertheless, students were able to learn the use of different tools through experience, without specific training. Their drawings became more accurate during the courses as a result of their growing experience and the use of more advanced drawing tablets. However, simple drawing tests in CSC2 showed that the students had to be taught to use the CAD programme when digital pen tablets were used and when they formulated three-dimensional drawings. It was also noted that their skills improved during the drawing tests, probably because they were effectively undergoing informal training. This highlighted how drawing skills are more important than the media employed to draw with. Three different drawing tools and the CAD software were tested:

a. The computer mouse, with the *Paint* software;
b. Initial digital pens with the CAD programme, inside the VRLE;
c. Wireless digital *Pegasus* pens, which were also ink pens with specific software.

Tests showed that the students were better at using pencils than the digital pen tablets. However, they worked faster with the digital pen tablets, rather than the computer mice, and their drawing improved. Observations indicated that the initial digital drawing tablets were not flexible enough and slowed down work; they presented limitations in that a pen was used on the tablet, but the mark only appeared on the screen. However, the designs appeared to be more advanced than those created with the *Pegasus* tablets, except in terms of accuracy*.* The Pegasus tablets were closest to the experience of drawing with a pen and were most accurate. Nevertheless, the video data indicated that better drawing tablets augmented students' idea generation. Students' drawings when using digital input devices were generally inaccurate, but demonstrated basic solutions to identified problem-needs and were therefore usable. However, Plimmer's (2008) research on digital pen input devices showed that the basic usability of pen-based input was lower than desired. He thus concluded that further research was required, in terms of the hardware, operating system support, recognition engines and design. This difference can be explained by the age of participants: in this research, the students were 12 years old, while, in Plummer's research, they were adult designers, with higher requirements.

In his research, van der Lugt (2005) categorised sketches according to the design progression they represented. He examined them as a mechanism for reinterpretation of an individual designer's ideas and found out that sketching is a way of stimulating innovative thoughts (van der Lugt, 2005). In case study series three, the teacher noted how limited drawing skills were a drawback, in terms of students' idea generation. He therefore offered to teach them formally, but the students asserted that they knew how to use the digital pens and the CAD programme (such instruction would most likely have improved the students work, both in terms of quality and productivity. A CAD programme was set up inside the VRLE, in order to enable the students to draw together. In case study series one and two, the CAD programme was only accessible from the VRE and thus students found it difficult to use. The reason for this appeared to be that they were drawing together on one virtual whiteboard. In chapters 5 and 6, this was noted and the author asserted that such difficulty was due to a number of reasons (the students were disturbing each other, the drawing was conducted in a virtual world, the students were using a basic mouse as input and they were generally unfamiliar with the equipment). It was thus concluded that individual drawing was easier.

In CSS3, the CAD programme was accessible from both the VRE and the MLE, where students could draw individually, undisturbed. However, students were asked to access it from inside the VRE, in order to enable communication and collaboration during their individual work inside the MLE. It was probably easier for the students to access the CAD programme directly from the MLE, as they would not have been dependant on the use of the avatars (which made their work more complicated); however, the influence of avatar communication would not have been noticed (see chapter 7.0). The teacher considered that the students were unable to collaborate easily, when drawing together inside the VRE. He possibly reached this conclusion as the students were not speaking much outside of the computers, during their work. However, it was identified that they were able to collaborate by communicating through their drawings. As Ferguson stated (1992, p97): ‘talking sketches (see 3 above), spontaneously drawn during discussions with colleagues, will continue to be important in the process of going from vision to artefact. Such sketches make it easier to explain a technical point, because all parties in the discussion share a common graphical setting for the idea being debated’.

10.2.8 The Perceived Value of IE in the School

Both the teacher and the headmaster argued about the value of using IE and both saw possibilities, in terms of IE being a part of the curriculum. The headmaster noted that using VRLE for IE would be useful in increasing computer literacy and improving ICT skills within individually-based studies; he also saw IE as a possibility in pursuing the school’s interest in constructivist theories. In his interview, the headmaster (see summaries of findings, analysis and discussion in section A7.7.7) described the school as democratic and the teachers held mutual respect for student autonomy, focusing on collaborative group work. This democratic spirit probably motivated the learning of students and one of the characteristics of the role of facilitator, in accordance with social constructivism, is that the instructor and the learners are equally involved in education, learning from each other (Holt and Willard-Holt, 2000).

The teacher considered it important to keep IE as an additional subject, but felt it was necessary to assess the results, as subjects without assessment commanded less respect. However, he also considered that IE enabled students to demonstrate learning through a different avenue. He believed it was better to integrate IE and the VRLE within existing subjects, rather than implementing IE as a specific subject: this would give students the incentive to employ IE within their daily lives. Knowledge should not be divided into different subjects or compartments, but should be discovered as an integrated whole (Ring & McMahon, 1997; Di Vesta, 1987). The world in which the learner needs to operate does not take the form of different subjects, but is a complex myriad of facts, problems, dimensions and perceptions (Ackerman, 1996).

The teacher asserted that the VRLE was useful as a medium for teaching idea generation. He and the students believed that the VRLE would help them to become more innovative in their daily lives and the teacher also believed that it would increase the students' understanding of the value of innovation, in terms of the economy and its impact on society. As the Icelandic National Curriculum informed: 'the main emphasis of IE is to train students to produce valuable and practical results of their knowledge through their work'. (1999, p31). The teacher noted that IE was able to meet the various needs of different students, at various levels, as it gave them the freedom to work with their interests (see section A8.5). Furthermore, both he and the headmaster believed that IE would help students with learning difficulties in building their self confidence. The author would agree, but adds the caveat that only when the learning context is carefully planned.

