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EDDE: A Framework to Explore, Design, Develop and Evaluate Technology-Assisted Instruction for Construction

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EDDE: A Framework to Explore, Design, Develop and Evaluate Technology-Assisted Instruction for Construction

by

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To Mom and Dad with love

Kính tặng Cha Mẹ thân yêu

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EDDE: A Framework to Explore, Design, Develop and Evaluate Technology-Assisted Instruction for Construction

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Technology-enhanced instruction has a great potential to support the learning process. However, the engaging power of technology can become a distracting factor if it is not deployed properly. Unfortunately, the current literature in instructional design and user interface design is broad and not easily accessible by construction faculty. This dissertation presents a framework to guide the development of technology-assisted instruction for the classroom. The framework developed is called EDDE which stands for four conceptual steps involved in the creation of a technology-supported teaching tool: Explore, Design, Develop, and Evaluate. EDDE contains a novel synthesis of the literature in instructional design and user interface design as well as survey data of student subject matter knowledge and information technology background. A computerized tool called EDDEaid makes accessible the large store of knowledge supporting EDDE. Assessment of EDDEaid is presented with evaluation results from nine university faculty that teach construction subjects as well as through critique of and changes to an existing interactive learning tool. EDDE and EDDEaid are found to contribute to the body of knowledge regarding the deployment of technology-enhanced instruction and provide support to construction faculty developing learning tools.

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CHAPTER 1: INTRODUCTION

1.1 Research motivation

Advanced technology has a great potential to support the learning process through effective use of multimedia and interactive interfaces. For example, a simulated jobsite on a mobile device equipped with good visualization and manipulation capabilities can provide students with virtual but meaningful learning experiences. If properly designed, a mobile tool can help reduce the tremendous amount of cognitive load imposed on students when learning about the construction process and as a result keep them actively engaged for higher-level tasks such as evaluation and decision-making.

The successful creation of such technology-assisted learning tools requires not only effective pedagogical design but also an efficient and innovative interface design. While technology has a special power of being engaging, it can also become a distracting factor if it takes the central role over pedagogy in the design. There is a broad but largely distributed body of knowledge in user interface design guidelines and there are well-established instructional design models in the literature. These bodies of knowledge, however, have not been consolidated into an operational framework that can be used to develop technology-supported teaching tools for specific instructional topics, especially for those in the construction domain. The main motivation for the research presented in this dissertation is therefore to synthesize and operationalize existing knowledge in instructional and interface design into a framework that allows for the creation of technology-supported learning tools.

1.2 Research vision and scope

The scope of this research is limited to the development of a framework that can be used to create technology-enhanced instruction at the classroom level, and more specifically, for a unit of instruction that spans over one or a few classes. Given an instructional topic and a student audience, it is expected that the framework would provide enough guidance for designers to come up with a reasonably well thought through conceptual design that takes advantages of the most suitable technology available while remaining truthful to the pedagogical objectives of instruction. The framework would act as both a centralized design resource and a formalized design procedure for the creation of technology-supported teaching tools. In other words, it will offer users a considerably large number of choices as well as a structured method to make the best choice for their specific needs at every step of the design procedure. It is not the purpose of the research, however, to address technology integration at the curriculum or system levels.

To populate the choices for each framework component, a comprehensive literature review of instructional design and interface design is conducted. This review is informed and guided by a pilot design of a materials management learning module that is used as an exploratory study. Details of the framework can then be developed by making logical connections between these components based on pedagogical and practical criteria for the learning tool being designed. The framework also emphasizes the importance of a student-centered design by incorporating several aspects of audience analysis in the design process.

This dissertation is anticipated to make both academic and practical contributions to the existing body of knowledge in the area of educational technology in general and construction education in particular. This contribution is the result of answering two main research questions: 1) "*What is student knowledge with respect to technology and construction, and what are the implications for pedagogical design?*", and 2) "*Can we synthesize existing knowledge in user interface design and instructional design into a framework that aids the development of technology-supported instruction?*". By putting a structure to the otherwise distributed knowledge in the literature and creating the missing links, I produce a design framework (and a software called EDDEaid) that helps create technology-supported learning tools that are both pedagogically solid and student-centered. While the framework has been tested in the domain of construction education, its generic characteristics made the tool applicable to any other domain. The research also leads to the creation of the Technology and Construction Baseline Survey that can be used for audience analysis as part of the instructional design process.

1.3 Reader's guide

There are eight chapters in this dissertation. This first chapter discusses the potential of technology-supported instruction in construction education and the lack of a coherent framework to guide the design process of technology-aided teaching tools. It also lays out the vision for such a framework and makes that the main goal of this research.

In Chapter 2, the pilot design of a material management learning module is described. It highlights the design process and the important lessons learned from the development and evaluation of the module. It also identifies the important aspects to be researched in order to lay the foundation for the framework being envisioned. These aspects will be studied in a much greater depth in the focused literature review of Chapter 5.

Continuing on the insights provided by the pilot design, Chapter 3 is dedicated to the formulation of the research questions that have to be answered to fill the gaps found in the literature and to make the necessary connections required for a coherent design framework. The chapter also describes the research methodology and how each question was addressed.

Before going into the details of the literature review needed for this framework, it was apparent that further audience analyses would be needed beyond what was available. This is why Chapter 4 is devoted to a survey study of students' technology skills and background knowledge in construction. It contains both the detailed descriptions of the instrument and the analyses of the data collected to date. The most important parameters measured by this survey would then be used in the design framework.

In Chapter 5, a thorough but focused review of relevant literature as identified from Chapter 2 and framed in Chapter 3 is provided. These selected pieces of knowledge in instructional design and interface design synthesized from the literature form the basis for the framework to be developed. Where appropriate, discussions are made on the necessary adaptations and expansions of existing literature in order to better serve the purpose of fitting in the framework being developed.

Chapter 6 provides a complete description of the components in the framework and how they relate to one another. It also offers a detailed walkthrough of all the steps involved in the framework with a specific example. EDDEaid, the software that computerized the framework into a handy packaged tool and made it easier to use, will also described.

Chapter 7 is devoted to the evaluation of EDDEaid. It starts with the formulation of research questions and methodology for evaluation. There will be summaries of the nine test cases, each of which involves the use of EDDEaid by a university faculty to create a conceptual design of a technology-supported learning module or improve an existing tool. Discussions on how the evaluation findings address the predefined research questions are then presented.

Chapter 8 summarizes the dissertation, highlights the contribution this research has made to the body of knowledge, and lays out recommendations for future research. The appendices supplement important details that were left out of the main dissertation for clarity purposes and provide the documentation and packaging for the EDDEaid software.

CHAPTER 2: MATERIALS MANAGEMENT LEARNING MODULE - A PILOT DESIGN

2.1 Introduction

The end goal of this research was to develop a structured framework to guide the design of a technology-supported teaching tool. In the exploratory stage, a learning module was developed as a motivational pilot study. The pilot design was created based on preliminary research, common sense, and judgment. It was expected that the process of designing, refining, and testing the module would help reveal the critical aspects involved in the creation of a technology-supported instructional tool. This process would enable the author to identify critical literature that could potentially be incorporated in the framework and recognize the need for further research in the areas that had not been adequately addressed in the current body of knowledge.

The inspiration for this learning module was the concept of intelligent jobsites and their potential to improve construction productivity and safety through an extensive deployment of wireless and mobile devices to support centralized planning and real time management. These new technologies make it easier for construction activities to be carried out in the field. Thanks to their sizes and abundance, they can be suitable for deployment in the school setting to replicate what goes on in the work force.

On modern construction jobsites, material palettes are often attached with RFID (Radio Frequency Identification) tags that contain all the information about the materials. When a person walks through the jobsite with a handheld device that is equipped with an RFID receiver, this device can communicate with all the active RFID tags present on the site and obtain material information to display on the screen of the handheld device. Based on this information, one can have all the information needed to plan construction activities.

The vision for the pilot design was to recreate this environment using mobile and sensing devices. More specifically, the plan was to simulate a virtual construction jobsite with sensors mimicking live RFID data and tabletPCs as the mobile devices receiving and processing those data for material management and site supervision tasks. There would be a simple but highly visual interface installed on a tabletPC; students would "manipulate" the materials by interacting with the interface. Overall, the learning goals of this module are:

- Experience the complex nature of real time planning and scheduling of construction activities;
- Be aware of the applications of RFID and other wireless technologies on construction jobsites; and
- Get familiar with the tabletPC and the software program installed on it.

The next section of this chapter will discuss the procedure in which the learning tool was developed from the simple vision described. The interface and pedagogy of the actual learning module will then be described in Section 2.3. Section 2.4 details evaluation methods for learning effectiveness and technology usability. Section 2.5 is devoted to the analysis of evaluation results and discussion about broader implications of these findings. Section 2.6 reflects on the lessons learned from the pilot design and how these laid the foundation for the next steps of the research.

2.2 Research methodology

The whole design task for this learning module could be divided into two stages: conceptual design and interface development/evaluation. In conceptual design, details of the platform on which the module would be built were developed, and the initial plan for instruction was created. The second stage was the implementation of the conceptual design: development of the user interface and refinement of the instruction.

2.2.1 Conceptual design

2.2.1.1 Hardware and software requirements for learning module

The flowchart in Figure 2.1 illustrates the research process carried out for the design of the learning module. It was the availability and capability of technology that inspired the vision of this module as described in the introduction. The first step of the design process was to develop the details for that technology platform, including both the requirements for the infrastructure (hardware and software components) and the facilitation of learning activities.

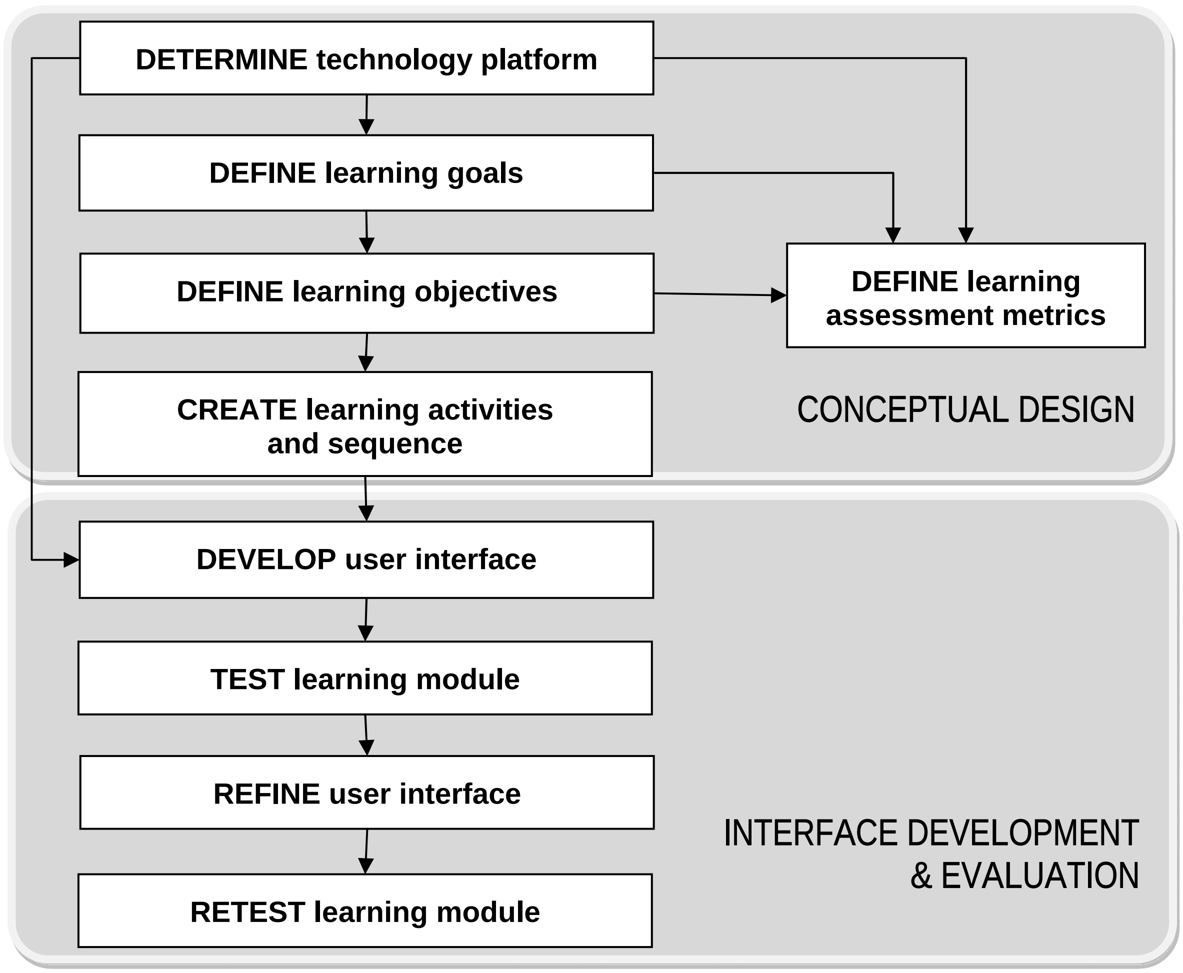

Figure 2.1 Research methodology for materials management learning module

The first component of the envisioned virtual jobsite was a "site", some physical place where a real job site could be simulated. The 5th floor corridor of our engineering school was chosen for this purpose as it was convenient and had enough open space for students to navigate around. The central device of this platform was a tabletPC equipped with an interactive software interface that received wireless information on material status (existence, location, quality, etc.) generated from pre-coded sensors located throughout the floor. Paper signs posted on the hallway represented materials. The software program created for the front-end of this application would be an interface where data would be displayed and planning activities could be documented and adjusted when needed. By having students walk along the hallway looking for "materials" aided by a tabletPC, the learning experience simulated, though simplified, would resemble the real jobsite to a degree that could facilitate meaningful interactions. The hardware infrastructure needed for this learning module (as illustrated in Figure 2.2) was readily available. The remaining task of designing this learning module was to develop the user interface.

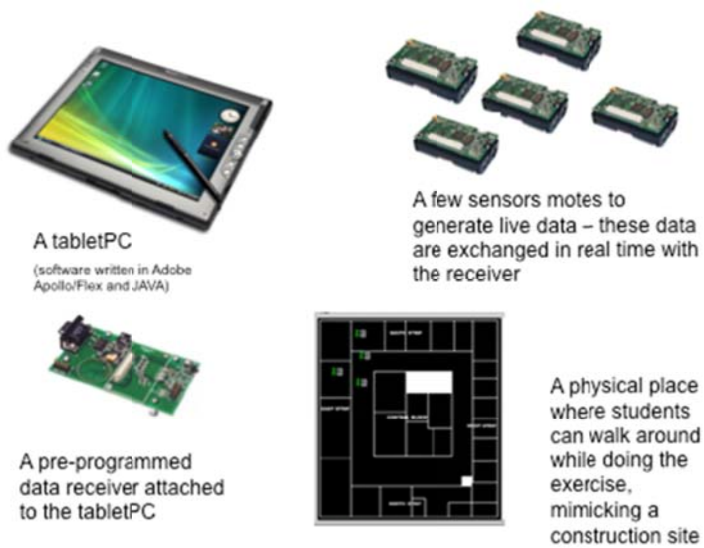

Figure 2.2 Hardware requirements for materials management learning module

2.2.1.2 Learning objectives, activities and sequence

The major learning goals for this learning module were defined in the introduction: experiencing real-time construction planning and scheduling, raising students' awareness of mobile technology applications on jobsites, and getting students familiar with tabletPCs and the interface created. The next step was to develop these into more specific and potentially measurable objectives. These objectives were translated into learning activities and learning measurement metrics used for assessment. Among the three learning goals established (Table 2.1), the first goal was the primary; the other two could be seen as consequences of the first. The learning activities were centered around this first goal, while software demonstration and training helped achieve some of the secondary goals. The assessment metrics would have to be aligned with the objectives defined.

Table 2.1 Learning goals and objectives for the module

Learning goal	**Learning objectives**
Experience real time construction planning and scheduling	Spatial reasoning Material identification Resource comprehension Spatial-time integration Logical reasoning
Examine RFID and wireless technology	Recognition of technology potential and limitation
Familiarity with tabletPC and software	Operation skill development

2.2.2 Interface development and evaluation

The development and evaluation stage involved design, testing and redesign in an iterative manner. The interface was developed in Adobe Air and ran on Flash. To evaluate the learning module, two tests were conducted involving four students each. The first test was done in August 2007 after the first version was completed, and the second test was done in November 2007 after the interface had been refined, both at the University of Texas at Austin. Before the testing started, participants were asked to complete a pre-test questionnaire (provided in Appendix A) on general demographics and past experience with mobile technologies. They were also asked to take the Index of Learning Styles questionnaire (Felder and Silverman, 1988, see Appendix D). The test supervisor then walked through a "training module" with participants to familiarize them with the program. Upon completion, participants were asked to answer a post-test questionnaire (Appendix B) based on which teaching effectiveness and other design aspects of the tool were evaluated. Details of the evaluation will be described in Section 2.4.

2.3 Design of the learning module

2.3.1 Pedagogy

For this materials management learning module, learning activities were built around the primary learning goal of construction activity planning and scheduling. Five learning objectives were identified: spatial reasoning, material identification, resource comprehension, spatial-time integration, and logical reasoning. These objectives were achieved by three learning activities that required the students to be able to locate the materials on the job site, associate the activities in the provided construction schedule, and based on what they found, identify any conflicts that were present and make changes to the schedule accordingly (Figure 2.3).