Interviews with the students, however, showed they viewed the course as a general school project and it had not significantly changed their way of thinking. Nevertheless, the teacher noted that the students had used their INs long after the course, for other tasks. It is thus hypothesised that a more extended programme of using the VRLE for IE may lead to a more significant manner in which the students approach idea generation.

10.3 Chapter Conclusion

The chapter has drawn together findings from the case studies and has discussed them in light of the literature. No similar work was found that related directly to IE within the context of blended learning. However, relevant literature from various areas of education was identified, in relation to the content of the categories. There were a number of similarities and some differences and, in general, the findings were supported by several pedagogical theories and the only previous research on IE (Gunnarsdottir, 2001a).

Blended learning was used as a framework to illustrate the educational activities in this enquiry and different learning theories were employed to highlight certain characteristics found within the categories. Discussion centred around the central research question, which was: *'How does the use of the VRLE affect teacher's pedagogy and student work in conventional Innovation Education in Iceland?'* The aim was to enrich the pedagogical understanding of IE, both in general and within a blended learning context.

The data was analysed and the findings discussed using the principles of grounded theory to carry out pedagogical disciplines and issues. The process attempted to understand, interpret and make meaning of the learning experience of students and the IE pedagogy employed by the teacher. The fact that the author was interpreting the data individually was a limitation and *thick description* (Geertz, 1973) was adopted to explain the pedagogical context, the interaction within the small IE society in the classroom and the interactions between the students home, the classroom and the VRLE. The processes of reflection, revisiting the literature and interpreting the findings helped the researcher to develop an understanding of undertakings. In dealing with small samples, it was possible for the teacher to collect more data and analyse it. It was, therefore, probably easier to see the interrelations between those involved that, for example, formed the characteristics of the collaboration and the teaching. However, the small sample of four to eight students and one teacher means the author cannot generalise the findings or establish a theory.

Gunnarsdottir's research (2001a) was based on the original IE pedagogical model (see chapter 1.0) and it was useful in enabling the discussion of pedagogical characteristics. Gunnarsdottir described IE using the paradigm of social constructivism; this enquiry was also based on IE, but under the paradigm of blended learning and the VRLE. Thus, a new basic model for using the VRLE for IE was established (see chapter 1.0). To enrich the understanding of the emerging pedagogy, the new model's relationship to different educational theories, such as constructivism, social constructivism and Vygosky's social constructivist theories, was identified and discussed. The original idea behind the IE/VRLE was to find a new way of supporting ideation, using virtual tools inside a managed learning environment, and using the two different parts of the VRLE (the MLE and the VRE), both separately and together, was discussed and contrasted: this offered possibilities for individually-based learning, computer supported co-operative learning and computer supported collaborative learning.

The teacher and his approach to his work was identified as an important category, as the teaching methods employed were based on professional discussion between the author and the teacher. The role of the teacher was ascertained as key to running the activities and his broad background and experience were useful in supporting his self-criticism and reflection during the enquiry. However, he was a single teacher in the enquiry and other teachers might have undertaken the courses differently; this probably made the teacher's role more complex and stressful. Subsequent research based on training a group of in-service teachers to collaborate via the VRLE might enable self-reliance and the use of technical advice.

Homework was seen as important in generating IE content within the context of home and was identified as one of the main characteristics of the pedagogy (see chapter 1.0); it enabled students to make meaning of their world and thus enabled their idea generation. Various elements related to teaching and learning were identified, in terms of influencing idea generation, such as training students to increase their knowledge and skills, in order to enable their work.

The value of IE in education, based on the context of blended learning, has been discussed, but not fully explored; this is reliant on further activities within the context of general school activities in full classes.

The final chapter will

- draw overall conclusions,
- summarise the pedagogical model of using the VRLE for IE ideation,
- review the research process,
- indicate the potential for further research,
- identify any contributions to knowledge.

Chapter 11. Conclusion

11.0 Chapter Summary

Chapter eleven brings together the central points raised, in terms of the overall research question. Limits and limitations are acknowledged and, subsequently, the basic IE pedagogical model is reviewed. The author then summarises his contribution to knowledge and puts forward suggestions for future research.

11.1 Introduction

The overall research question of the project was: 'How does the use of the VRLE affect the teacher's pedagogy and the students' work, in conventional Innovation Education in Iceland?' This was broken down into several more specific questions, which were answered in the chapters covering the literature review and the case studies*.* The limits and limitations of the research are revisited and considered further.

The overall research aim and objectives have been achieved and is outlined in this chapter. The case studies supported the author's attempt t*o identify the pedagogy required to use the VRLE in this context* (see objective a on page 8, the case study chapters and 11.3 in this chapter), within the limits and limitations of the research (see 11.2): this in turn *explicated the pedagogy of using the Virtual Reality Learning Environment (VRLE) in supporting conventional Innovation Education within Icelandic schools* (see overall aim on page 8 and 11.3). An earlier pedagogical model, prior to the introduction of the VRLE, was subsequently upgraded and *a new IE pedagogical model presented, in terms of supporting the VRLE* (see objective *b* on page 8 and section 11.4). *Students' ideation when using the VRLE was illuminated* in the case studies, within the context of IE (see objective c, chapters 5, 6, 7 and 9 and 11.3.4) *and their ability to draw inside the VRLE* (see objectives d and 11.3.5). *Some values in using the VRLE for IE were recognised* (see objective e on page 8 and 11.3.6), but this requires further research. *Finally the study has provided indications to enable continuing research* (see objective f on page 8 and 11.6).

11.2 Discussion of the Limits and Limitations

This section revisits the limits and limitations already covered in chapter 3.0 (methodology). Many of the limits and limitations were caused by the very specific context; i.e., the school where the enquiry was conducted and the nature of the relationship between IE, the VRLE and the software. The Icelandic culture and educational system were also specific contexts, as was the fact that the author was the sole researcher: these factors all contributed to the formation of a highly-complex research context, which was managed through the use of qualitative methods and grounded theory principles. These methods have been described and the limitations of the data generated were acknowledged in chapters 5.0 to 7.0.