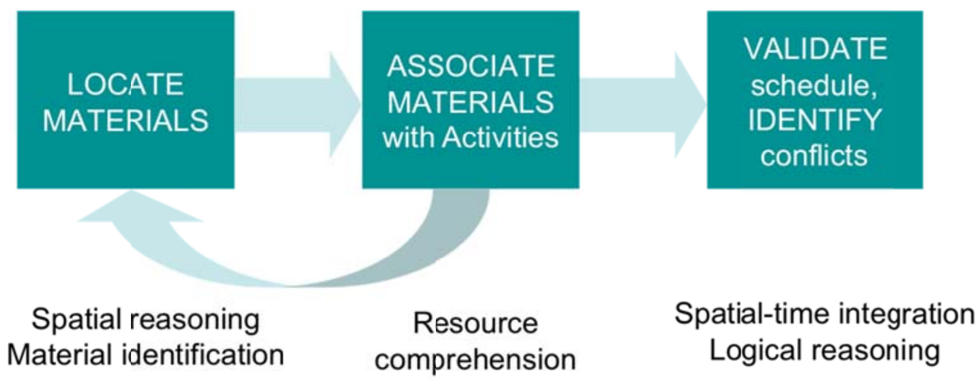

Figure 2.3 Learning activities sequence and educational objectives

It should be noted that these objectives and activities went through a series of metamorphism before arriving at their final forms. The starting point was the general idea of having students to recognize materials and do some simple tasks with them, but it was not clear right from the start exactly how much of this could be built into the interface. During the development process, the objectives were simplified and refocused, which thus resulted in redesigning activities. Defining learning objectives is indeed an iterative process. This iteration is especially true in the case of designing technology-supported instruction as design feasibility is both constrained by what can be actualized on the technological platform and expanded by the additional capability of technology to allow for some extraordinary activities to be carried out and performance to be recorded for assessment. This process will be elaborated in more detail during the discussion of learning assessment in the Section 2.4.

2.3.2 User interface

Figure 2.4 captures the user interface of the learning module. There are four interactive panes on the screen. Pane 1 displays the data received through live communication with the RFID tags (in this project, sensors were used to mimic RFID tags for learning and teaching purposes). Pane 2 is the map of the virtual construction jobsite. Pane 3 is the current construction schedule with activities and their start and finish dates as well as durations. Pane 4 is a supporting feature to Pane 3: when an activity in pane 3 is selected, Pane 4 displays the material required for that activity to be carried out.

As described earlier, the virtual jobsite used was the fifth floor of the civil engineering building, with the map shown in Figure 2.4. The map was drawn purposely like a 2-D engineering drawing with black background and white lines as this is the kind of drawings used on most construction jobsites. There were offices all around and in the central block. Sensors were hidden in the ceiling along the hallway. As the students carried the tabletPC and walked along the corridor, they had to look for the materials that were supposed to be physically present on the jobsite (which were presented by big white paper signs). Live RFID-like data generated by sensors were displayed on the tabletPC (top left corner panel in Figure 2.4), which allowed students to compare what they saw with their own eyes to what was detected by the tabletPC and then take actions.

For each of the material items detected and displayed in Pane 1, the information includes material name and quantity. When the student finds material and locates it on the map (by dragging and dropping), the pushpin sign turns into a green dot to reflect the action. The student can also make some notes for each material by clicking on the plus sign icon and typing into a blank space expanded below. A material item can be attributed to an activity by dragging and dropping it on the activity to be associated.

A color coding scheme is built into the display of the Gantt chart bars to indicate activity status. A green bar means all materials for that activity have been found and associated. A gold bar means some but not all materials for an activity have been associated. A purple bar means no material has been associated with that activity. This color code aims to help students see the big picture of material availability and schedule status better. Moving the mouse over a Gantt chart bar also results in the display of a hover tooltip with activity-relevant information (lower right corner of Figure 2.4). Figure 2.5 provides a close-up look of the interface.

Figure 2.4 Four panels in the interface of material management learning module

The user interface illustrated is, again, the result of several design iterations. The most changes were made after the first module testing in August 2007. The feedback from this testing revealed that in general the participants found the interface visually appealing. Three people out of four found the tabletPC, the stylus and screen comfortable or very comfortable to work with. All of the four participants thought the screen size was just right. They often or very often found what they wanted to find on the screen and on the jobsite. The consensus was that technology made the exercise more interesting. However, the exercise was too long, and the tabletPC was rather heavy to carry around for the duration of the exercise. The specifics of the testing procedure and lessons learned after the second testing (November 2007) will be discussed in the next section.

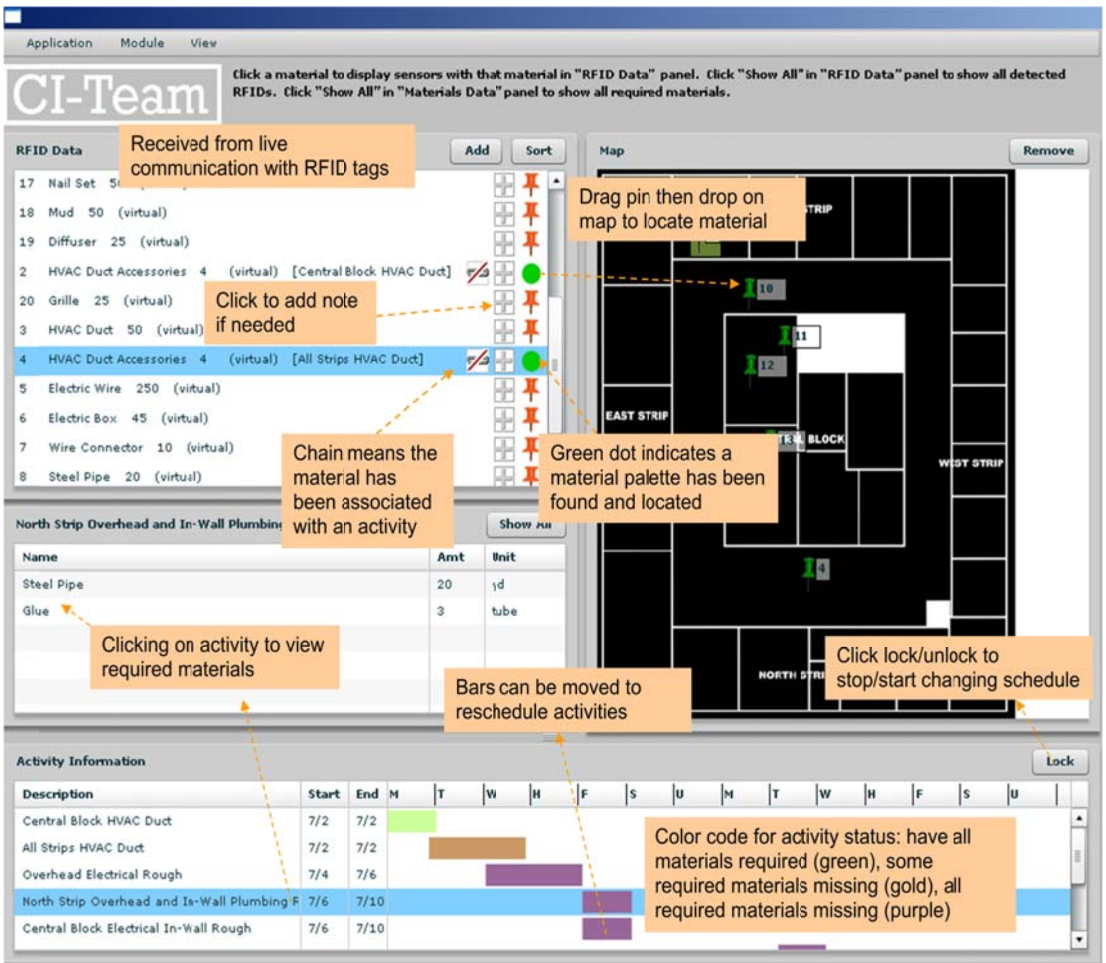

Figure 2.5 Learning module interface in close-up

In terms of structure and content, the second version of the learning module was essentially the same as the first one, except for the following modifications made based on the feedback obtained:

- Reduced the number of materials from 34 to 20;

- Reduced the number of construction activities in the schedule from 14 to 9;
- Added the ability to list RFID data by IDs or alphabetically;
- Added the ability to remove a material from the map or re-locate it if previously misplaced;
- Added the ability to lock or unlock schedule to avoid accidental changes to the schedule.

2.4. Evaluation of the learning module

2.4.1 Learning assessment

Regardless of how interaction design might appear to be the focus of our design problem, it is important that the central task remain instructional design. The effectiveness of a learning tool is measured by the fact whether or not students learn the knowledge the teacher wants to teach them. Hence learning assessment has to be a critical aspect of learning tool design right from the start although most of student performance can only be evaluated at the end of the learning process. Wiggins and McTighe (2005) calls this process “backward design” (Figure 2.6). This tenet is analogous to purposeful task analysis. With instructional design, assessment of learning is designed at the beginning rather than at the end of the process. Once the learning outcomes have been determined, measurement methods are created to assess the effectiveness of teaching. These measurements can be made more specific as learning exercises are developed in greater detail later in the process.

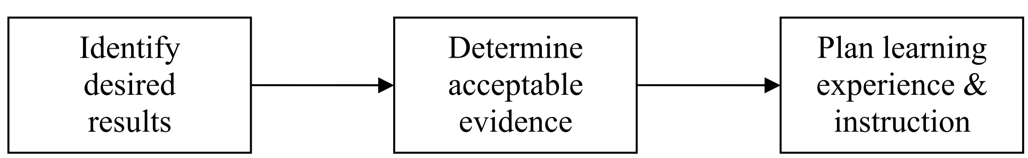

Figure 2.6 Stages in the Backward Design Process

The learning goals and objectives (desired results) have been defined in Section 2.2 (Table 2.1). The next step was to determine how the achievement of these objectives can be measured. Table 2.2 provides potential performance indicators (acceptable evidence) that could be used for assessment. These indicators came from two sources: the data electronically captured within the learning module when students used the program, and a post-test quiz (called The Learning Module Recap) completed by participants at the end of each test as part of the post-test questionnaire (Appendix B). The electronic data indicated how much of the task the students completed. The Learning Module Recap was a short quiz with problem solving questions, multiple-choice questions, short answer questions and true/false questions. These questions required students to recall what they learned about material locating, resource allocation, conflict diagnosis, and RFID awareness. The final metrics used for learning assessment are listed in the last column of Table 2.2.

Table 2.2 Performance indicators and metrics

Learning objectives	**Performance indicators**	**Performance metrics**
Spatial reasoning	Spatial conflict diagnosis	• % task completion (electronic) • Conflict diagnosis (quiz) • Material availability and status (quiz)
Material identification	% task completion	
Resource comprehension	Determination of material availability and status	
Spatial-time integration	Schedule adjustment based on material availability	
Logical reasoning	A derivative spatial reasoning	
Recognition of technology potential and limitation	Ability to diagnose communication failures	Results from quiz
Operation skill development	Time on task	Time on task

2.4.2 Learning experience

In addition to the formal learning assessment of the material management exercise measured by the performance metrics described earlier, there was another aspect of learning that was of interest in this pilot design study: student learning experience. While often not a formal part of assessment, good learning experiences reflect good instruction. Students' own assessment of the learning process helps teachers improve instructional design. The role of learning experience in a technology-supported learning environment can be even more significant because of the power of interaction with technology.

In the second part of the post-test questionnaire, General Learning Experience, the students were asked to reflect on their learning experience with the module. They were to describe their feelings in the process, how comfortable they were with different stimuli, what got them motivated, and what interfered with their learning. Students were asked to indicate whether or not they agreed with each of the 16 provided statements about different components, logics, and features of the learning module. Participants also gave their opinion on the overall design of the exercise, such as the clarity of task descriptions, the logic of task flow, the amount of instruction given before the task, the length and difficulty of the task, and their enjoyment with the experience. In addition to the questionnaire, student engagement and learning motivation could be indirectly reflected in the level at which students completed the exercise. Good performance reflects high engagement, while incompleteness might reflect frustration.

It was also expected that student feedback on the general learning experience would help shed light onto the correlation between learning styles and learning motivation and effectiveness. Prior to testing, students completed the Index of Learning Styles questionnaire (Appendix D), which is a self-assessed questionnaire that measures students' tendencies to process information and acquire knowledge along four dimensions: general information perception preference (sensing or intuitive), sensory information perception preference (visual or verbal), information processing preference (active or reflective), and generic understanding formation (sequential or global). The meanings of these styles are summarized in Table 2.3.

Table 2.3 Descriptions of learning styles (Felder and Spurlin, 2005)

Active Learn by trying things out, enjoy working in groups	**vs**	**Reflective** Learn by thinking things through, prefer working alone or with familiar partner
Sensing Concrete thinker, practical, oriented toward facts and procedures	**vs**	**Intuitive** Abstract thinker, innovative, oriented toward theories and underlying meanings
Visual Prefer visual representations of materials, such as pictures, diagrams, flowcharts	**vs**	**Verbal** Prefer written and spoken explanations
Sequential Linear thinking process, learn in small incremental steps	**vs**	**Global** Holistic thinking process, learn in large leaps

The literature suggests that the matching or mismatching between the learning style of undergraduate engineering students and the instructional materials delivered to them might have important impact on learning. According to Felder and Silverman (1988), among the data they had, while 63% of students were sensors, the instruction was focused on theory and modeling which was more suitable for intuitors. Similarly, heavily verbal materials with written explanations and theories did not favor the 82% visual learners in the audience. Of interest to this study was to observe if similar patterns existed in our student population.

2.4.3 Technical usability

The premise of using technology in instruction is that it helps students learn better by supporting their cognitive processes and enabling learning activities that would not be possible otherwise. This, however, can only be achieved when technology has good usability, that is, when it is straightforward, intuitive, and physically comfortable to use. Since this learning module used both an interface and a physical device, it was important to evaluate the impact these could have on the learning processes of the students. Part three of the post-test questionnaire was dedicated to this purpose with questions about the visual appeal of the interface, physical comfort when using the device including the tabletPC and stylus, the touch screen, lighting, screen size, etc. Usability was also evaluated by metrics such as the attractiveness of technology (whether or not it made the exercise more interesting), technical failure (e.g., sensors not working), and other problems that users might have run into.

2.5 Findings and observations

As mentioned earlier, the first working version of the materials management learning module was tested by four students in August 2007. Some substantial modifications were then made to both the interface and the assessment design to reflect the lessons learned from the first testing. The improved second version was then retested in November 2007 by four different students. All the eight participants were graduate students in civil engineering or construction management. In the following discussions, focus will be on the results of this second testing. More importantly, the significance of these findings will help inform more focused research of the literature in order to develop a comprehensive design framework for similar design missions.

2.5.1 Student performance

Table 2.4 summarizes the performance metrics for three out of four participants of the second testing. One participant did not turn in the post-test questionnaire for unknown reasons. From Table 2.4, it can be seen that participants #1 and #3 did an excellent job, while participant #2 seemed to have struggled and also took the longest time to complete the exercise. Overall, the learning objectives were successfully achieved for two out of three participants. It was realized that the wording of some questions in this assessment test might have been the reason for the poor performance of participant #2 (and #1 occasionally).

Table 2.4 Student performance in November 2007 testing

Participant #	**1**	**2**	**3**
Task completion	Completed	Substantially completed	Completed
Conflict diagnose	2/4	1/4	4/4
Representations of material availability and status	3/3	3/3	3/3
Understanding of RFID communication	3/4	2/4	4/4
True/False questions on RFID and wireless communication	8/8	5/8	8/8
Time on task	40 min	1 hour	25 min

<u>*Observation1: the importance of pedagogical design and assessment.*</u>

Assessment design has to be incorporated in the design process from the very first stage. When designing with technology, this also means that it is a constantly active task, and the results are always changing due to the fact that the technological platform on which the lesson is built might dictate what performance data can be captured and what cannot. It might limit the ability to assess student performance, although in many cases the opposite is true. For this learning module, the last saved interface captures the deliverable students have to make for the lesson, which is both visual and statistical.

There are other aspects of learning that are more abstract and might not be reflected in actions that produce quantifiable results, such as student perception about RFID technology. In this case, student reflections and self-assessment can be taken as part of the formal assessment.

As designing technology-supported instruction requires a tremendous amount of time and effort to develop an interface, the focus on pedagogy, which should always be the central task, can sometimes be lost. To avoid this pitfall, the design needs to be built on a structured and well-established instructional design model. This process needs to be much more elaborated than the "backward design" process described in Section 2.4. Technology also offers various options for assessing learning that are not possible in the traditional lecture setting, such as the ability to accurately record all actions performed by students. This is not only limited to recording quantifiable data. If a built-in camera or microphone had been installed, students' facial expressions and conversations (if the exercise was done in groups) could have also been captured. Other data that might tell a better story about how students interact with the interface are screen captures or records of mouse clicks.

2.5.2 Learning experience

In general, the participants found the exercise long. However they all found that the task descriptions were clear, the flow of tasks was logical and easy, expectations were communicated effectively and the amount of instruction given before carrying out the task was just enough. Participant #1 thought the task was very easy, participant #2 found it challenging, and participant #3 thought it was average. In general they enjoyed the experience somewhat (except for #2 was neutral).

Observation 2: communicate learning objectives clearly

All participants thought that the short instructional presentation at the beginning of the testing was very helpful in establishing learning expectations and providing guidance to an otherwise completely self-paced learning experience. In technology-enhanced learning tools, there is usually significantly less direct instruction from a teacher, therefore the design should have an imperative structure to make sure the students know what is expected of them and they are not carried away from the central learning task.