11.2.1 Limits

The overall aim of the research was 'To explicate the pedagogy of using the Virtual Reality Learning Environment (VRLE) to support conventional Innovation Education within Icelandic schools' and, as such, the research was culturally limited to Iceland, IE and the specific VRLE used. Exploring the IE model in other countries would be a natural development of this project (see section 11.6.9). The research considered teaching and learning within the pedagogical context described and, while the context of the project was the pedagogy of developing students' ideation skills in IE, the measurement of these skills is an issue for further research (see section 11.6.6).

11.2.2 Limitations

Chapter 3 set out the applied research methods in a generic manner; this section related such research methods to the actual fieldwork conducted and the limitations of this research.

11.2.2.1 The Author's Presence inside the Classroom and the Impact on the Teacher

This research was based on one researcher and one teacher, plus a small sample of students. Thus, the personality effects between the teacher and researcher were clearly significant. The teacher managed the course, while the researcher remained in the background during lessons, collecting the relevant data (see chapter 5.0; 6.0 and 7.0); nevertheless, he was present in the classroom and sometimes communicated with the teacher and the students. He was therefore involved in the activities and must have affected such activities in some way. His closeness must also have affected the teacher and the students, as he was an outsider; in addition, he was a teacher trainer at the University of Iceland.

Cohen et al. (2005) described this situation using the term *reactivity* (the Hawthorne effect): this refers to where the presence of a researcher affects a situation. Participants may wish to avoid, impress, direct, deny and influence the researcher and the problem of reactivity is usually addressed by careful negotiation in the field and by the researcher remaining in the field for a considerable amount of time, ensuring (as much as is possible) a careful presentation of oneself. In this case, the researcher attempted to stay in the background during lessons. Children in this school were also used to staff visiting the computer classroom during lessons and the school had an open policy (see in chapter 6.0).

The teacher's actions were also part of the data and his performance was a vital part of the enquiry; for example, in case study series three, it was noted the teacher lacked confidence in conducting lessons: this may have been related to the presence of the author, as the teacher was his former student. It was also noted in all the case study series that the teacher was self-critical and was often unhappy with his performance; he felt badly prepared for both the course and the lessons and this was probably due to the novelty of the course and the teacher's wish to impress his former tutor.

11.2.2.2 The Researcher as an Interpreter of the Data

The author was a solo researcher; thus, his interpretations were based on his self-reflections within an interpretive paradigm. Neuman (1997:p68) defined interpretive research as 'exploring socially meaningful action through the direct and detailed observation of people in natural settings, in order to arrive at understandings and interpretations of how people create and maintain their social worlds'. To retain the integrity of the phenomena being investigated, efforts are made to 'get inside' the person (in this case, the teacher and students) and understand them (Cohen et al., 2005:25).

The fact that the author was interpreting the data as an individual was a limitation and the author himself acknowledged that he began the process of research as a novice, bringing his own values, beliefs and self. The processes of reflection, reading and gaining experience helped the researcher in developing an understanding of the interpretation of data.

11.2.2.3 Small Samples and Thick Description

This research could not incorporate a large sample of participants and thus *thick description* (Geertz, 1973) was adopted, in order to maximise the potential data from the small samples available. ‘Thick description’ refers to the context of practices and discourse within a society, so that the behaviour may be understood by outsiders.

In dealing with small samples, it was possible for the researcher to collect more data and analyse it appropriately. Thus, it was probably easier to identify the interrelations between those involved in the research; this formed the characteristics of the collaboration and the teaching styles observed. However, the small sample prevented the author from generalising the findings or establishing a theory. Nevertheless, the research contributes to the grounded approach to developing theories (Glaser and Strauss, 1967).

11.2.2.4 The Author’s Background

Along with Gunnarsdottir (2001a), the author was one of the originators of the conventional IE model and thus he had expectations, with regards to the outcome of the research. This may have affected his collection of data (for example, from the semi-structured interviews) and the interpretation of such data.

The author was a teacher trainer and had experience of teaching both the pedagogy of conventional IE and the Icelandic subject *design and craft*. He organised the case studies and gave the teacher training. The author’s personal vision and understanding will thus have affected the course settings and the teacher’s role (both his method of teaching and his understanding of IE). Thus, the author’s background will also have influenced the outcome of the research. This could be mitigated by the subsequent replication of the research by others and the triangulation of results would also minimise these specific context effects.

During the research, the author was aware that he was both a data collection instrument and the researcher and, as a result of this, he tried not to let his own background and characteristics bias his interpretation. Establishing an effective process for the analysis of data (see chapter 3.0), including triangulation, helped minimise any personal background effects.

11.2.2.5 Fieldwork Based in a Different Country

The fieldwork was conducted in Iceland, but formed part of the author's research in the UK. During his studies, the researcher had worked within English academia, which has a different culture than its Icelandic counterpart. Such cultural differences thus might have had an impact on the way the author saw the activities and interpreted the data and one example of this may have been the influence of the English National Curriculum (specifically, the subject of design and technology).

11.2.2.6 The Teacher's Circumstances

The teacher conducted the course as an after-school activity and thus this represented an extra workload for him. This may have affected his preparation and teaching, in terms of his mental and physical capabilities. The teacher repeatedly noted throughout the interviews how conducting lessons inside the school's regular hours would have been more effective, as students would have been fresher and more capable than in the after-school lessons (they were more tired in these lessons). The same principle would apply to the teacher also.

The teacher was the only person inside the school who dealt with IE and the VRLE. The headmaster and the teacher's colleagues were informed of the research and supported and encouraged him in this. The headmaster was interested in making IE a compulsory subject and this was an important issue, as the research was conducted within a school context. Nevertheless, this might also have enhanced the novelty factor of the subject and placed pressure on the teacher, in terms of him having to prove his teaching abilities.