From the learning style questionnaire results, it was found that all three participants were active learners who preferred to actively do things to understand about them, as opposed to just read and reflect. Two of them preferred global thinking over sequential, and one was neutral. They seemed to strongly prefer visual learning to verbal, and did not have a clear preference between sensing and intuitive methods of learning.

The analysis of post-test questionnaire results indicated that the learning module effectively supported the users' learning preference. Participants confirmed that they felt comfortable with the graphical user interface and did not feel the need to have more text-based information. It was also revealed that the flexibility of the program and the content of the instructional presentation supported the participants' preference of global thinking.

The students' learning preferences did play an important role in their interaction with the learning module and hence influenced their performance. Some students liked the large degree of freedom that the interface offered; they could go back and forth to explore the relationships between the components of the tools instead of having to follow a rigid procedure to get to the final point. Some students, however, were less comfortable with and less confident in having to guess what to do next. A versatile application should have a mechanism to make sure both styles of learning will be supported.

Observation 3: accommodate students' learning preferences

Some researchers believe that instructional design should support learning by matching instruction with students' learning styles, hence providing comfort (Lovelace, 2005; Mahlios, 2001; Ogden, 2003; Stanberry & Azria, 2001). Others argue that by mismatching instruction and learning styles, we help stretch students' abilities and make them learn more effectively (Miller and others (2001); as cited in Brown, 2003). However, both groups agree that instruction should not be tailored to fit a certain learning style but instead must have enough diversity in format and content to support the range of learning preferences that exist in the student audience. The reason is that no learner is strictly active or strictly sequential. They might have a strong tendency to perceive a certain type of information better than other types, but this does not mean that they do not respond to other forms of stimuli. An instructional module therefore should support the typical profile student and offer equally good alternatives to those who stray from the norm. This is beneficial to both the whole student group as well as every individual.

This accommodation necessitates the need to know our students' learning characteristics, which is part of a more comprehensive student background. For most of the eight students participating in our two tests, it was their first time to use a tabletPC or to have direct experience with sensor technology. This was why they were provided a little orientation at the beginning of the test to familiarize themselves with the device and the way it works. This leads to the fourth observation: are our students ready?

Observation 4: student readiness

In the case of this project, the tabletPC was a relatively easy gadget to get used to; therefore students did not have to spend too much time making themselves comfortable with it. This, however, might not be the case when the technology adopted is far more radical than what the audience is accustomed to. For example, if most students in a have never played any complex strategy game, having to interact with something that technologically sophisticated might not result in effective learning, at least not without any serious orientation and training. In addition to the technical challenge, there is also the attitudinal aspect of technology perception that needs to be taken into account when designing a learning tool for a particular audience.

During the testing, it was observed (and reported through the post-test questionnaire) that the students were highly engaged in the exercise. Among the reasons given are hands-on experience, appealing interface, technology relevance to the construction domain, and its applicability to the real world. This evidence of engagement is the strongest indication of an active learning process occurring when students both actively carry out the activities and reflectively think about the meaning of their actions in relation to their understanding of the world. The design of this module as a simple simulation of a construction jobsite (the material component of it) helped bring about a sense of relevance and excitement, which in turn resulted in engagement at the core of active learning.

Observation 5: use technology in a way that creates engagement.

That technology excites and engages users is nothing new. The hugely profitable and ever expanding gaming industry is the living proof of technology's power to captivate the human mind (and their money). Although most of the gaming industry's products are geared toward commercial and entertainment purposes, the educational value of these creations has been widely recognized and appreciated. Teaching tools similar to this learning module, in principle, are games and simulations in another context. There are scientific reasons for the engaging power of commercial games and simulations that are applicable to any educational design and this should be exploited for instructional design.

When designing the learning module, one of most desirable qualities was intuitiveness. One way to achieve this was through the use of several metaphors, both for the graphical representations of visual components and for the events or actions that took place. For example, the action of locating materials on the jobsite was done by dragging and dropping, and the visual representation of that was a pushpin either in an unused form or pinned form. Pins could be moved around on the maps just as materials can be moved around the job site. This feature proved to resonate well with the students, as they reported to like these metaphors and benefit from them cognitively. The use of metaphors, in fact, is a common design principle in the world of interaction design. In the case of an interaction interface used for learning, some principles like this one might play a more important role than others.

There were, however, some complaints about the repetitiveness of a few tasks that were, in the students' opinion, simple. Once the students reached the learning curve's plateau of the material locating task, for example, they tended to get bored if they had to keep doing it. They wanted new challenges. This is an area where exact replication of the real world is not necessarily a desirable feature in pedagogical design. In reality, the number of materials, and hence the number of repetitive material locating task can be hundreds of times bigger than in the simulation. However, the students just want to know how to do the task, they do not want to have to do as much as it requires in the real world (at least for the purpose of learning). Therefore certain simplification of reality is needed to keep students motivated and engaged.

Observation 6: Pedagogical significance of interaction design principles

There is a huge body of knowledge that has been created concerning best practices in interaction design by well-known industry leaders such as Apple, Microsoft, Sun, IBM, etc. Most of these practices are in the context of commercial software (and hardware) design and hence might not always be appropriate in an educational interface. It is therefore important to look at these guidelines from a pedagogical perspective and assess their validation when applied to the design of a technology-enhanced teaching tool.

To illustrate this point, let us look at a common belief in the interaction design world that states that good applications should not make users think what to do; such action should be effortless. For learning purposes, however, this might not be entirely desirable. It is good to free the students of cognitive loading when it comes to operating the application. Nevertheless, it is important that they focus on thinking about the subject matter and reflect on their actions. Effortlessness, therefore, could eliminate the context for real learning to occur. This learning module could have had a feature where only materials corresponding to a construction activity can be associated with that activity so that students would never make a wrong association. It was not done so to allow students to make mistakes and then re-evaluate the consequences of their actions when conflicts emerged.

2.5.3 Technical usability

The most unexpected feedback from the first testing in August 2007 was that the tabletPC was too heavy for the length of the exercise. The learning module required one participant to spend more than one hour to complete, and some others more than 45 minutes. As the students had to carry the tabletPC (which weighed more than 2 pounds) and walk the "jobsite" for an extended period of time, their arms became tired, which was a great demotivator. Some other comments regarding the technical usability of the tool include:

- "It was hard to drag and drop push pins on maps.
- Materials had to be dropped right on the bars otherwise it could not be associated with the activities.
- The Activities window was small. I would rather scroll the list of items than the schedule.
- Size of window should be adapted to screen.
- Difficult to use stylus."

2.6 The next step

To explore the process of designing technology-supported instruction, a material management learning module was created as a pilot study. The backend of the module consisted of a few sensors pre-programmed with material data, a tabletPC that could receive live data from sensors, and a floor plan from the engineering building to be used as the virtual jobsite. The front-end was an interactive interface installed on the tabletPC that used live material data as input. The students carried the tabletPC and walked around the virtual jobsite doing basic material management tasks. The learning module was designed and refined based on testing results. During the testing, module evaluation was conducted for learning assessment, student learning experience, and technical usability.

The design and evaluation process revealed several insights on key aspects of instructional design and the impact of technology. It is believed that an effective framework for designing technology-supported learning tools needs to address the following areas adequately:

- Employ an instructional design model that is effective in helping teachers define accurate and measurable learning objectives and align those with learning activities and assessment;
- Incorporate student learning preferences in the process, including their readiness for and attitude toward technology;
- Capitalize on the potential of technology to be engaging. Explore the types of games and simulations that are suitable for learning purposes;
- Apply user interface design principles to enhance pedagogy and achieve good usability.

These lessons learned from the pilot study will lay the foundation for the literature review and framework development in the next stages of the research project.

CHAPTER 3: RESEARCH QUESTIONS AND METHODOLOGY

3.1. Research Questions

The main goal of this research is to build a framework to guide the design of technology-supported teaching tools. As described in Chapter 2, to help narrow down the focus of research, an exploratory case study was conducted with a pilot design of a materials management learning module. By using prior knowledge and common sense without following an elaborated formal design framework, the module was created with mobile technology as the backend infrastructure and a stand-alone software program run on a tabletPC platform as the frontend interface. The process of designing, refining and testing the learning module helped determine the key steps involved in the creation of a technology-supported instructional tool. Preliminary literature review also found that there were important issues in the domain of technology-supported instructional design that had not been adequately addressed in the current body of knowledge. Key points to be explored as suggested by the pilot study include: 1) identifying a sound model of pedagogical design to guide the framework, 2) addressing students' skills and learning preferences in the design, 3) taking advantage of the engaging capability of technology and the potential of games/simulations as learning strategies, and 4) capitalizing on basic interface design principles to achieve solid pedagogy.

These observations and a thorough assessment of the current literature lead to the formation of the following research questions. Question 1 is formalized to address a major gap in the understanding of civil engineering students' technology background which is considered a critical input to the design of technology-supported learning tools. Question 2 investigates the key components of the design framework to be developed and what existing and additional knowledge is needed to turn these components into an actionable process. Each of these questions is divided into sub questions that explore critical aspects of the issue under consideration.

Question 1. What is student knowledge with respect to technology and construction, and what are the implications for pedagogical design?

- *Question 1a*. How much do students know about and use technology?
- *Question 1b*. What are students' attitudes toward technology?
- *Question 1c*. What learning activities do students find engaging?
- *Question 1d*. What is the current state of students' construction knowledge?

Question 2. Can we synthesize existing knowledge in user interface design and instructional design into a framework that aids the development of technology-supported instruction?

- *Question 2a*. How can the distributed knowledge in instructional design, interface design, and student background be systematically embedded in the design process?
  - Is there a classification of educational games and simulations that can be used as a taxonomy for technology-aided instructional strategies?
  - What existing guidelines in user interface design have important pedagogical implications?
  - How can we use our knowledge about the students to improve the effectiveness of technology-aided instruction?
- *Question 2b*. Is such a framework helpful in facilitating better creation of technology-assisted instruction?

3.2 Research methodology and process

Each of the major research questions stated above requires a different method of inquiry that suits the purpose of the specific issue under investigation. Due to the open-ended and exploratory nature of these questions, most of the research methods employed to address them are qualitative. Qualitative methods such as survey studies, case studies and literature analyses are particularly useful when new topics are of interest and no predetermined hypotheses are to be confirmed or rejected as new knowledge and information might change the course of investigation (Jones, 1995, de Vaus, 2001, Eisenhardt, 1989). Table 3.1 summaries all the research questions and their corresponding methods of inquiry. The actual breakdown of research tasks for the whole dissertation is depicted in Figure 3.1. Both Table 3.1 and Figure 3.1 will be used in conjunction to explain the research methodology (how the questions were answered) and process (what research inquiries were used and when) in the following sections.

Table 3.1 Major research questions and corresponding methods of inquiry

#	Questions	Specific methods of inquiry
1	What is student knowledge with respect to technology and construction, and what are the implications for pedagogical design?	Survey (Technology and Construction Baseline Survey)
	1a How much do students know about and use technology?	
	1b What are students' attitudes toward technology?	
	1c What learning activities do students find engaging?	
	1d What is the current state of students' construction knowledge?	
2	Can we synthesize existing knowledge in user interface design and instructional design into a framework that aids the development of technology-supported instruction?	
	2a How can the distributed knowledge in instructional design, interface design, student background be systematically embedded in the design process?	Exploratory research (pilot design) Critical analysis and synthesis of literature Analysis
	• Is there a classification of educational games and simulations that can be used as a taxonomy for technology-aided instructional strategies?	
	• What existing guidelines in user interface design have important pedagogical implications?	
	• How can we use our knowledge about the students to improve the effectiveness of technology-aided instruction?	
	2b Is such a framework helpful in facilitating better creation of technology-assisted instruction?	Case studies Participant observation Structured interview

The research is broken down into four main phases. The first phase involves the pilot design as exploratory research, which was already described in Chapter 2, followed by a focused literature review (Chapter 5) and the formulation of research questions. The second phase is the design and implementation of the Technology and Construction Baseline Survey (Chapter 4), which provides a complete answer to the first research question. The last two phases are dedicated to the development (Chapter 6) and evaluation (Chapter 7) of the actual design framework. In other words, their role is to answer the driving research question of this dissertation, Question 2.

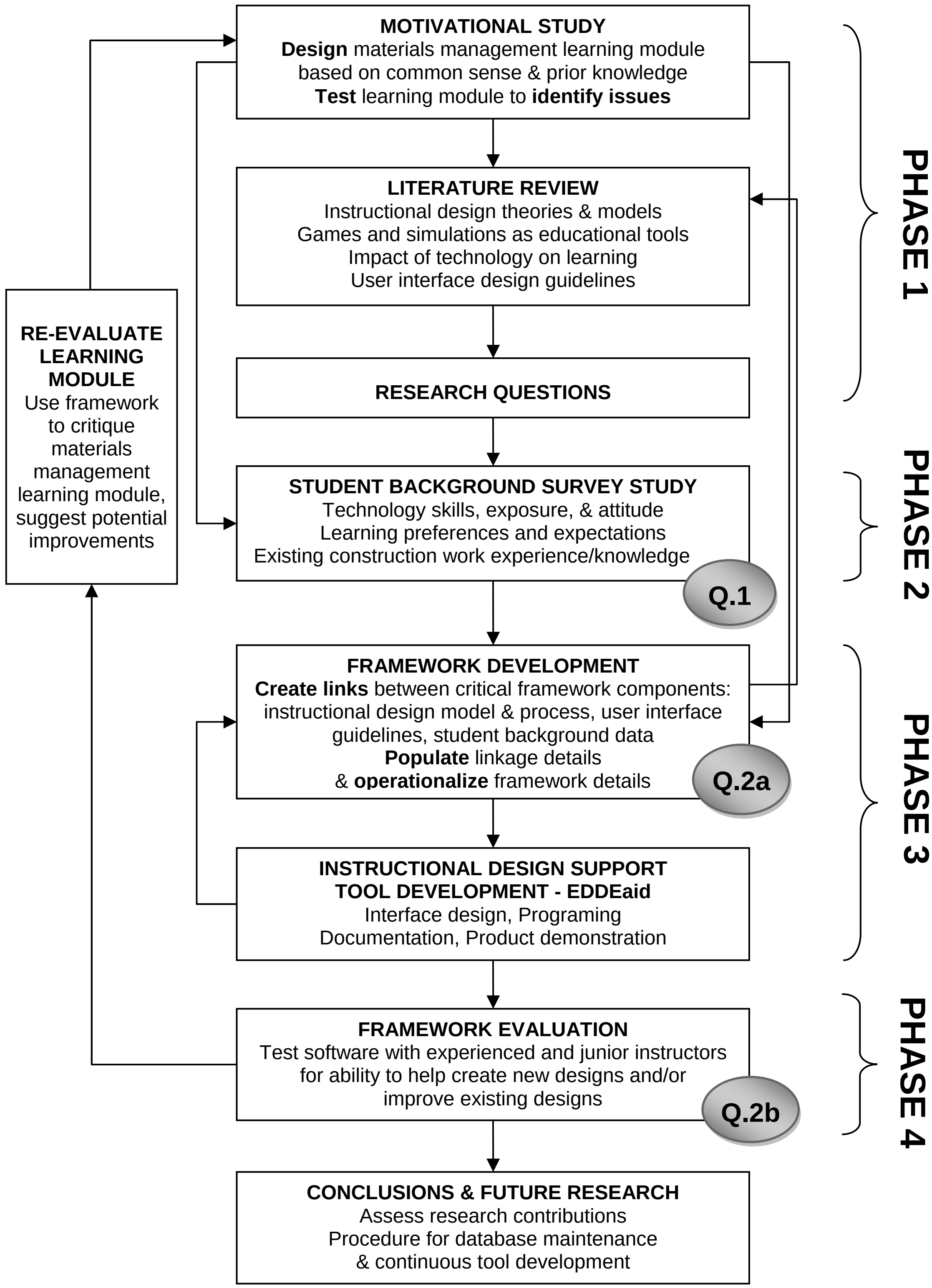

Figure 3.1 Research process

3.2.1 Literature review

A review of current literature is conducted in four areas of knowledge: instructional design theories and models, existing game/simulation genres that could be used as learning strategies, impact of technology on learning, and the basic user interface design principles. As there are two dimensions to the design framework being developed, structure and content, the role of the literature review is also twofold. First, a broad review is conducted to identify the components that would constitute the framework. Once these components have been defined, a more in-depth analysis of the literature will be needed to 1) establish the rules that would relate the components to one another and operationalize the framework, and 2) generate the specific content at the level of details necessary for the framework to be useful. This literature review is a continuous process that is revisited in light of new needs created during framework development.

3.2.2 Student background survey study

Based on the insights obtained from the pilot study and preliminary literature review, it was determined that student background information needed to be incorporated into such a framework for it to produce truly student-centered instructional design. Studies by Prensky (2006) and the National Survey of Student Engagement (2009) reported a rapidly changing profile of today's college students, especially in areas related to technology adaptation and learning expectations. The data provided by these studies, however, were for college students in general, not specifically for the engineering student audience (who might possibly be somewhat different from the rest in terms of technology skills and attitude due to the nature of their majors). Furthermore, these data were mainly broad and generic descriptions of students' habits and experience that could not be used directly to guide the design of technology-supported learning tools. It is necessary that a new study be conducted to obtain data on the basic learning preferences, technology skills, and domain knowledge of construction students. As the study is to collect descriptive data on trends, attitudes and opinions of a population, the survey method is the most suitable (Creswell, 2003). This method is also the easiest way to obtain a large number of data points to improve the representativeness of the sample and allow for stratification of the population along certain dimensions during data analyses.