11.2.2.7 Novelty Factor

The novelty factor (Cohen et al., 2005; chapter 3.0) might have had a bearing on students' motivation to join the IE courses. In case study series one and two, fewer students joined than was desirable; however, in case study series three, even fewer students volunteered, possibly because the novelty factor of the course had reduced; this could also have been due to the timing of the case studies (i.e., after school).

Ideally, this project would be followed up with similar research featuring a larger number of students and over a longer period of time, in order to reduce any novelty effects; this would give a more secure database and enable a more reliable understanding of the work. Furthermore, it would give teachers the opportunity to develop their teaching methods and ascertain the impact of the approach.

11.2.2.8 Limitations of Time and Space

Initially, the research plan was to observe a typical class over a number of weeks, but the author's professional commitments meant that this was not possible in the timeframe available. Thus, it was necessary to adopt a pragmatic approach and a series of voluntary after-school classes were implemented. The work conducted so far has indicated many unexplored possibilities for the use of the VRLE, in terms of both IE and general education. However, due to time limitations, the author had to stop at this point.

11.2.2.9 Summary of Limitations

Any research has limitations and in a research context such as this, featuring a single researcher, small samples and a specific context are important in clearly outlining the limits and limitations of the research; this enables the reader to be able to make judgements on the value of the research.

11.3 Answering the Overall Research Question

The main categories established demonstrate the significant pedagogical issues relating to the impact of the VRLE on pedagogy and the categories identified as affecting the IE pedagogy, when used in the new VRLE, are summed up below.

11.3.1 The Teacher and His Approach to his Work

The core category was the teacher's approach to his work. He was using the VRLE for the first time and was also new to IE; thus, he had to test and develop many new ideas, in order to implement action for change. Such actions included methods for teaching, managing the new technology, preparation for the courses, training students in the use of the VRLE and in IE and teaching them idea generation.

11.3.1.1 The Teacher's Mindset and Responsibilities

To establish IE/the VRLE, the teacher required effective training and significant personal experience in the use of IE and the VRLE (Demetriadis et. al., 2003; Walker, 2000; Witfelt, 2000). The novelty of the new technology and complications arising from the teacher conducting lessons within the framework of blended learning meant that there was conflict between the teacher's roles of administrator and tutor, causing him to feel insecure. The increase in the number of facets to the teacher's professional role appeared to be largely caused by the additional complication of adding the VRLE to IE lessons and limited preparation (Bingimlas, 2009; Bradley & Russell, 1997).

The case studies indicated that the teacher also lacked confidence in teaching IE and this was partly due to his responsibility for implementing appropriate teaching methods for the new technology, solving technical problems and adapting to new circumstances (Demetriadis et. al., 2003; Hennessey & Deaney, 2004; Hennessy et al., 2005). A high workload and limited preparation time also contributed (Fabry & Higgs, 1997; Preston et al., 2000).

11.3.1.2 Teacher's Background

The teacher's background (as a teacher of ICT and design & craft and the school's ICT administrator) was appropriate, in terms of him undertaking the IE courses, and the experience enabled him to change his teaching mode between instructor and facilitator (Bauersfeld, 1995).

11.3.1.3 Identifying an Appropriate Pedagogy in the Use of the VRLE for IE

The approach reflected blended learning, where the teacher's role was based on multiple teaching methods that supported idea generation inside the VRLE (Page et al., 2008; Thorsteinsson & Denton, 2008; Worthington, 2008). Courses were built on combinations of conventional IE learning with the VRLE, using different didactic methods and delivery formats (Whitelock & Jelfs, 2003; Kerres & De Witt, 2003) and the teacher's role was to enable idea generation inside the VRLE through appropriate teaching methods. Lessons were thus based on the following basic structure:

a) introduction;
b) basic training;
c) students reporting needs and problems;
d) brainstorming sessions;
e) students developing solutions inside the VRLE, both as individuals and in groups;

f) summarising lessons and looking forward to/preparing for the next lesson in the series.

Due to the ability of the VRLE to enhance individual work, collaboration and co-operation, the teacher was able to employ different teaching methods (Thorsteinsson & Denton, 2008) and the MLE was used to encourage individual idea generation, supported by the students' collaboration inside the VRE. However, the VRE was used for co-operative work and to support collaboration during individual idea generation inside the MLE.

The VRLE provided the teacher and students with an electronic form of individual and group learning support (Loiselle et al., 1998; Schrum & Berenfeld, 1997) and, in addition to being able to collaborate in a face-to-face manner, the VRLE supported the students in communication via computer-supported media, which enabled them to interact with each other (Thurlow, Lengel & Tomic, 2004; Wolz et al., 1997). The VRLE also facilitated students' access to information within the conventional classroom and enabled multi-modal communication (Gilbert & Dabbagh, 2005; Gabriel, 2004).

11.3.1.4 Basic Training for Students, in Terms of the Use of the VRLE and IE

The teacher required a basic understanding of IE and the VRLE, in order to enable him to teach these aspects to students. He was also required to understand the value of homework and how to organise such homework (Cooper et al., 2001; Hoover-Dempsey et al., 2001; McCarthey, 2000): this helped students to generate the initial content, which was to be worked on in class (von der Glasersfeld, 1989).

Discussion at the beginning of lessons was important in helping students to understand the innovation process and to get started in generating solutions to work with. To enable this, the teacher needed to be aware of the need to employ focusing techniques at appropriate points, an example of which was brainstorming (Osberg, 1993; Buzan, 2005). Brainstorming was also used at the start of lessons, to enable students to begin idea generation inside the VRLE.

The case studies showed that students were strongly motivated by playing inside the VRLE and this supported the researches conducted by Ricci et al. (1996) and

Cordova and Lepper (1996). Furthermore, this reduced the teacher’s workload and provided students with experience; in this sense, play had an informal training role (Sancho et al., 2008; Prensky; 2001).

11.3.1.5 The Teacher as Instructor and Facilitator

The IE teacher adopted both the role of traditional instructor and facilitator, within any one lesson. As an instructor, the teacher in this research provided basic training in the use of the software, in addition to the input devices for drawing and idea generation. As a facilitator, he encouraged and enabled students in the use of the VRLE, in order to facilitate the generation of ideas. Providing the students with detailed instructions, before work began inside the VRLE, appeared to increase their self-reliance in collaborative work and this in turn helped the teacher to develop his self-confidence.

The research identified the importance of the IE teacher, in both roles of traditional instructor and facilitator and adapting to the role of facilitator rather than instructor echoes the social constructivist approach (Bauersfeld, 1995; Gunnarsdottir, 2001a; Jonsdottir, 2005). However, the teacher appeared to feel uncomfortable during the case studies, especially when operating primarily as a facilitator, and he asserted that he wanted to incorporate more formal taught sections within the course, in terms of the use of the VRLE and the use of the input devices for drawing. He believed that training students, providing them with knowledge (i.e., instructor role) and personal experience (facilitator role) were beneficial in idea generation and he also considered that students should learn to draw, in order to speed up their work. The structure of the VRLE supported the teacher in his role as facilitator, as indicated by Bonk & Cunningham (1998) and Heinze (2008). Furthermore, it appeared to enable individuality, collaboration and cooperation and supported students’ autonomy.

The teacher’s technique of leaving the class for short periods of time fostered students’ autonomy and, as the case studies indicated, increased their collaboration. His background enabled him to change his mode of teaching in accordance with the circumstances; he was required to assist the students when they were working inside the VRLE, yet he attempted to improve their self-reliance and develop their autonomy by leaving the class for short periods of time (see chapter 9.0 and similarities in Gunnarsdottir, 2001a; Holt and Willard-Holt, 2000).

11.3.1.6 Time Issues

The case studies showed that a good lesson plan and control of pace was important in maintaining the focus of students, which echoes the work of Andrews and Farris (1972). The teacher specifically applied time pressures, through the setting of short deadlines, as a technique for keeping students on task and the case studies indicated that this was effective.

Brainstorming under time pressures, during individual work, appeared to refocus and refresh the students and enhanced idea generation, to some extent. However, the overuse of time pressures appeared to limit the effectiveness of idea generation (see section 7.8.5), as suggested by Yerkes and Dodson (1908), Broadhurst (1957), Duffy (1962) and Anderson (1988).

11.3.2 Homework

Homework was considered important, as it generated the course tasks through the identification of problems and needs (Runco & Dow, 1999; Luckin et al., 2007). Problems and needs identified by the students at home constituted the initial state of the IE innovation process and activated idea generation (see 1.6 and Thorsteinsson & Denton, 2006). This was supported by the use of the inventor's notebook (IN), students' communication with their families and social interaction within the students' homes, the classroom and the VRLE.

It was imperative that the teacher understood the meaning of homework and was able to exploit it for the purpose of idea generation inside the VRLE (see similarities in Jonassen, 2002; Hutchison, 2006; Gredler, 1997 and Gunnardottir, 2001a). Subsequently, the teacher placed an emphasis on the students' identification of problems and needs during their homework and supported their idea generation during lessons. However, students usually brought initial solutions to the class via their INs, rather than problems or needs. Runco and Dow (1999) pointed out that an essential step in solving problems is to firstly define them and one issue was whether the students had identified a need and were jumping immediately into a solution or whether they simply looked for solutions.

11.3.3 Use of the VRLE

Throughout the research, the VRLE worked well in general: it was stable and the students found it easy to register. The VRLE guided the students work, provided structure and reflected the role of the computer as a tutor, tutee and tool (Blom & Monk, 2003; Taylor, 1980) and enabled both CSCL and CSCW (see section 11.3.1.4; Thorsteinsson & Denton, 2008; Thorsteinsson, 2009). The VRLE was employed as a tool, in that students used it to enable their work: it incorporated help pages and was structured around the innovation process. This guided and directed students during their work and thus, in this respect, the computer was both tutor and tutee.

During the research, students had no major problems in using the VRLE and quickly became self-reliant (Thorsteinsson & Denton, 2006). Their confidence and IT ability enabled them to begin using the VRLE with confidence. However, the case studies showed that additional training was needed, in terms of the hardware (specifically, the graphical input devices) and the VRLE. The teacher also considered that the students required training in the use of the VRE for co-operative idea generation (Thorsteinsson, 2009) and this involved the use of avatars and the CAD programme.

Social presence was an important aspect of using the VRLE and enabled a community of learners to grow, as indicated by Hamburg et al. (2003), Thorsteinsson and Page (2007) and Hauber et al. (2005). Playing informally in the VRE was also shown to promote the students' skills, their confidence in the use of the VRLE and familiarity with other students (also see Prensky, 2005 and Hussain et al., 2003). The case studies indicated that students being physically together and being able to speak to the teacher, both inside the classroom and over the Internet, appeared to assist their learning, probably via the multiple modes of communication (see also section 11.3.4.3; Loiselle et al., 1998; Schrum & Berenfeld, 1997; Thurlow, Lengel & Tomic, 2004; Romiszowski & Mason, 1996). The capability of students in personalising the interface of their virtual workshops appeared to be important, in terms of increasing their perception of the relevance and ownership of the VRLE (as in Oulasvirta & Blom, 2008 and Blom & Monk, 2003).