The instrument is designed as a questionnaire with hybrid question types, ranging from Yes/No to multiple choice (qualitative) and Likert scaling (quantitative) questions. In observance of good survey question design, most questions are designed with specific descriptions of the parameters to be measured and multiple choices to stimulate recall of the subject. When rating is required, rating dimensions are carefully described and value clearly ordered. It is also important to avoid having unrelated dimensions in the response categories (Fowler, 1995).

The survey was distributed to whole classes in engineering schools as well as accessible online for any individual with an interest in participating. Data analyses focus on descriptions of student characteristics and correlations among certain variables instead of exploring causal relationships that existed in the data. The goal of this survey study is not to build statistical or prediction models for student skills and learning preferences. Instead, it is to understand the constituents and diversity of a certain student population in order to make instruction comprehensive and versatile. These analyses will then be used as input to the design process of the framework to make sure instructional design produced by it addresses the learning needs of the majority of learners.

3.2.3 Framework development

Framework development is the main task of the research and spans almost the entire process. It interweaves with the literature review process, constantly informing, shaping and being reshaped by one another. Through critical review of the literature, key framework components are identified to be: 1) a model to guide instructional design (define instructional goals and objectives and create specific instructional events), 2) student learning preferences, technology skills and domain knowledge, 3) taxonomies of game-based instructional strategies, and 4) basic user interface design principles.

Now that initial framework components have been identified, the main task of framework development is to define the rules that link these components to each other in a logical manner, such as how to choose an instructional strategy for a certain instructional goal, which instructional activities should be designed for a chosen strategy, or how to accommodate students' technology skills in the learning tool. In other words, it requires a mechanism that turns these unrelated items into a flow of linked design actions. For the most part, each of these component items is identified with a set of properties or descriptions provided by previous studies. These, however, do not automatically translate into a direct link in the decision making process. Framework development, therefore, is the process of creating these links to operate the design process.

To do this, a systematic and critical analysis of the literature is conducted to explore the pedagogical value of each of the game-based instructional strategies as well as the cognitive requirements and actionable qualities of learning objectives and activities when implemented with technology. By assigning cross-attributes to the most two important design aspects, instructional design and interface design, linkages among framework components can be revealed and populated to operationalize the framework. This analysis involves classification of concepts and events, grouping and dividing up categories, and attaching to them labels that reflect some of their pedagogical or interactive characteristics.

For example, the learning goal “judgment” represents a high-level intellectual task that required students’ understanding of the problem from multiple perspectives. It is therefore characterized as “open-ended” and “evaluative” (corresponding to one of the higher levels on Bloom’s scale of intellectual development - evaluation), among others. Similar analysis is done for the instructional strategies, in which “role-playing” is a strategy that is open-ended and capable of exposing learners to different viewpoints. This common “open-ended” nature of the learning task and the learning strategy suggest that role-playing might be a suitable way to teach “judgment” to students. Detailed linkages like this are needed at different levels for the framework to be operational. While the literature provided some high-level principles for these connections, most of the specific details that materialize the framework are created using the researcher’s own judgment and validated by experts in instructional (Dr. Kathy Schmidt, Senior Research Associate, The Schreyer Institute for Teaching Excellence, The Pennsylvania State University) and user interface design (Dr. Randolph Bias, Director, Information eXperience Lab, University of Texas at Austin).

The final framework is named EDDE, which represents the four conceptual stages in the design process of a technology-supported learning tool: Explore (the options), Design (the interface and instructional events), Develop (the software), and Evaluate (the end product).

3.2.4 Support tool (EDDEaid) development

In its completed form, the content of the EDDE framework is a document more than 100 pages long. While comprehensive and rich in information, it is not easy to use as the paper-based content has to be presented in a linear format while the process of using EDDE requires constant cross-referencing from different parts of the document as well as participation from the user's end. The linear and one-dimensional nature of paper-based content is a hindrance to the supposedly dynamic and interactive characteristic that EDDE represents. The natural solution to this problem is to computerize the framework to take advantage of technology's interactivity and efficient information delivery potential. For this reason, a stand-alone software application called EDDEaid is created.

EDDEaid provides an interactive interface that modularizes the framework into relatively independent work phases. Each phase is carried out on a separate screen with all relevant elements permanently visible and additional information displayed when there is an inquiry for it from the user. This interactivity makes using the framework remarkably less overwhelming, encourages user learning and interaction (which is key to achieving meaningful results), and helps avoid confusion and frustration for users. The goal is to have EDDEaid as a design support tool that is practical, appealing, and educational for repeated uses.

3.2.5 Framework evaluation

The validation of the framework is done through the testing of EDDEaid. The goal of this testing is to gather evidence that confirms the usefulness and efficiency of EDDEaid as an instructional design support tool and to explore the potential strength and long-term value of EDDEaid. User testing also helped identify the weaknesses of EDDEaid and ways to improve the framework in terms of both logic/content and technical usability.

A combination of exploratory research, participant observation and in-depth interviews with test subjects is used to obtain the data needed. The target audience is university professors who want to create technology-supported teaching materials. A group of university faculty with varying teaching and technology experiences is chosen to use EDDEaid to either conceptually design a new technology-aided teaching tool, or to improve/critique an existing tool. Evaluation will then made based on users' perception of EDDEaid, their satisfaction with the designs produced by the tool, their concrete evaluation of specific EDDEaid recommendations, as well as the researcher's observations of users in progress. Each testing session is designed to last one and a half to two hours and consists of three parts: 1) a pre-test interview to gather information on participants' teaching backgrounds and approaches to instructional design; 2) the actual interaction with EDDEaid to produce a technology-enhanced instructional design, and 3) an in-depth post-test discussion with the researcher to evaluate the value of EDDEaid and other aspects of the experience. Some user feedback will be immediately adopted to improve the tool, while those beyond the scope of this research will be recommended for future research. A re-evaluation and re-testing of the materials learning module created as the motivational study is also conducted based on the newly developed framework.

Chapter 4: UNDERSTANDING OUR STUDENTS: A TECHNOLOGY AND CONSTRUCTION BASELINE SURVEY

4.1 Introduction

Research has shown that technology can greatly enhance learning effectiveness if done right, such as achieving superior retention through the use of multimedia and learning materials of multiple formats (Issa et al, 1999, Hanafin and Land, 1997, Mayer, 2003). In the process of using technology to learn specific domain knowledge, students get exposed to technology and develop a more positive attitude toward learning (Kulik, 1994). Technology also complements the information processing methods of today's college students, which are described as "twitch speed, random access, parallel processing, graphics first, and connected" (Prensky, 2001). The adaptive nature of twenty first century students, the abundant availability of technology and its potentially engaging power make technology-supported instruction a promising solution to the problem of improving teaching and learning effectiveness in college education.

To properly design technology-supported instruction, there is a great deal of input needed, of which student background and prerequisite understandings are arguably the most important of all. This background information ranges from technology exposure and attitude, preferences for using technology in learning, and expectations for the learning environment, to prior knowledge in construction as well as the general level of academic achievement. This step in instructional design is called learners and context analysis (Dick, Carey and Carey, 2005). Each of the abovementioned aspects will have implications on the choice of technology used to deliver the knowledge to students, as well as the specific design features or learning activities to include or not include in instruction. Lessons learned from the pilot design in Chapter 2 also emphasized the importance of incorporating student background data and learning references in the instructional design process.

While a large amount of research has been done on profiling average college students in terms of general technology attitude, learning expectations and gender differences, there is little literature that provides data with direct implications for designing educational technology. Most of the existing knowledge does not focus on the instructional design aspects, such as how students want to use technology in their learning or what kind of activities they want to have in class. To answer these questions, a survey instrument called the Technology and Construction Baseline Survey was created to gather information on our students' educational technology and domain knowledge background. The survey captures students' preferences for lecture format, learning activities, ways of interaction, and use of modern technologies to support learning. It also assesses students' levels of acquaintance with seven areas of knowledge in construction management. This understanding of student knowledge will have direct implications on instructional design as well as help set benchmarks for the definition and assessment of learning objectives.

Section 4.2 below provides a brief literature review of the background of today's students, focusing on their changing expectations, some gender differences with pedagogical implications, and their technology exposure. Section 4.3 states the research questions and describes the structure and content of the survey. Data obtained are summarized in Section 4.4 with comparisons to the literature to see how much of the current belief about today's college students holds true and how their technology attitude translates into learning habits, preferences and expectations. Section 4.5 is devoted to further discussions of pedagogical impact of student background.

4.2 Literature review

4.2.1 The changing students' characteristics and expectations

In Prensky's (2006) study of the "digital native learners," a term used to refer to the current generation of college students, the author found that the average student in college today has spent some 5,000 to 10,000 hours on video games, watched 10,000 hours of TV with around 500,000 commercials, and spent less than 5,000 hours reading books. 70% of students play video, computer or online games at least once in a while; 30% of them even do so during class. In another study, Jones (2003) reports very similar numbers of student gamers in and outside of class. Jones also reports an overwhelmingly positive attitude toward gaming among students.

In 2009, the National Survey of Student Engagement attracted 643 colleges and universities to participate in its study (NSSE, 2009). For both the freshman and senior groups, each student read about three textbooks or book-length packs of course readings, and two books on their own for personal enjoyment or academic enrichment. 98% of freshmen and 99% of senior students use e-mail to communicate with their instructors. 51% of freshmen reported to use a computer “very much” and 34% “quite a bit” in their academic work, while the numbers for seniors are 60% and 28% respectively.

Besides a constant exposure to technologies of all kinds, today’s students have also changed in their approach toward information processing. Prensky (2001) describes the digital natives’ methods of acquiring information and knowledge as “twitch speed, random access, parallel processing, graphics first, and connected”, as opposed to the “conventional speed, step-by-step, linear processing, text first, and stand-alone” mindset of non-natives to the digital land. These learners are described by Aldrich (2005) as pragmatic, problem solvers, demanding interaction and personalization, and adverse to text-based information (and hence, reading). The changes in students’ technology background and learning expectations suggest that learning and its tools should reflect what is happening in our “Information Age” and that there is a real need to create instruction that addresses the needs and interests of today’s students.

With technology advancing at an increasingly rapid pace, there is a reason to believe that two generations, five or ten years apart, can have significantly different technology skill sets and expectations. Similarly, there might be a gender bias in technology preferences or group work activities. Previous studies already suggest that low scoring students benefit more from multimedia-based instruction than high scoring students (Issa et al, 1999), and collaboration helps under-represented groups more than it does others (Prince, 2004, Schmidt, 1992).

The student profile described above is applicable to general college students across disciplines. These statistics, however, do not exist for engineering students, or more specifically, civil engineering students. It is expected that differences might exist for these particular groups of students due to the more technology-oriented nature of engineering classes as well as a different kind of interests in their daily life. A database of civil engineering students' technology background, therefore, would be valuable if instruction is to be created for the civil engineering domain.

4.2.2 Computer skills of civil engineering students

In 1989, 1995, and 2002, the American Society of Civil Engineers' (ASCE) Task Committee on Computing Education conducted a longitudinal survey study to assess the computing component of the civil engineering curriculum in which educators and practitioners were asked to rank the importance of different computing skills, the competence in these skills of undergraduates, and the level to which the engineering curriculum covered these areas (Abudayyeh et al, 2004). The 2002 survey revealed that the academics and practitioners ranked spreadsheets, word processors, computer-aided design, and electronic communication among the most important skills, which was the same as the previous study. It was also found that students had limited skills of geographic information system and specialized engineering software, the two areas that were considered increasingly important according to the survey subjects. As these findings are eight years old and from the educators' and practitioners' perspective, it would be interesting to see if students' technology skills have changed in the last decade during which non-traditional computing areas such as mobile technology and web-based applications have developed at a dramatic rate. The difference, if any, between the students' own assessment of their skills and that done by academics and professionals (as in the case for the ASCE survey) would also have pedagogical implications.

4.2.3 Gender differences

The gender differences are of interest, especially those related to technology, as in the past, women were reported to have significantly lower computer skills and confidence than men, which means technology-supported instruction would give a big advantage to men over women. Although this gap has been reduced by a large extent (Schumacher and Marahan-Martin, 2001), not all differences have been eliminated. An important phenomenon that remains and has been confirmed by several studies is the tendency for women to underestimate their technology skills regardless of their actual competency (Cassidy and Eachus, 2002, Sanders, 2005). Despite the fact that women report a greater level of computer discomfort and incompetency, they tend to use technology to communicate more often than men, while men are found to do more searching and exploration than communication with technology (Jackson et al, 2001).

Another gender difference that has been persistent through the years is the fact that female students generally have higher average GPAs (Grade Point Average) than male students, although the margin is not the same for all reports. Depending on the gap, this might have pedagogical implications in terms of the marginal benefit technology brings to groups of students with different levels of academic achievement, as discussed earlier. For example, the average GPA for Iowa State University students in Fall 2003 was 2.96 for female and 2.70 for male (IOS, 2003); for University of Virginia in Spring 2008 the numbers were 3.305 and 3.207 (UV, 2008); 3.15 and 2.85 for Northern Arizona University in Fall 2009 (NAU, 2010). These statistics are available for most colleges and universities, and the trend of female students having higher GPAs than male students is consistent.

4.2.4 Summary

Students' perception of different learning activities is another dimension of interest with potential implications for instructional design. Knowing how students prefer to learn will help instructors keep them engaged. This is critical as engagement, it turns out, might be the single most important factor in improving learning effectiveness for today's students (Prensky, 2001). A lot of this interest can be attributed to the fact that this student generation was born and grew up in an era where technology had permeated into every aspect of life. They are accustomed to the excitement of video games, YouTube, instant messaging, and handheld entertainment devices. This expectation has a significant impact on their learning needs. While content is always at the core of good instruction, engagement is the means to deliver this content to the students effectively.

As discussed earlier, the data that exist, while rich with information on students' general exposure to and attitude toward common technologies such as games or multimedia, do not provide a close-up picture of what students think about the technologies (or the lack thereof) being used in learning and how they have blended their prior technology knowledge and habits into the academic environment. It would be useful to know how students are using new technologies, such as mobile devices and social networks, or applying new skills, such as game knowledge, to support their learning.

4.3 Research questions and methodology

4.3.1 Research questions

The purpose of this survey study is to capture a picture of today's student's background that is more relevant to the design of technology-supported instruction than what is available in the literature. A part of the survey is devoted specifically to understanding the current domain knowledge of construction students, while the rest is suitable for the general student population. The main research question to answer in this survey study is: *What is student knowledge with respect to technology and construction, and what are the implications for pedagogical design?* Specifically, the survey study seeks to learn about the following aspects of student background:

- How much do students know about and use technology? What are students good at?
- What are students' attitudes toward technology?
- What learning activities do students find engaging?
- How do students want technology to be incorporated in the classroom?
- What is the current state of students' construction knowledge?

4.3.2 Structure of survey

The survey study is designed as a questionnaire to be answered by civil engineering students in the United States, Canada, and Australia. It has three sections: Demographic and Background Information, Technology Attitude and Exposure, and Construction-Related Knowledge (Figure 4.1). The first section captures basic participant demographic information such as age, gender, GPA, academic major and standing, work experience, and intended work area after graduation. The questions in the other two sections help reveal where the students are in terms of technology skills and domain knowledge, which are deemed important to the successful deployment of student-centered technology-assisted teaching. The complete questionnaire can be found in Appendix C.

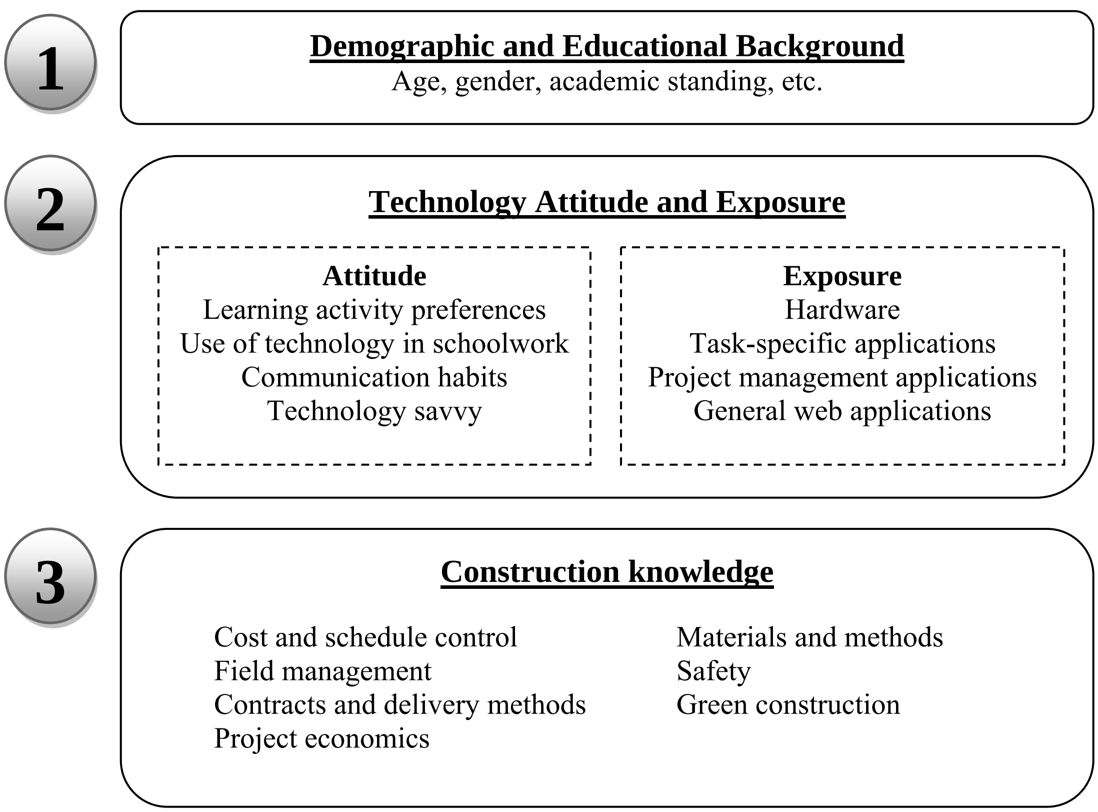

Figure 4.1 Structure and content of the Technology and Construction Baseline Survey

4.3.3 Demographic and educational background

The reason for demographic data collection in the survey is the interest in investigating potential differences in terms of technology skills, learning behaviors and preferences in different groups of students. It is also of interest to observe if there is a gender difference in certain dimension, or if there are any patterns in the population that might be related to work experience or the lack thereof. It is beyond the scope of this study to confirm or reject causal relationships among variables in the data; such work will require an expanded database and rigorous statistical modeling. The purpose of slicing the data in some interesting dimensions is to be aware of the impact that student background diversity might have on the design of technology-enhanced instruction for construction engineering. Such insight can be used to create a design that is student-centered and avoids usability problems that might arise when implementing current educational technologies in construction engineering curriculum.