11.3.4 Innovation Education and Idea Generation

It was the teacher's role to help students to understand IE and the innovation process, both within and outside of the VRLE (Gunnarsdottir, 2001a; Thorsteinsson & Denton, 2008). The students quickly became familiar with the innovation process, in bringing basic ideas to school as the starting point for the effective implementation of collaborative idea development. However, it was evident that the students in the case studies did not understand the fine differences between problems, opportunities, needs and initial ideas (see further in chapter 7.0 and section 10.3.6.2). Collaboration played an important role at home, in the classroom and inside the VRLE, in terms of the facilitation of idea generation, supporting the position of Hamburg et al. (2003).

11.3.4.1 Training Students in Idea Generation

Training students in idea generation, via the VRLE and in the classroom, appeared to encourage self-reliance and independence and appeared to be beneficial in idea generation. Furthermore, it gave the teacher a little more freedom to stand back and carefully observe the group; this supported him in adopting the role of a facilitator to a greater extent (Thorsteinsson & Denton, 2008).

11.3.4.2 Identifying Ideas and Using the Inventor's Notebook

The inventor's notebook was used as a tool in the identification of problems and needs, in order to activate ideation (Runco & Dow, 1999; Luckin et al., 2007). However, the students found it easier to express basic solutions, rather than attempting to articulate problems and needs (see further in section 11.3.3 and 11.3.4). Ideas were connected to family members or based on personal problems and played an important role in the interaction between home, school and the VRLE (Thorsteinsson & Denton, 2008; and according to Gunnarsdottir's work on IE, 2001a).

11.3.4.3 Brainstorming and Idea Generation

Brainstorming, both inside the classroom and the VRLE, was shown to positively affect idea generation (see chapter 7.0 and Mullen et al., 1991); the technique was also used to support collaboration (Cartwright, 1968). After brainstorming sessions, students submitted the majority of their ideas to the VRLE database. Furthermore, short brainstorming sessions during lessons were shown to trigger students' idea generation and refreshed and refocused them (Denton, 1994; Thorsteinsson & Denton, 2006).

11.3.4.4 Idea Generation inside the VRLE

Students often shared needs and solutions inside the VRLE; they usually came up with many ideas when working inside the MLE, but, subsequently, typically worked co-operatively inside the VRE on one idea chosen from the ideas presented by the group (Thorsteinsson, 2009).

Students in the case studies were generally self-reliant and often worked individually inside the MLE part of the VRLE; however they also worked collaboratively inside the VRE and this collaboration supported individually-based idea generation, as it enabled students to help each other (see section 7.9.1.3 and Dennis & Valacich, 1993). Students were also able to access separate virtual whiteboards, but communicated their ideas inside the VRE and the classroom at the same time. However, students were still less productive and fewer ideas were generated, as this was time consuming (see Taylor et al., 1958 and Paulus et al., 1995).

Being able to play inside the VRE, when working in the MLE, was a form of informal ‘edutainment’, which supported collaboration and the generation of skills (Rieber, 2001; O’Quin & Derks, 1999). A light-hearted spirit in lessons appeared to positively influence idea generation, supporting the position of O’Quin and Derks (1999).

11.3.4.5 Idea Generation within the Case Studies

All the students’ solutions concerned general problems: 48.3% of all solutions were based on needs identified at home and 51.7% on needs found at school. 64% of solutions concerned everybody, 16% the students themselves, 3% concerned the teacher and 17% referred to the students’ families: this achieved the main emphasis of the pedagogy of IE, which aims to ensure that students are better equipped to deal with their world and that they take an active part in society through innovation (see section 1.2; Gunnarsdottir, 2001a and Thorsteinsson & Denton, 2003).

11.3.4.6 Co-operative Idea Generation inside the VRE

Students showed an expected range of capabilities, in terms of co-operative ideation inside the VRE. Their levels of communication and skill varied, as did their initiative, and they tended to adopt different roles, in terms of the technical and aesthetic elements of their design (Thorsteinsson, 2009): this indicates the value of the VRLE as a flexible learning tool in, enabling students to work with others (Thorsteinsson, 2009; Denton et al., 2007; Karagiorgi & Symeou, 2005).

The IE approach enabled students to work collaboratively and to contribute in terms of their own knowledge. At the same time, they were also able to learn from the contributions made by other students, whose expertise was in other areas (also according to Vygotskian theory, 1978). Students were able to co-operate inside the VRE by using text and drawings to form relative suggestions, with regards to the students' design communication (van der Lugt, 2005; Karsenty, 1999).

11.3.5 Drawing

Drawing was identified as an important tool in idea generation, as it enabled students to record, communicate and develop solutions (van der Lugt, 2005; Purcell & Gero, 1998; Ferguson, 1992; Chin & Tan, 2007). The students' drawing supported individual work and the ability to work co-operatively as a group inside the VRE, as indicated by Ferguson (1992).

Effective and useable digital drawing input devices and the CAD software were also important in enabling students to draw and manipulate images. The different input devices gave lower quality graphical outcomes than drawing with a pencil, as reported by Plimmer (2008). Students were very self-confident in their ability to learn to use these devices and it appeared they were able to learn to use them to a reasonable standard, without specific training. Nevertheless, training and experience were identified as important, if students are to attain a higher standard of drawing (Vlach, 2008; Cheng & Lane-Cumming, 2004; Ning et al., 2004; Blackwell et al., 2008). The students' drawings became more accurate during the courses, as a result of their growing experience and the use of more advanced drawing tablets. The Pegasus digital pen on paper was the most accurate of the drawing devices employed in the case studies, as it placed the image in the same place as the pen and emulated drawing on paper (in that students followed the marks made by the pen nib, rather than looking separately at the screen).

Students' drawings were relatively inaccurate; this was partly due to limited input devices, but their drawings were good enough to demonstrate basic solutions (see also Plimmer's research, 2008).

11.3.6 Values

In the research, the headmaster and the teacher viewed the use of the VRLE for IE as a possibility in increasing students' computer literacy and ICT skills. Furthermore, focusing on collaborative group work will increase their belief in their autonomy. The headmaster and teacher also believed that the democratic spirit inside the classroom motivated the learning of students (see similar in Willard-Holt, 2000).

As use IE gives students the freedom to generate the course content, the teacher and the headmaster believed that IE could help students with learning difficulties build their self-confidence (see similarity in Youngblut, 1997).

11.4 Upgrading the IE Pedagogical Model

The following model below (see figure 11.1 and 10.2.9) was designed to deepen the understanding of the IE pedagogy, in terms of the VRLE, in the context of the research. The model shows how students learn through idea generation. Individual and social events are significant in the process of idea generation and the teacher plays a important role in both training and the enabling of learning. The learners' interactions among home, the classroom and the VRLE are fundamental to the idea generation process.

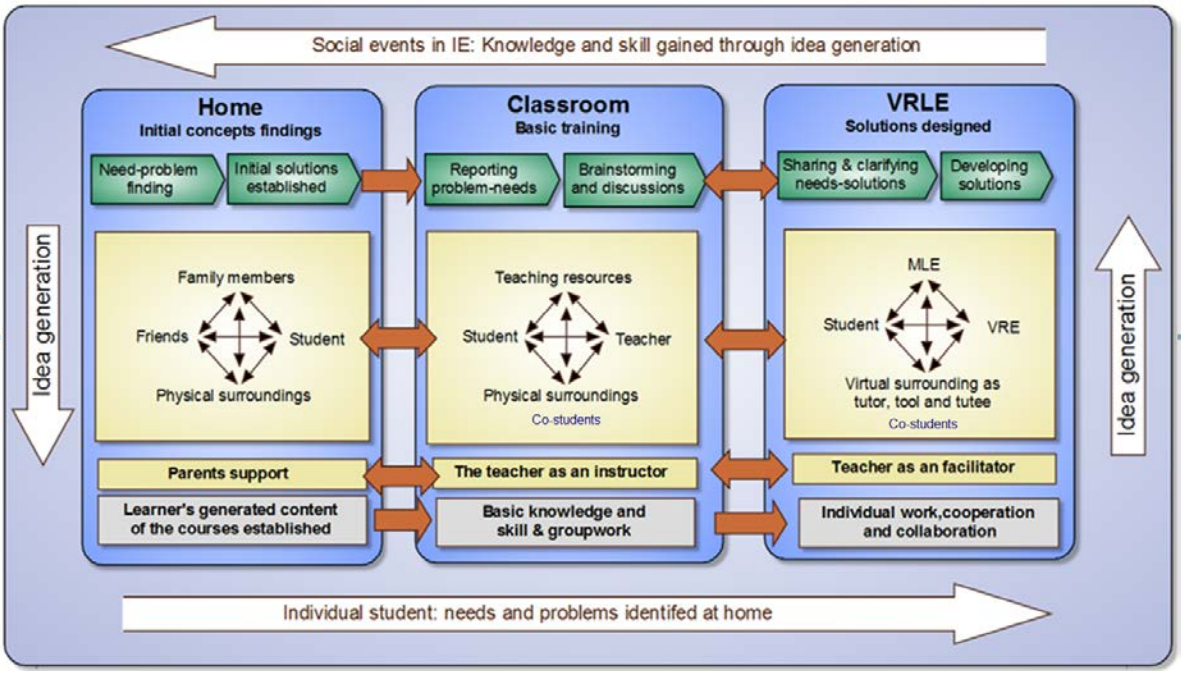

Figure 11.1: The pedagogical model for IE incorporating the VRLE.

11.5 Contribution to Knowledge

The work contributes to academic knowledge in two ways: firstly, it adds a layer of data, enabling the grounded theory to develop and, secondly, it offers a unique perspective, in terms of observing the pedagogy employed to teach IE incorporating the use of the VRLE. There are two further dimensions to this: developing an understanding of the topic area and developing an understanding of the appropriate research methodologies relating to the understanding of the topic.

The research also contributes to the practical use of IE in education and the general pedagogical understanding of using the VRLE for developing student ideation skills in IE. Furthermore, the research is an additional exemplar of a qualitative approach based on case study methodology and grounded theory within an educational context. The research also provides a starting point for other researchers in exploring this field and thus further developing grounded theory (see section 3.10).

11.5.1 Understanding of the Use of the VRLE for Innovation Education

The use of the specific VRLE was grounded on the original IE pedagogy and the teaching methods developed in Iceland and, to date, the author has not discovered any similar enquiries. Any contribution to the general understanding of the use of the VRLE for IE was developmental, rather than revelatory, and the thesis contributes an increased (although incomplete) understanding) of:

- An appropriate, developing pedagogy for the use of the VRLE in Innovation Education, within the Icelandic context;
- The relationships between IE and pedagogical theories, such as constructivism, social constructivism and Vytgosky's social constructivism;
- The on-going pedagogical discussions of blended learning;
- The role of the teacher, in terms of the development of teaching methods and training in the use of the VRLE in IE;
- Pedagogical knowledge, which might be a useful basis for writing educational material on the use of the VRLE for IE, in Iceland and in other countries;
- Knowledge concerning the IE ideation process and how individual student's idea generation could be supported by different teaching methods, both within the classroom and the VRLE;

- An information source and guidance for educators who want to undertake studies researching the using of VRLEs, on both a national and international basis;
- Information about how the VRLE could be developed further, in terms of IE in education, according to the opportunities discovered in this research project (such as the use of blogs, mobile technology and more advanced cad and digital drawing input devices);
- The significance of homework in IE and the context of IE learner-generated content;
- The ability of the VRLE to undertake the roles of tool, tutee and tutor and the ability of the software to support the contexts of individual work, collaboration and co-operation.