4.3.4 Educational technology attitude and exposure

There are two groups of questions in this section. The first part, Technology Attitude, has 14 multiple-choice questions concerning students' preferences of lecture material format and learning activities, ways of interaction with peers and professors, and the use of modern technologies to support learning. The second part asks students to self-rate their skills in several technology groups ranging from common desktop programs to specialized construction management applications.

The questions in the first part of this section cover these specific topics:

- Opinions on PowerPoint presentations as a lecture format;
- Types of background activities students do in class, and how much distraction these cause to their learning;
- Preferences for interactive learning (discussions, group projects, role playing, simulations, or individual assignments);
- The use of videos and animations in classes and their effects on learning;

- The use of collaborative tools in-group projects (face-to-face meetings, email, telephone, instant messaging, etc.);
- The use of social networks to support schoolwork;
- Ways of communicating with professors outside of class;
- Preference between computer and manual tools to do homework;
- The level of effort made when learning to use new computer tools;
- Comfort with mobile and touch screen devices; and,
- Self-assessment of technology savvy.

In the second part of this section, Technology Exposure, students are asked to rate their skill level for each of the 20 popular technology groups on the scale from 1 to 5, with "1" being "no skill", "2" being "beginner", "3" being "low intermediate", "4" being "high intermediate", and "5" being "expert." These 20 groups are divided into four categories as shown in Table 4.1. Included in this list are both technologies that are commonly used for everyday purposes such as Web and office applications and a few construction management applications in order to compare students' familiarity with these two groups. The data from both the Technology Attitude part and this Technology Exposure part will provide a picture of technology fluency among the students and their willingness to use technology to support learning. With this information, educators will be better informed when choosing a certain technology to use in the classroom and the level of training needed to prime the learning process. It is also of interest to compare the data obtained from this survey on general student technology savvy with Prensky's (2006) data to determine if the trend observed previously still exists.

Table 4.1 Technology exposure checklist

Group	Technology examples
Hardware	
Basic hardware	Computers, printers, fax machines, scanners, digital cameras, projectors, etc.
Touch screen devices	TabletPCs, PDAs, iPhones, iPods, GPS, etc.
Sensing technologies	RFID, sensors, etc.
Task-Specific Applications	
Office document tools	Word processors, spreadsheets, presentations, etc.
Graphic and web design tools	Photoshop, Paintbrush, Fireworks, CorelDraw, FrontPage, Dreamweaver, etc.
Time/Task management tools	MS Outlook, Mail, desktop organizers, iCalendar, Google Calendar, etc.
Knowledge and Data management tools	MS Access, EndNote, Time Machine, etc.
Structural & Architectural design tools	SAP2000, ADINA, STAAD-Pro, ArchiCAD, etc.
2D- & 3D-CAD	AutoCAD, Unigraphics, Solid Works, Inventor, MicroStation, Revit, etc.
Computational	MathLab, LabView, etc.
Computer games	Strategy games, simulation games, eductional games, etc.
Project Management Applications	
Scheduling	Navisworks, Microsoft Project, Primavera, etc.
4D tools	4D/nD-CAD
Estimating	PROEST, Bid4Build, etc.
Contracts	Primavera CONTRACT MANAGEMENT, Meridian Prolog, Autodesk Constructware
General Web Applications	
Email & Instant messaging	Yahoo Messenger, AOL, MSN, Google Talk, etc.
Search engines	Google, Yahoo, etc.
Social networks	Facebook, MySpace, LinkedIN, Twitter, etc.
Web/Video conferences	Webex, GoToMeeting, Adobe Connect, etc.
Electronic Resources	Online publications, online libraries, YouTube, wikis, blogs, etc.

4.3.5 Construction-related knowledge

The third section of the survey is dedicated to assessing students' levels of understanding in seven areas of knowledge in construction management: cost and schedule control, field management, contracts and delivery methods, project economics, materials and methods, safety, and green construction. For each of these topics, the students are to score their own knowledge of the topic on the scale from 0 to 5, with "0" being "no knowledge", and "1" to "5" corresponding to the five levels on the Bloom's taxonomy of cognitive domain: "1" is "remembering", "2" is "understanding", "3" is "applying", "4" is "analyzing", and "5" is "evaluating/creating", as shown in Figure 4.2 (reproduced from Anderson and Krathwohl, 2001). Bloom's Taxonomy has been in use for more than 50 years and has provided a framework that helps define clear learning objectives that are tangible and appropriately difficult. This taxonomy is incorporated in the questions in hopes of helping teachers align student background knowledge obtained from the survey with desirable learning outcomes in a more systematic manner.

Figure 4.2 Bloom's taxonomy of learning outcomes for the cognitive domain

As these data are captured as students' self-assessments, some level of subjectivity and bias is expected to exist. To reduce this effect, survey participants are provided with relevant examples for each of the answer choices, as shown in Table 4.2. The results, therefore, should be used as a guideline for teachers to determine appropriate learning goals for the subject being taught. It might also be useful in making assessments of learning by measuring the level of knowledge after the learning experience and comparing that to the starting point.

Assessment of the level of knowledge students possess at the beginning of instruction is needed so that teachers can better define the learning outcomes and begin instruction at the appropriate level. While this survey is by no means an absolute measure of knowledge, it is a reasonable guide for establishing instructional objectives for construction education. More often than not, teachers will find that their students are all over the place in terms of current knowledge in a subject. Data like this will provide a picture of students' knowledge spectrum that enables teachers to define more realistic goals and satisfy different learning needs instead of imposing a goal that is not suitable for most of their learners.

Table 4.2 Explanations of Bloom's taxonomy with examples

Level of acquaintance	**Example – Safety Management**
0 – I never heard of this concept.	
1 – (Remembering) I recall/recognize this concept	Know the safety rules.
2 – (Understanding) I can explain the basics of this concept and give some examples.	Explain the procedure of evacuating when an emergency occurs.
3 - (Applying) I can implement this concept in a problem with minimum instructions.	Recreate a similar set of previously learned safety rules for a similar facility.
4 – (Analyzing) I can look at a problem and break it down into conceptual components, such as assumptions, context, hypothesis, evidence, structure.	Recognize all the important components interacting in an emergency situation, such as weather, equipment, human psychology, physical layout, emergency response capacity, and how each component can influence the emergency procedure.
5 - (Evaluating/Creating) I can make a judgment or take a stand about a problem related to this concept. I can challenge the learned concept based on my prior knowledge and experience, and create a new viewpoint or practice.	Realize the inappropriate or dangerous safety practices in a setting different from conventional. Develop new rules to address the uniqueness of the situation.

4.4 Findings

4.4.1 Surveyed population

From spring to fall 2009, the survey was completed by 280 students from eight civil engineering and construction-related schools in the US and one from Australia. The summarized statistics in terms of age, gender, academic standing, and GPA are shown in Figure 4.3. As expected, 80% of the participants are 25 or younger, and the field of study is male dominated with a ratio of male to female of 3 to 1. If the public perception holds true, these people are mostly classified as generation Y (Tulgan, 2009) and dedicated gamers. Female is clearly still the significant minority. 98.5% of the students are at least three or more years into the program, with about a quarter attending graduate school. Our students are high achievers; almost three quarters of them have a GPA of at least 3.0 on a 4.0 scale (or 85% in the Australian grade system).

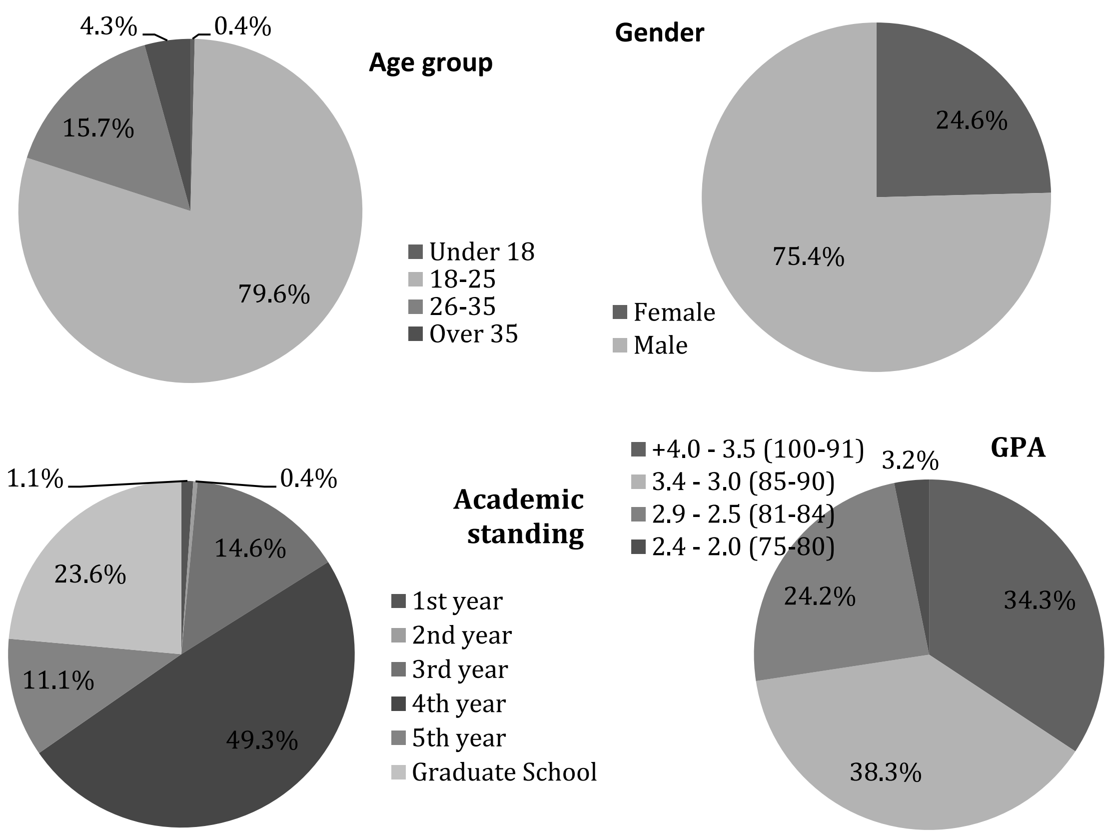

Figure 4.3 Summarized statistics for the survey population

4.4.2 Gender differences

4.4.2.1 Technology savvy by gender

Overall, 47% of the students consider themselves as average in terms of technology savvy, as shown in the pie chart in Figure 4.4. Roughly the same number of students self-report as savvy (36%) or very savvy (10%). Only a tiny portion (6%) of them think that their technology skills are either low or very low. Looking at these statistics from a gender perspective, there is a noteworthy difference. As reflected in the bar chart of Figure 4.4, male students are much more likely to rate themselves as at least technology savvy (with a lot more males than females in the “very savvy” category); females largely fall into the average range. This finding is consistent with other research on gender attitudes towards educational technologies mentioned in the literature review. It is clear from the data that most students show a very confident attitude toward their technology skills, although guys are quite significantly more so than girls.

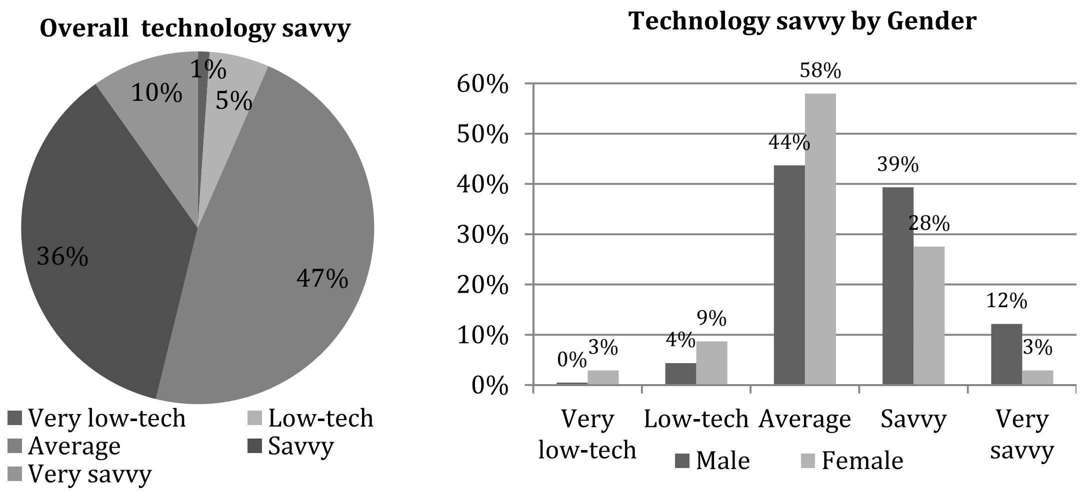

Figure 4.4 Technology savvy of surveyed population

4.4.2.2 GPA by Gender

If GPA is any indicator of academic achievement, female engineering students definitely outperform their male friends, as can be seen in the left graph of Figure 4.5. The distribution of GPA for male students peaks in the 3.0-3.4 range, while that of the females is extremely skewed toward the left (reflecting higher GPAs) with half of them landing in the highest GPA bracket of 3.5-4.0+. This pattern agrees with the fact that the average GPA of female students across disciplines is slightly higher than that of male students, as discussed in the literature review.

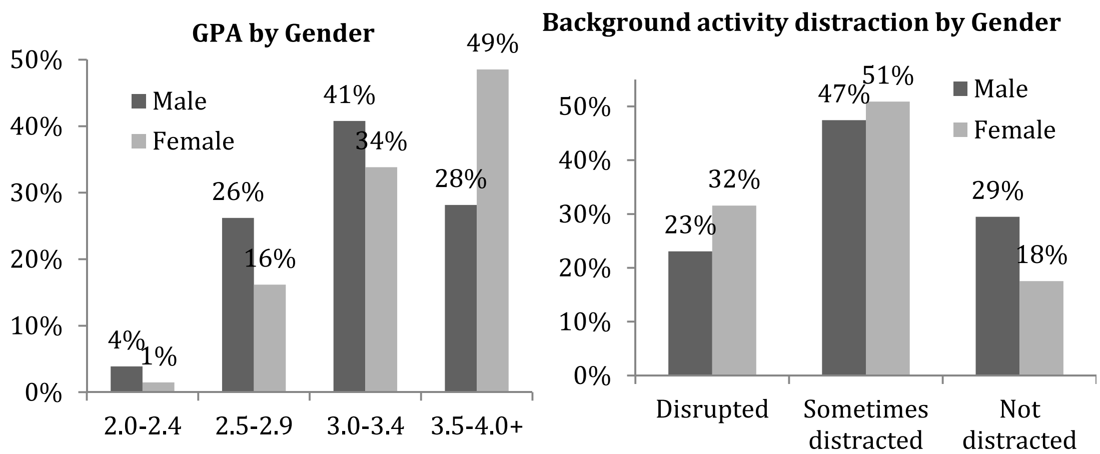

Figure 4.5 GPA and Background activity distraction by Gender

4.4.2.3 Distraction by background activities in lectures

In terms of engagement in learning, the survey found that only 56% of students (61% of female and 53% of male) generally stay focused in class, while the rest do some background activities ranging from internet surfing, writing emails, to playing games. In doing so, half of them sometimes get distracted and miss a few points in the lecture, and about 25% admit that learning is disrupted. Despite the fact 58% of students think that PowerPoint presentations are sufficient as a learning aid to help them follow the instructors, these findings suggest that a lot of room is left for improving students' engagement in class. There is virtually no difference in terms of the percentage of students staying fully engaged in class across all grade levels (50% focused, 50% distracted), except for the seniors (of which 60% stay focused in class).

When it comes to managing divided attention while in class, male students report doing a better job than their female counterparts as implied by the second chart in Figure 4.5. Among those who do perform background activities in lectures, male students are less likely to let their learning be disrupted and more likely to be able to follow the lectures as if they were not doing other things. It is easier to keep women attentive, but once they get distracted, it is more difficult to bring them back.

4.4.3 Age differences

4.4.3.1 Technology savvy by Age

It can be seen from Figure 4.6 that the youngest (and the largest, 80% of the population) group of students is the most technology savvy of all. Even when compared with the next youngest group of 26-to-35-year olds, they are twice as likely to be technology savvy (although it is self-assessed). Half of students in the 18-25 range consider themselves as savvy or very savvy, compared to only 31% of 26-35 students and 27% of over 35 students. There is, therefore, evidence for the belief that there is a strong tendency for a few years' difference in age to lead to a significant gap in technology attitude and maturity.