11.6 Recommendations for Future Research

The work generally requires further replication and development; for example, within a normal classroom and timetable context, within other countries, etc.. A number of suggestions have been made, in terms of the contexts of the sub-sections above, and, in addition, relevant specific areas of future development are listed below.

11.6.1 Using the VRLE for IE in Normal Sized Classes and within a Normal Timetable

This would give more detailed information on how the VRLE could be used for general education and as a part of a school curriculum. Furthermore, it may identify different combinations of teaching methods more relevant for use with larger groups than those featured in this research: this would be helpful in a number of ways, one of which would be the reduction of novelty effects over time.

11.6.2 IE within the Context of Open and Distance Learning

The VRLE offers the ability to manage open and distance learning and there appears to be considerable potential in this. Further research could highlight communication, co-operation, brainstorming and ideation issues, amongst others, with regards to cultural and linguistic differences within the VRLE. Such an approach would also examine the impact of the teacher communicating with students inside the VRLE.

11.6.3 Mobile Technology and Blog to Support Idea Generation in IE

The possibility of using mobile phones and blogs to support homework was identified during the research as an interesting possibility; in this, students could send needs and images directly to the VRLE, instead of using the IN. Blogs and mobiles could also be useful tools within the context of open and distance learning; however, it should be noted that, while the teacher considered that the IN might be old fashioned, it was very favourably received and widely employed by the students in this research.

11.6.4 Parental Support in IE

None of the parents in this research had experienced IE or the VRLE before, as it was new to the curriculum. Thus, the teacher provided parents with a relatively detailed course plan, prior to the course. Further research could focus on specific training for the parents, in terms of providing support to students in the initial stages of the innovation process. Such research may also have general value for other subjects.

11.6.5 Digital Drawing and IE

The drawing tests (see chapter 6.0) underlined the need for pre-training in the use of the cad programme, the digital pen tablets and three-dimensional drawing. The students' drawing skills was a limitation during their idea generation inside the MLE, yet it was noted that their skills improved during drawing tests, possibly because students were, effectively, informally trained. Further research could focus on examining the impact of training students in the use of the CAD programme and their ability to both co-operate and collaborate inside the VRLE, using this programme. The research could also look at different age and ability levels, in relation to drawing, ideation and IE/the VRLE.

11.6.6 Measuring Ideation inside the VRLE

As this research focused on developing an understanding of an appropriate pedagogy for IE within the context of the supporting VRLE, the measurement of ideation skills was outside the scope of the research. However, it may be relevant to focus specifically on measuring students' ideation, in order to enable a finer illumination of their learning process. This might be done by employing quantitative methods of research that compare conventional IE and the VRLE approach in classrooms; such research would focus on measuring the quality and the quantity of generated ideas, with a larger sample of students over a longer period of time. Another option would be to employ the *Torrance Tests of Creative Thinking* (TTCT) as the criteria for examining students' divergent thinking (see further in section 2.9). Once a reasonably valid and reliable method of measuring any changes in ideation was developed, it would then act as a key to a number of specific questions relating to ideation, IE and the VRLE. This appears to be a priority for further research.

11.6.7 Game Based Learning (Edutainment) in IE

It was noted that the students had a strong motivation for playing inside the VRE and such play appeared to make the students more skilled and confident in using the VRLE and in becoming familiar with each other (albeit with restricted data). This activity may be referred to as *edutainment*; a term used to describe computer software that both educates and entertains. This area appears to offer significant areas for development.

11.6.8 Humour and Idea Generation in IE

Research has shown that humour may facilitate idea generation (O'Quin & Derks, 1999; Cayirdag and Acar, 2010; Howrigan & MacDonald, 2008; Kaufman et al., 2008). Within the context of the fieldwork in this study, the students stated that they were happy with the IE courses and often demonstrated a light-hearted spirit through humour. This positive atmosphere may have influenced their motivation and engagement with idea generation work. Further research could specifically focus on the effects of generating a light hearted spirit within class and its effect on students' ideation.

11.6.9 Using the VRLE in Different Countries and Across Countries and Cultures

The IE model and the VRLE were developed in Iceland and thus it was logical to base the research there; however, it would also be possible to examine the VRLE within the various educational systems of other countries. A comparative research approach would also be interesting, in order to contrast any differences between countries and to identify cultural issues affecting students the idea generation of students, in IE.

11.7 Conclusions

A possible pedagogy of using the VRLE for developing students' idea generation skills in IE has been examined and conclusions have been made, supported by evidence. The limitations of the methodology have been acknowledged and the author has reflected on the approach, has outlined his contribution to the knowledge and has put forward suggestions for future research. Nevertheless, there are still critical issues and considerations that offer opportunities for further research, with regards to the use of the VRLE technology in education. Such technology means extra costs for schools, in terms of software and equipment, and schools' management will base any spending plans on evidence of success. This research, within its limitations, contributes to such decision-making. It should be noted that the VRLE used in this research was implemented through normal school computers, so costs were limited to software. Digital input devices would present advantages for other areas of the curriculum and, to enable further progress and development within Innovation Education, there should be an awareness of any technological developments, in terms of the hardware and software that may be employed within the pedagogical context of IE and other subjects in the curriculum.

During the research, the author has contributed to pedagogical debate and understanding, through conferences and academic journal papers that were published during the process of the study. The research indicates that this specific VRLE technology plays a positive role in enhancing learning in IE and, possibly, other related contexts. The pedagogical understanding of using the VRLE for ideation has to be developed further and the educational efficacy of using the VRLE in schools is dependent on the development of meaningful forms of such learning support. The basis of the technology is already part of the daily lives of young people, but, to date, is less advanced within general education.

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