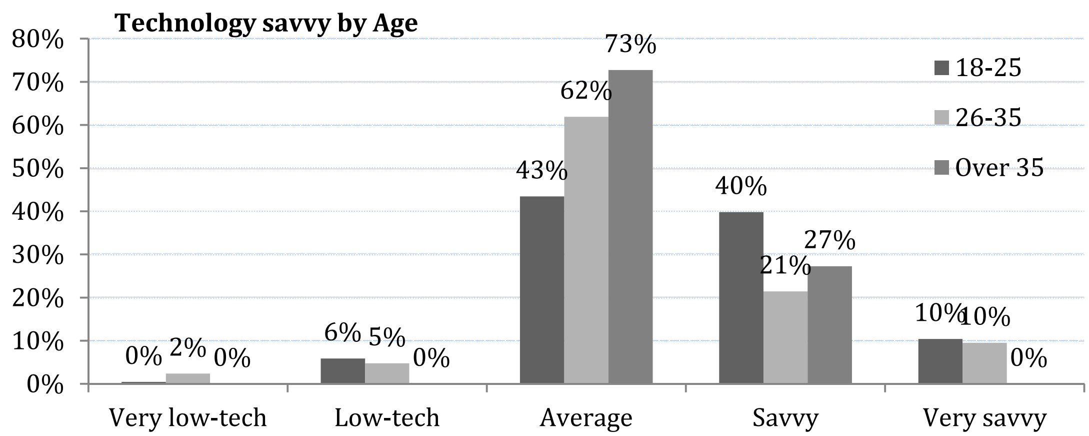

Figure 4.6 Technology savvy by Age

4.4.3.2 Use of Social networks and Instant messaging by Age

The above mentioned observation is further reinforced with the data on the use of social networks and instant messaging among the students, as shown in the first part of Figure 4.7. Those in the 18-25 groups are 80% more likely to use social networks to support their schoolwork than their friends in the 26-35 group, although it might be as simple as sending a message to a classmate. They also use instant messaging almost three times more than the next age group. Both technologies are real time, either by default like in the case of instant messaging, or by choice with the email notification features offered by most social networks. Today's college students are no doubt very wired, which means that they might have similar expectations for learning in terms of information delivery and communication.

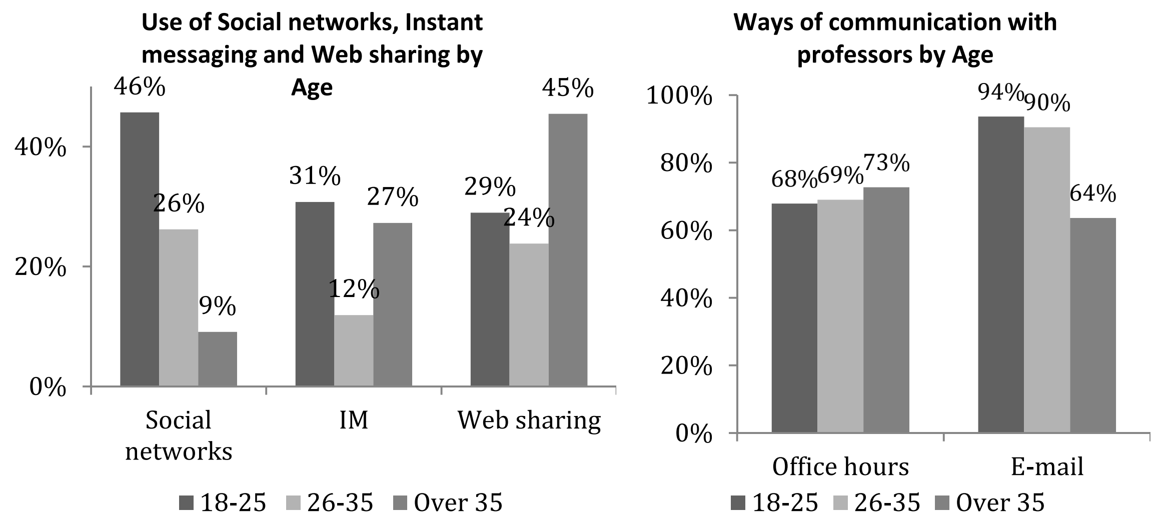

Figure 4.7 Use of web tools and Ways of communication, by Age

4.4.3.3 Ways of communicating with professors

In terms of communication channels with professors outside of class, e-mail has replaced regular office hours to become the norm, as reflected in Figure 4.7. This finding agrees with the data reported by the National Survey of Student Engagement (NSSE, 2009) reviewed earlier. There is virtually no difference between the 18-25 and 26-35 groups in the way they communicate with professors. It was also found from the data that students do not send instant messages to professors. The remarkable popularity of instant messaging in the student population discussed earlier is probably strictly among students as it is a lot more informal and personal, which is not well suited for the formality of student-professor relationships. Another important finding was the fact that only 5% of the students post questions to class discussion forums, such as those on a course learning management site. This feature, despite the consistent endorsement of almost every campus, has failed to facilitate discussions among students and professors outside of class.

It can be noted that there seems to be striking differences between the over 35 group and the other two in the bar charts of Figure 4.7. While these are interesting and noteworthy, it is not realistic to draw hard conclusions on the over 35 population as there were only 12 data points in this group at the point of analysis. Nevertheless, when comparing age groups across multiple dimensions, there are noticeable differences that might suggest that certain trends do exist for this mature group of students. If the survey could be maintained online to collect more data over time, it would be possible to result in a better understanding about this portion of the population regarding their use of and attitude toward technology. Although the vast majority of college students do not fall into this age category, it is important that teachers understand the pedagogical design implications of these facts so as not to create unfavorable learning conditions for this minority group. Furthermore, this piece of data will be extremely useful in designing learning materials for the vocational training programs whose audience are much more likely to be over 35 years of age.

Existing literature suggests that when it comes to Internet usage, females tend to use it more to communicate, and males to search for information (Jackson et al, 2001). Findings from the survey tend to support the first observation. As can be seen in Figure 4.8, female students come to office hours quite more often than male students (80% compared to 65%), and they also e-mail professors and use Web sharing tools more frequently. A later analysis will reveal that female students favor discussions more than male students do. All these observations might lead to a converging point: women seem to have a greater need for interpersonal interactions in learning.

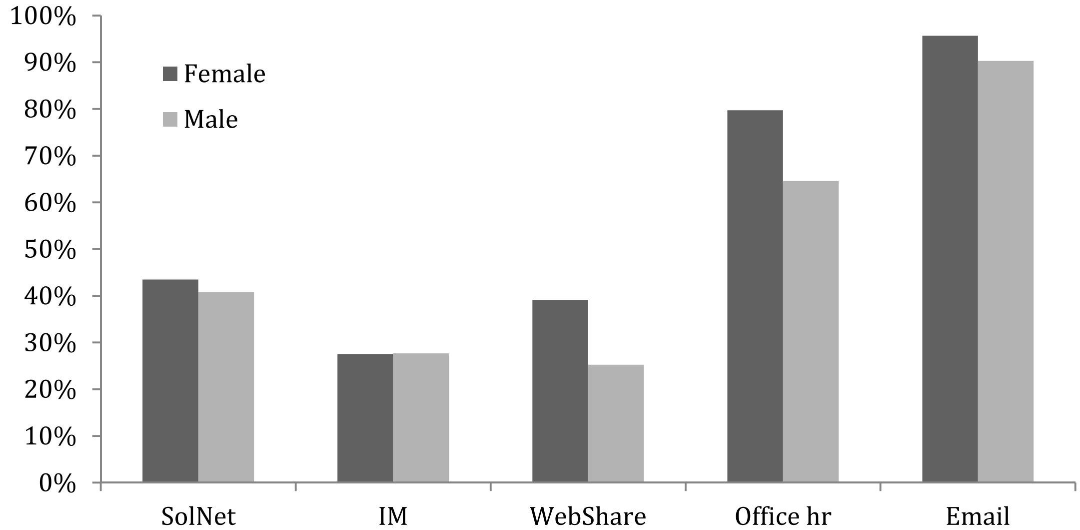

Figure 4.8 Use of communication and collaborative tools by Gender

4.4.4 Games skills

In Prensky's 2001 study, it was reported that 70% of college students play games, with 30% doing so even during the lectures. The data to date from this survey suggest a slightly different picture with 90% of students playing computer games but less than 10% doing so in class. The breakdown of students in terms of game skills is as follows: 10% no skill, 16% beginner, 30% low intermediate, 27% high intermediate, and 17% expert. While it might be the fact that the games played by students are almost solely for entertainment purposes, the skills that they acquire from playing can become handy when interacting with technology-enhanced learning tools. It might be a long shot to think that lectures can be as addictive as games are to the students, but a more aggressive use of technology in classes might make learning look more friendly and attractive to students.

Game skills, as expected, are not even among groups. Not surprisingly, the youngest group is the best at games: in Figure 4.9, the 18-25 bars are significantly more skewed to the left end of the skill spectrum compared to the 26-35 group, representing a higher level of expertise. Boys are also found to play games more than girls and are much better at it. In the distribution of game skills among groups of different technology savvy levels in Figure 4.10, there seems to be a very strong correlation between these two (self-rated) qualities. If instructional designers are to design game-like learning tools, these are some facts they should be aware of to not give any particular group in the student audience too much of an advantage because of the existing skills they possess.

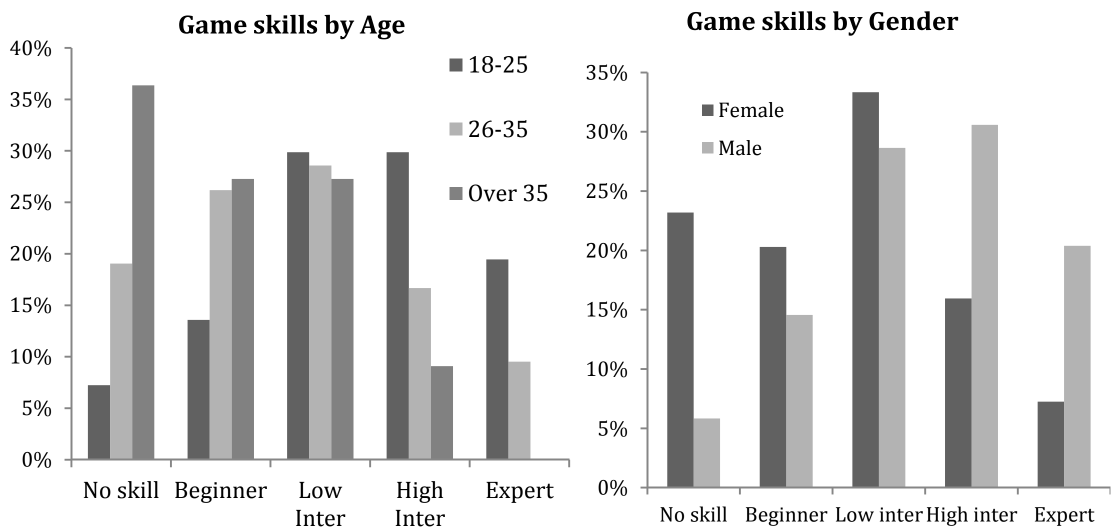

Figure 4.9 Game skills by Age and Gender

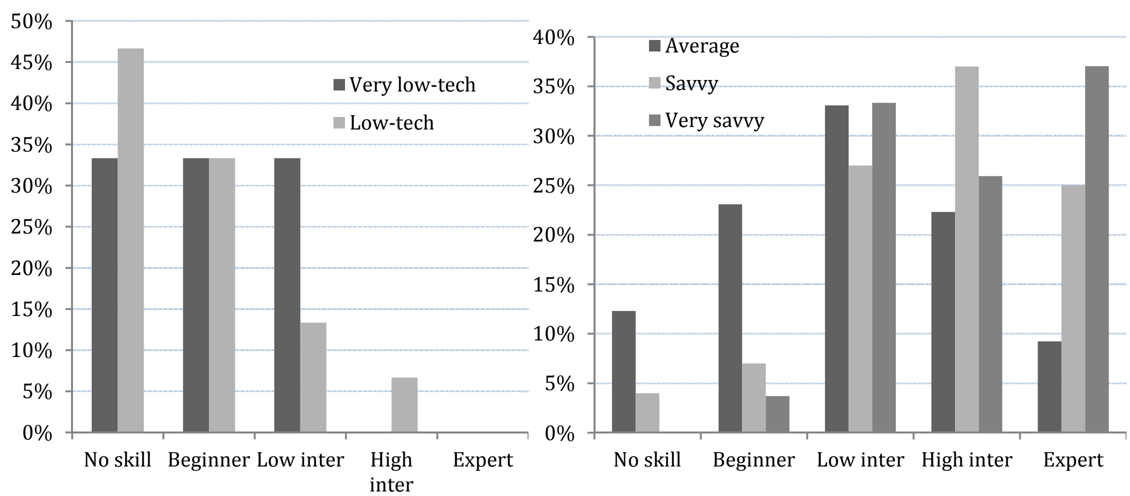

Figure 4.10 Game skills by Technology savvy

4.4.5 *Preferences for learning activities*

In Figure 4.11, the last bars of the five groups represent the overall percentage of students wanting to have certain learning activities included in their lectures or classes, while bars of other shades represent the four GPA groups surveyed. In general, in class discussions, group projects, and simulations are all desired by more or less half of the students. It is interesting to note that very few students surveyed like the idea of role-playing in class. It might be that engineering students are less people-oriented and favor problem solving more than their peers in social and humanity sciences do. Nevertheless, it does not mean that engineering students are less likely to be interested in interactions with peers and professors, as reflected in their preference for in class discussions and group projects. Their favor of simulations reflects a preference for another form of interactions: simulated interactions. While technology cannot substitute for face-to-face interactions, it definitely can facilitate such conditions to a large extent, and in some cases is a great alternative where hands-on learning is infeasible. This is the area where technology can be integrated into teaching to take advantage of students' new expertise and at the same time promote active learning through interactive and highly customizable learning experiences.

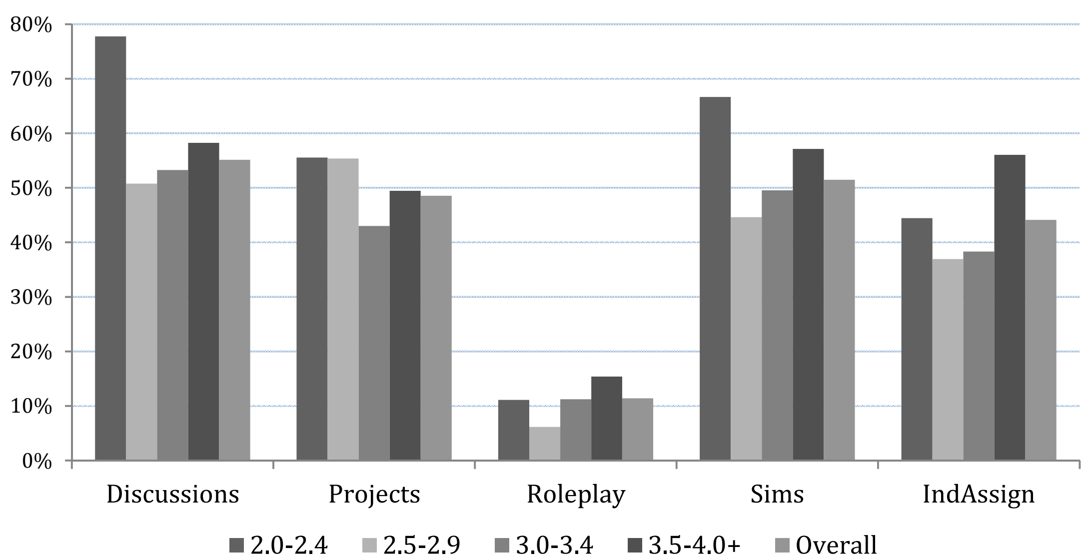

Figure 4.11 Learning activity preferences

It can be seen that there is no considerable difference in terms of learning activity preferences between groups of high and low GPA, except that the highest scoring students seem, unsurprisingly, quite more comfortable with individual assignments than others do while the lowest scoring students strongly prefer in-class discussions (and simulations, for some reason). However, this trend does not persist across all GPA groups. There are reasons to be cautious with this observation considering that the lowest scoring students only account for 3% of all the students surveyed, and hence any patterns observed among them might not have enough statistical validity. It is expected that when more data become available, it would be possible to confirm or examine some previous research findings about the benefit of multimedia and collaboration among low scoring and underrepresented groups. This insight will help teachers set appropriate learning objectives, choice of teaching tool, and learning activity arrangements.

4.4.5.1 Learning activity preferences by Gender and Technology savvy

It is observed from Figure 4.12 that female students are slightly in favor of both discussions and individual assignments, although the difference is not significant. While gender does not play an important role in learning activity preferences, a close look at the impact of technology savvy on learning choices provides a slightly different perspective. It was found, as can be seen in the second graph of Figure 4.12, that technology savvy or very savvy students are about 50% more likely to choose simulations as one of their favorite learning activities compared to the average students. Their preference of both group projects and simulations probably suggests a tendency toward active learning in which learners are more in control of their learning than they are in other kinds of activities. Conclusions about the low-tech group, however, should be drawn with great caution because as of now they only account for 5% of the surveyed population.

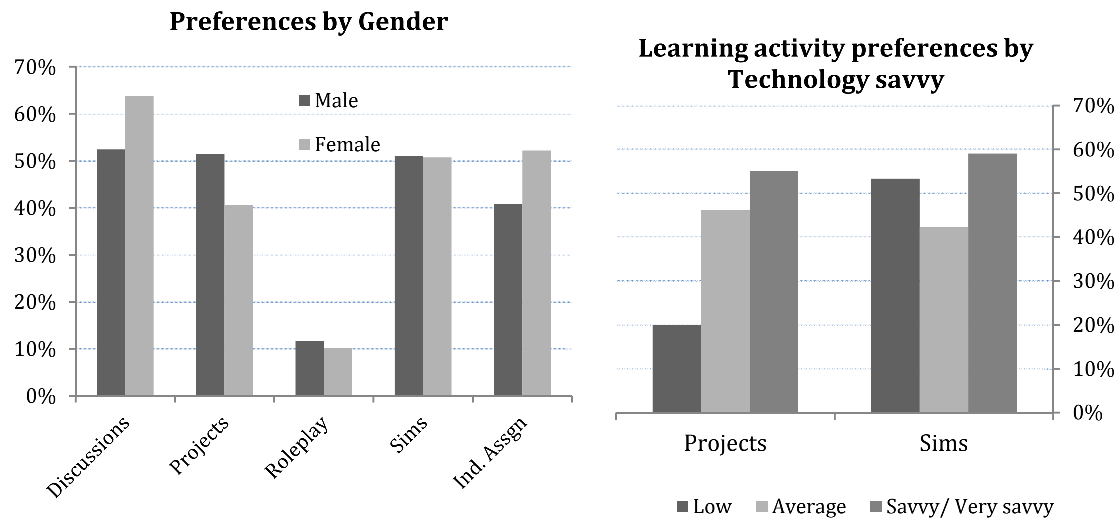

Figure 4.12 Learning activity preferences by Gender and Technology savvy

4.4.5.2 Learning activity preferences in Distracted students

It was reported earlier that almost half of students do not stay focused in class, but instead perform some background activities during lectures. Some of these students do not suffer from this divided attention and can still follow the lectures, while some are distracted and 25% admit their learning is affected. The introduction of simulations in class, as implied by Figure 4.13, seems to help alleviate this problem. Students who are most distracted by background activities favor simulations twice as much as those who also perform background activities but are not distracted by them.

Student engagement in the classroom can be improved by taking advantage of technology's ability to get students' attention. The fact that a vast majority of the students surveyed (95%) consider themselves either confident, savvy, or very savvy with technology suggests that they will enjoy this inclusion of a familiar everyday artifact into the classrooms traditionally perceived as unexciting. The positive impact of technology as used in videos/animations is confirmed by the data from this survey where students much more often finding them engaging and helping remember and understand learning materials better. Only 1.8% of students find videos/animations distracting when used in lectures (Table 4.3).

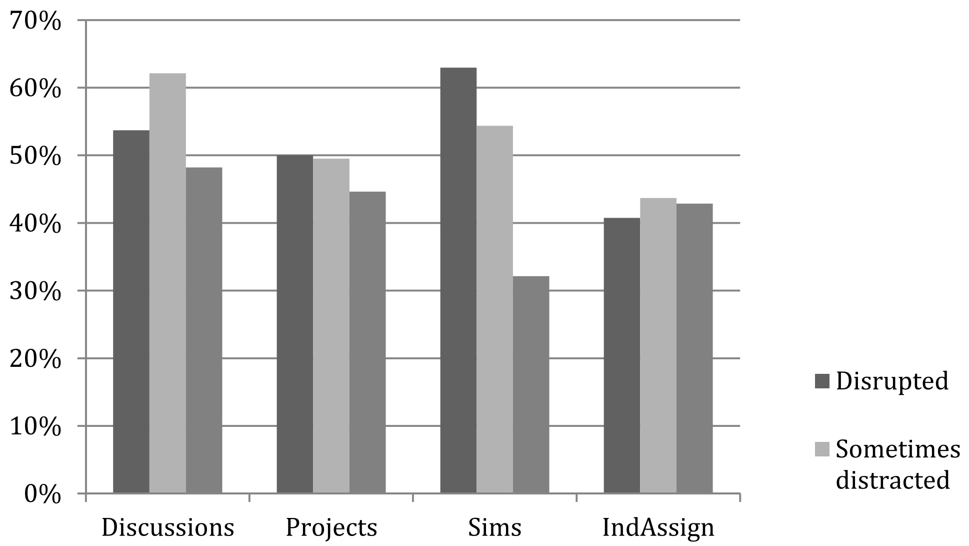

Figure 4.13 Learning activity choice by Distraction in class

Table 4. 3 Impact of videos/animations on learning

Answer Options	**Response Percent**
Engaging	43.6%
Better retention	48.4%
Better understanding	45.5%
Engaging but no impact on understanding/retention	22.2%
Distracting	1.8%

4.4.5.3 Learning activity preferences by Year in college

It was observed from the data that as students advance in their academic program, their preference for interactive learning activities gets stronger. As evident from Figure 4.14, graduate students (and 5th year students in some programs) are in favor of simulations and role-playing quite more than their peers in junior and senior years. The difference is noticeable for discussions and projects as well. One of the reasons might be the increased level of comfort graduate students have in dealing with open-ended problems and global thinking as they mature intellectually. The difference between 3rd and 4th year students, however, is not quite as significant. As there are only six data points for the freshmen/sophomore group, no conclusion can be made for this parameter.

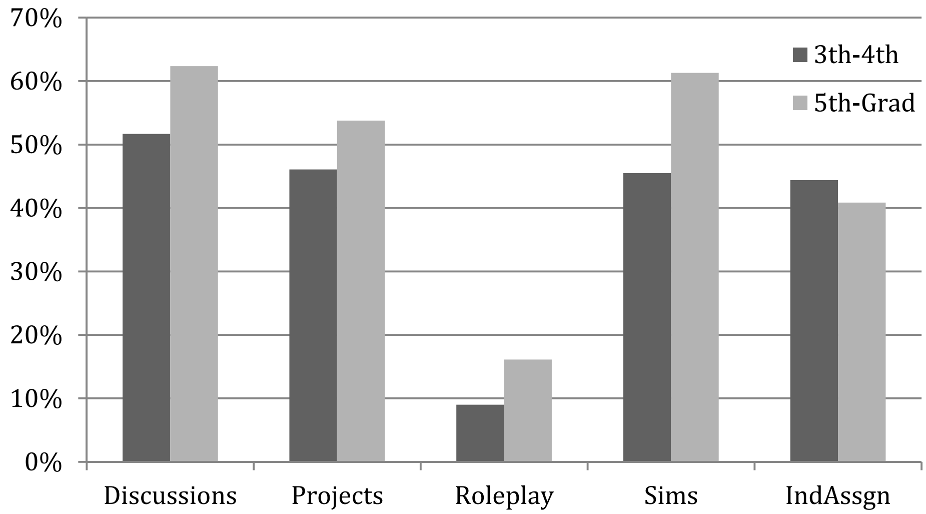

Figure 4.14 Preferences for learning activities by Year in college

4.4.6 Technology exposure

In the second section of the survey, Technology Exposure, students are asked to rate their skills in 20 technology groups from "no skill" to "expert." These groups are classified into four categories: basic hardware, task-specific applications, project management applications, and general Web applications. These skills are very diverse and some are very technical. It is not reasonable to expect that students will be highly skilled in all of these areas. The purpose is solely to get a big picture of what they are familiar with and at which level their technology skills are. In general, the students surveyed seem to possess a broad understanding of various technologies. There are very few groups with which more students report to have no skills, and all of these groups are technical, such as structural/architectural analysis, computational, 4D tools, estimating and contracts (for construction management). They are most savvy with general web applications and hardware devices and the least with project management applications. Understanding what types of technology the students are good at using (or learning to use) will help instructors provide enough training to learners (if necessary) or choose appropriate hardware and software to support the teaching of specific domain knowledge.

4.4.6.1 Technology exposure – Hardware

When it comes to operating basic hardware such as computers, printers, scanners, digital cameras, projectors, etc., 75% of students consider their skills at the high intermediate or expert levels (Figure 4.15). They are also very good with touch screen devices such as tabletPCs, PDA, iPhones, iPods, GPS, etc. They are least familiar with sensing technologies such as RIFD or sensors. This is consistent with the expected level of their daily exposure to these groups of hardware.

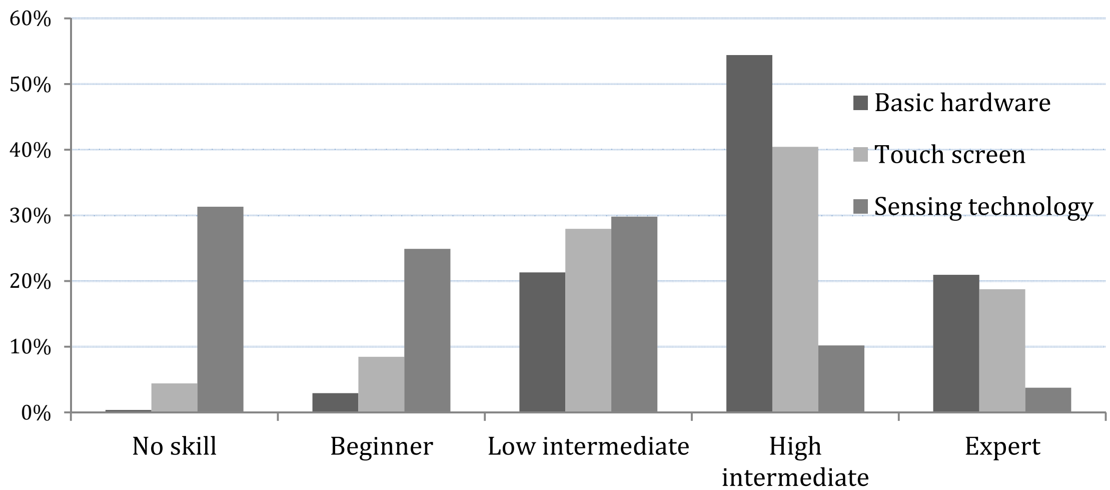

Figure 4.15 Technology exposure – basic hardware

4.4.6.2 Technology exposure – Task-specific applications

Table 4.4 provides summary statistics for the eight technology groups in this category. Among these, students have limited exposure and skills in technical applications, including knowledge/data management, structural/architectural analyses, and computational (such as MathLab, LabView). This is reflected in the extreme rightward skew in the second graph of Figure 4.16. In contrast, the first graph is significantly skewed to the left, suggesting that students have much better skills in office document applications, time/task management applications, and computer games.

Table 4.4 Technology exposure – Task-specific applications

Task-Specific Applications	**No skill**	**Beginner**	**Low intermediate**	**High intermediate**	**Expert**
Office documents	0%	0%	16%	58%	26%
Graphic and web design	11%	32%	36%	18%	3%
Time/Task management	4%	15%	35%	34%	12%
Knowledge/Data management	29%	34%	25%	11%	1%
Structural/Architectural design	37%	33%	21%	8%	1%
2D- & 3D-CAD	12%	30%	32%	23%	4%
Computational	40%	34%	19%	6%	1%
Computer games	10%	16%	31%	26%	17%

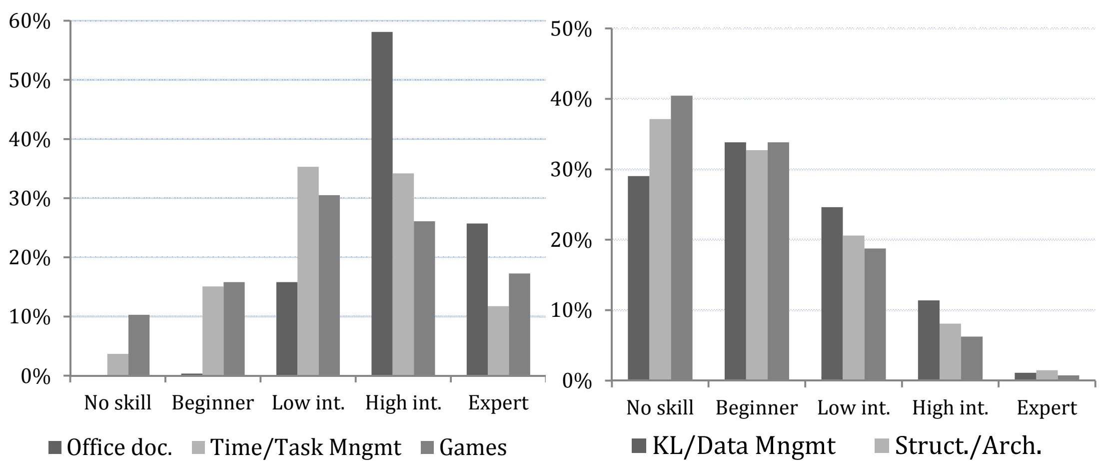

Figure 4.16 Technology exposure – Selected task-specific applications

4.4.6.3 Technology exposure – General web applications

Web applications are the area the students are most savvy with, as illustrated by the leftward skew of almost every single category in Figure 4.17. They are most skilled with search engines, followed by e-mail/instant messaging and social networks. They are least familiar with web and video conference applications, which can be explained by their limited exposure as most of these are geared toward the business users.

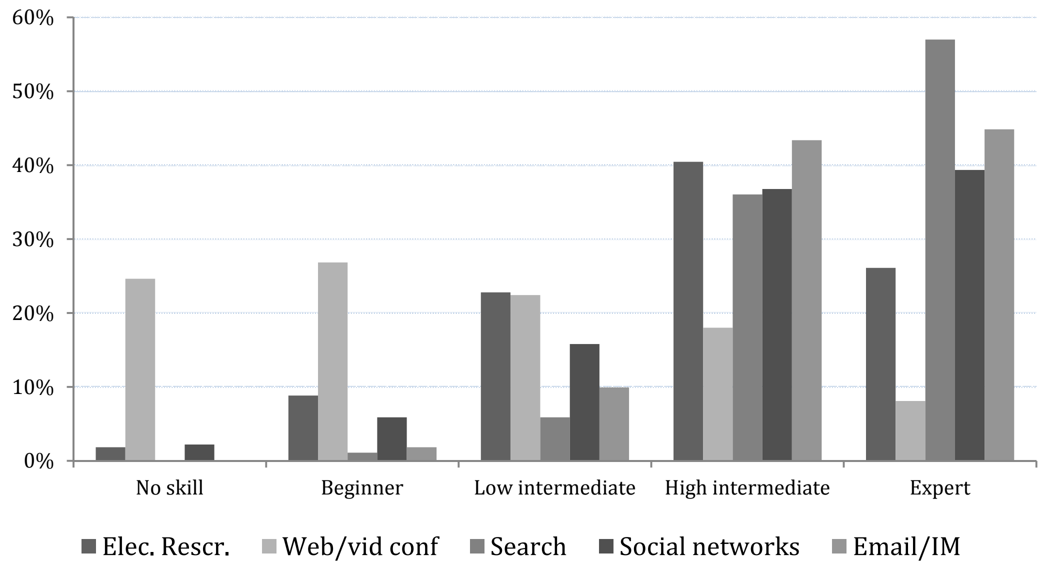

Figure 4.17 Technology exposure – General applications

4.4.6.4 Technology exposure – Project management applications

Among the four project management application groups surveyed, students are most skilled in scheduling (Figure 4.18). More than half of them have never used 4D tools, estimating and contract applications, with the rest at the beginners' level. If any teaching tools are designed for these topics or employ existing applications in these areas, instructors should provide substantial training to make sure the students are comfortable with them. For project management applications, the general level of technology savvy of today's student does not exist, yet.

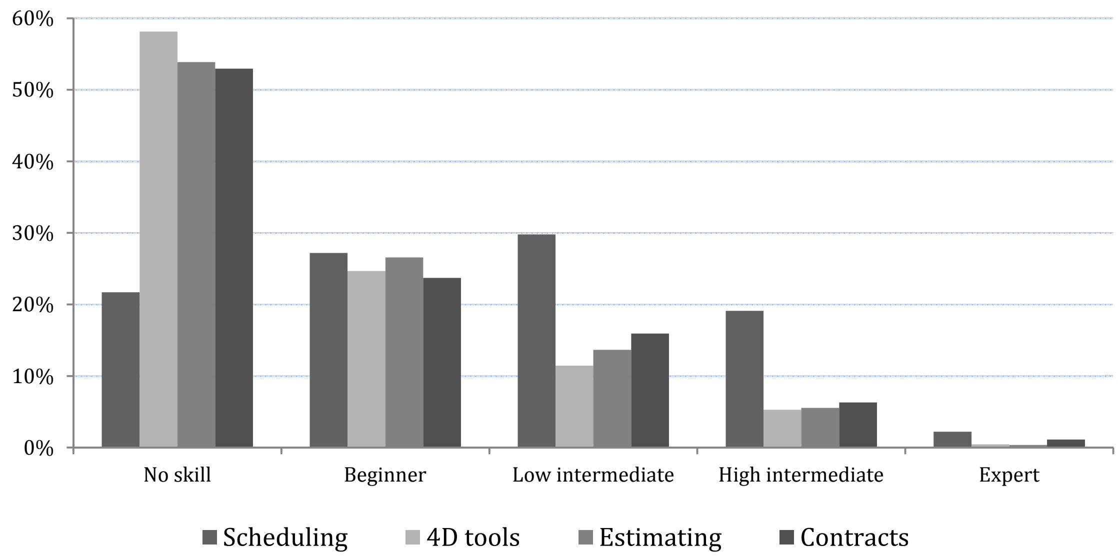

Figure 4.18 Technology exposure – Project management applications

4.4.6.6 Comparison with ASCE survey

Table 4.5 provides the ranking of the 17 technology groups (hardware skills not included) considered in the survey. It can be seen that all four of the technologies in the general web applications category make it to the top five; of the rest only "Office document tools" is comparable. As the ASCE survey on computing competence of civil engineering students (Table 4.6) used the same rating system, the results of two surveys can be compared. Two areas where the two surveys agree are office document tools (word processor, spreadsheet) and email/instant messaging (electronic communication). However, the students participating in this survey reported a completely new set of outstanding skills as a result of their exposure to the Internet: information searching and the use of electronic resources. Two surveys generally agree on the level of competence in specific civil engineering applications.

Table 4.5 Ranking of student's exposure and skills from survey study

#	Technology	Category	Skill level*
1	Search engines	General web applications	4.48
2	Email & instant messaging	General web applications	4.3
3	Office document tools	Task-specific applications	4.09
4	Social networks	General web applications	4.04
5	Electronic resources	General web applications	3.8
6	Time/task management tools	Task-specific applications	3.36
7	Computer games	Task-specific applications	3.25
8	2D/3D CAD	Task-specific applications	2.78
9	Graphic and web design tools	Task-specific applications	2.7
10	Web/video conferences	General web applications	2.59
11	Scheduling software	Project management applications	2.52
12	Knowledge/data management tools	Task-specific applications	2.22
13	Structural/architectural design tools	Task-specific applications	2.03
14	Computational	Task-specific applications	1.93
15	Contracts software	Project management applications	1.78
16	Estimating software	Project management applications	1.71
17	4D tools	Project management applications	1.64

* 1 = no skill, 2 = beginner, 3 = low intermediate, 4 = high intermediate, 5 = expert

Table 4.6 Survey of competence results from ASCE survey*

	Practitioners		Educators	
Skill	Rank	Rating[a]	Rank	Rating[a]
Word processor	1	3.81	1	4.10
Spreadsheet	2	3.80	2	3.83
Electronic communications	3	3.52	4	3.47
Computer-aided design	4	2.97	5	3.15
Presentation packages	5	2.84	3	3.71
Equation solvers	6	2.67	7	2.82
Structural software	7	2.64	6	2.99
Database	8	2.58	15	1.91
Environmental/water resources software	9	2.34	8	2.59
Transportation software	10	2.31	9	2.54
Geotechnical software	11	2.24	10	2.52
Construction software	12	2.22	11	2.38
Geographic information system	13	2.21	17	1.08
Collaborative environments	14	2.10	13	2.14
Other civil engineering software	15	2.08	14	1.98
Programming	16	2.07	12	2.15
Expert systems	17	1.63	16	1.41

* 1 = unskilled, 5 = expert. From Abudayyeh et al, 2004

4.4.6.7 Efforts made to learn new tools

When there is a need to train learners for a new technology, it is helpful to know their habits of learning to use a new tool. One of the questions in the survey asks student what they usually do when using a computer program: whether they just use the basic and commonly used features, or make the extra effort to explore more sophisticated feature to get a feel of the software's potential, or even better, perform in-depth explorations to become an expert user. Overall, 43% of students just use the basic functions of software, almost half of them do a lot more explorations beyond what is required, and around 10% eventually become expert users (Figure 4.19). As a whole, the students are quite technologically curious, which suggests that they will likely be willing to make an effort to learn new tools should the learning context require. In a related analysis, it was found that students who tend to master the computer tools that they use also strongly prefer to use computer methods to do their homework, projects and assignment, as shown in the bar graph in Figure 4.19.

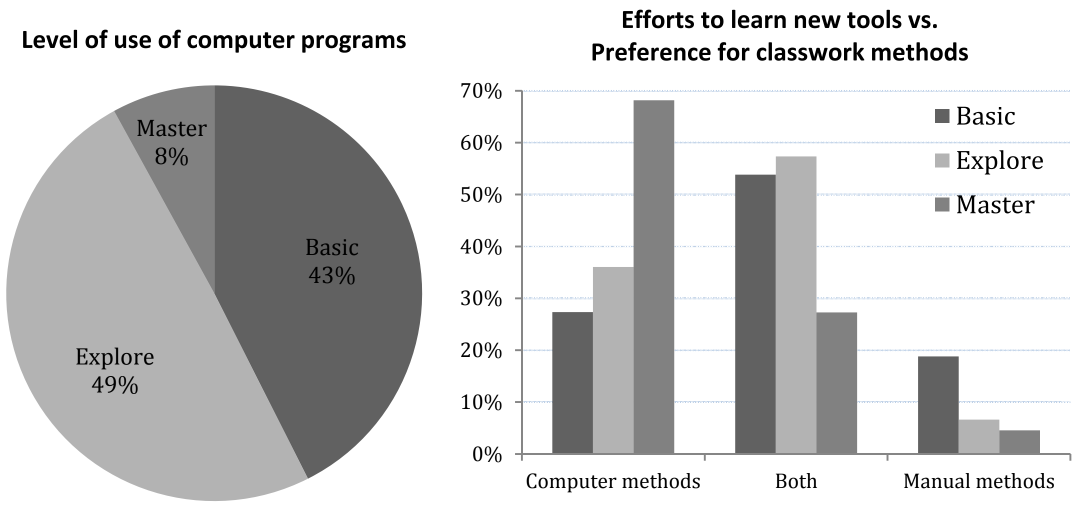

Figure 4.19 Level of use of computer programs

4.4.7 Construction knowledge

4.4.7.1 Overall results

Students' background in the domain to be taught is an important benchmark based on which learning goals are defined. This is the reason why part of the survey is dedicated to examining the students' level of knowledge for the seven major areas in construction management: cost and schedule control, field management, contracts and delivery methods, project economics, materials and methods, safety, and green construction. It was found that the level of knowledge the students possess is higher for the topics of materials and methods and safety, as shown in the first graph of Figure 4.20 with the knowledge distribution peaks around Apply/Analyze. It is surprising to see that students know more about green construction than they do project management. The level of knowledge in the areas of cost and schedule control, field management and contract and delivery methods is slightly lower, with most students at the Understand stage.

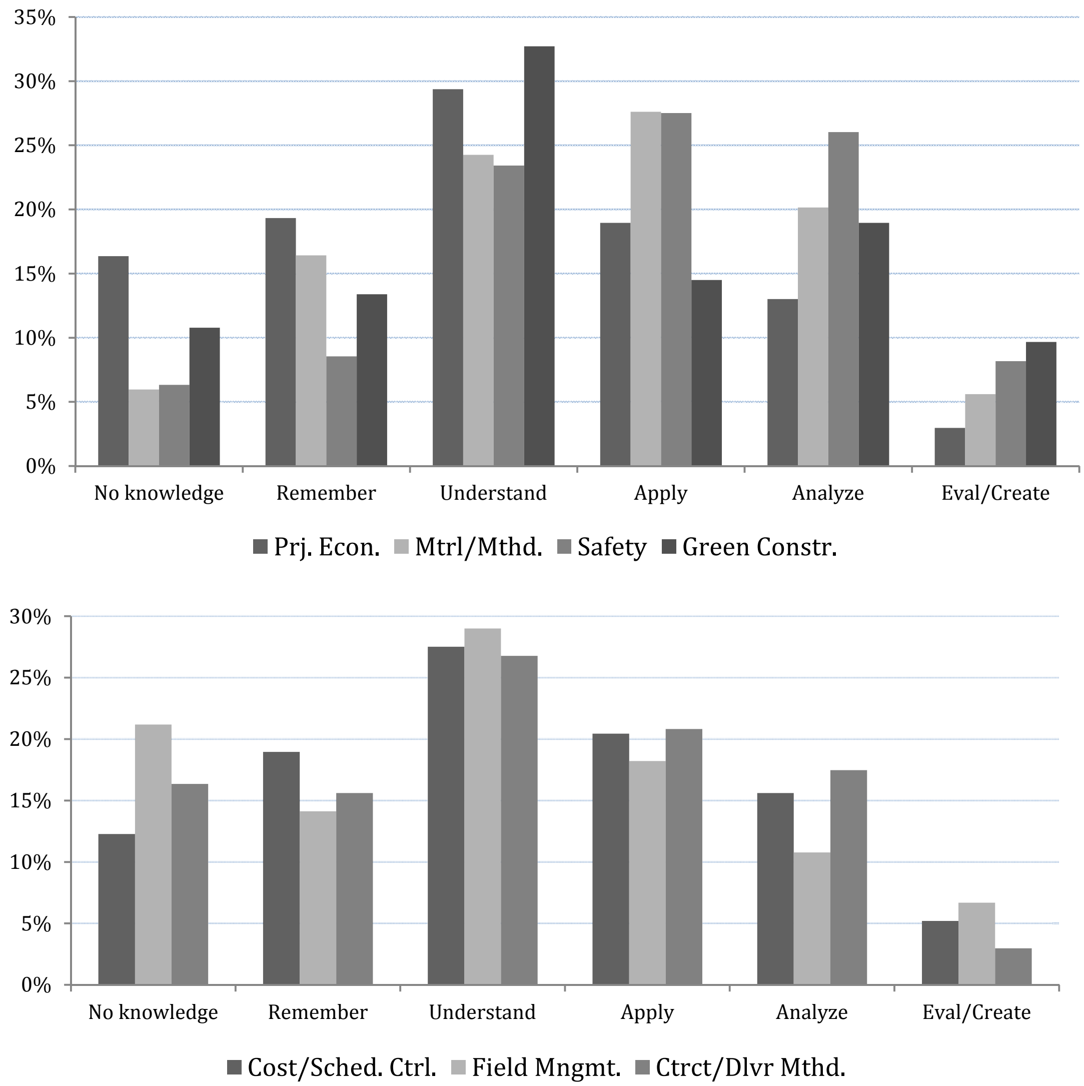

Figure 4.20 Construction-related knowledge

4.4.7.2 Construction knowledge by Year in college

Not surprisingly, the level of construction knowledge students possess increases with the number of years they are in college (Figure 4.21). The trend is strong and consistent for all grade levels and all knowledge areas. The virtually identical patterns for 4^{th} and 5^{th} year students might be explained by the fact that they both are in the final year of their respective programs and hence are at similar stage in terms of intellectual maturity.

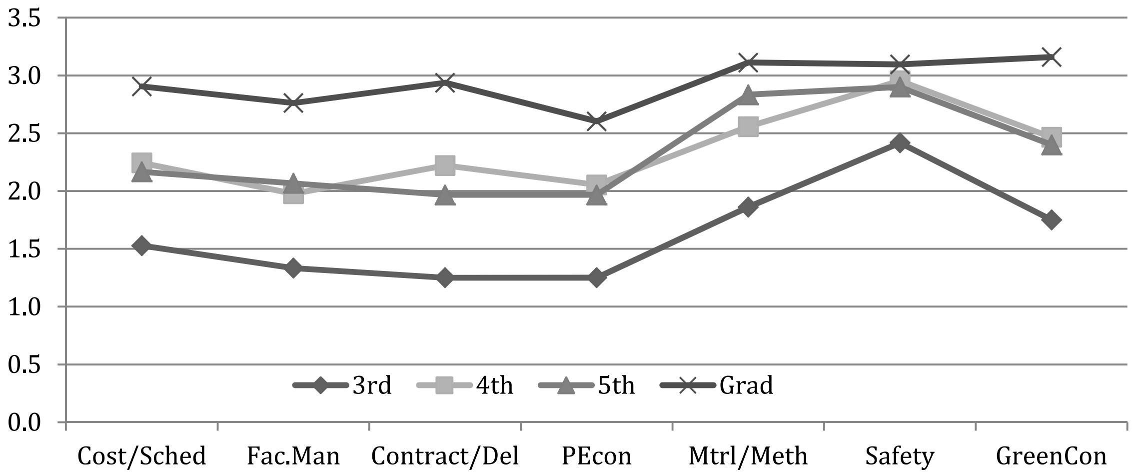

Figure 4.21 Construction knowledge by Year in college

4.4.7.3 Construction knowledge by student type

In the data collected, about 110 out of 280 students surveyed are building construction students. These usually have a full year in their curriculum devoted to construction-related courses. As expected, they show a significant higher level of construction knowledge across the board compared to engineering students (Figure 4.22). As a consequence, learning goals and objectives designed for this group of students should reflect their level of intellectual development in the field: as they already have substantial background knowledge in the domain, they are ready for higher level learning tasks.

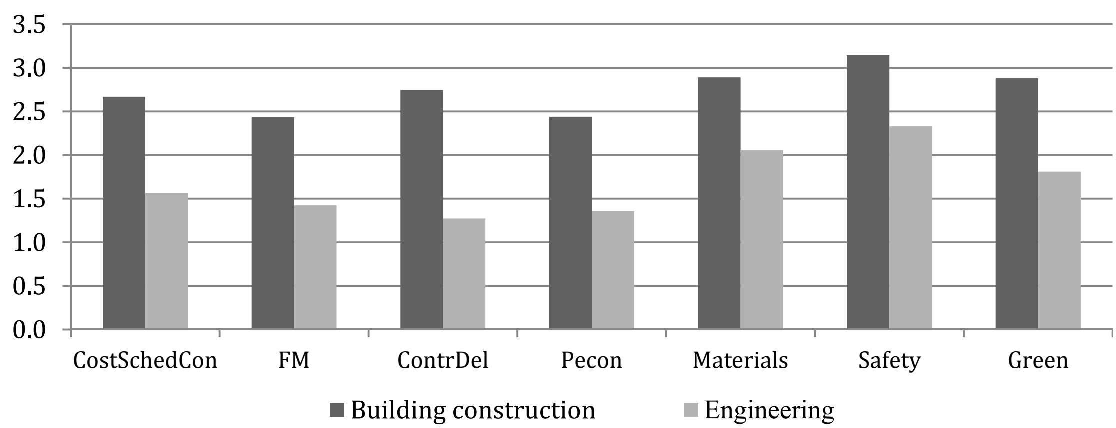

Figure 4.22 Construction knowledge by student type

4.4.8 Student work experience and work expectation

The data from the survey reveal that one third of the students surveyed did not have any work experience of any kind in construction, as shown in Table 4.7. 30% to 40% of them have some experience in project management, engineering/design, site supervision or labor. Roughly 20% have work experience in operations, project controls, and other areas such as sustainability design, accounting, and marketing. The average amount of work experience in months is 14, 16.3 and 21.5 for the 3rd-4th year, 5th year and graduate students, respectively.

While the work experience of students covers a wide range of specialties, most of them intend to build their career in either project management (57%) or engineering/design (25%), as shown in Table 4.7. Knowing what students want to do after they graduate will help educators design more effective curriculum in order to equip them with appropriate knowledge for their desirable future career, as well as introduce them to other areas of knowledge to give them a broader perspective. This is equally applicable to the design of individual courses.

Table 4. 7 Work experience and intended work area in construction

Work experience area	% students with experience	% student expected work area after graduation
None	33.6%	
Engineering/ Design	32.5%	24.6%
Facilities Management/Operations	19.3%	1.4%
Project Management	40.4%	56.4%
Site Supervision	29.3%	5.0%
Project Controls	21.8%	2.1%
Labor	36.8%	0.0%
Other	18.9%	10.4%

4.5 Summary of findings and discussions

<u>Gender differences</u>

The results from this survey study do confirm the trends reported in current literature about the gender differences in terms of academic performance, as indicated by the GPA, and self-rated technology skill level. From the collected data, female students are outnumbered by their male counterparts by three times, but have a significantly higher GPA. Although the literature suggested that multimedia teaching has more benefit for low scoring students than it does for high scoring students, the differences in the two sexes' GPAs might not be significant enough for that impact to happen.

The female students participating in the survey also have considerably lower self reported confidence in technology skills than their male friends. Women seem to have a greater need for communication and interpersonal interactions both in and outside of class. As discussions are rated among the most desirable learning activities by all students, it is important that this needs to be adequately addressed when incorporating technology in the classroom, as more technology usually means less human interaction and more individual learning time. The lack of face-to-face interaction can be compensated for by effective simulated communication within the learning tools so that students can benefit from a community of learners even though they sit in a room by themselves.

<u>Technology savvy and game skills</u>

The survey results from this study reinforce the stereotype of college students as enthusiastic gamers suggested by previous research findings, at an even higher rate of 90% of students reporting playing games (compared to 70% previously reported). This might be caused by the increased popularity of computer games in the years between 2006 and 2009, or simply by the fact that engineering students probably play computer games more than an average student because of their technology-oriented background. Regardless of the reasons, it is obvious that a vast majority of students are familiar with game-like interactions and might benefit from similar experiences in learning. Most students also consider themselves having good technology skills, with many very confident about their savviness with technology. This is also the reason why they are excited about involving more technology in the classroom, such as videos, animations, and simulations. Technology-supported instruction should take advantage of students' positive attitude to and strong skills of game playing and provide learning platforms that possess the engaging attributes of conventional games.

Technology exposure and skills

Compared to the 2002 ASCE study of student computing competence, this survey revealed a new set of skills today's students possess: the ability to use various electronic resources for their information needs. The lectures and textbooks are no longer the only, or arguably not even the most authoritive, source of information anymore. This suggests that a shift in focus in the classroom might be a good idea: instead of trying to push a lot of content to the students in the lectures, instructors should spend more time cultivating interest and motivating students to learn more about the subject. If teachers can find a way to strike the balance between imposing instruction on students and guiding them through exploratory learning, the availability of electronic resources and students' advanced skills in using them can bring a huge advantage to pulled learning compared to pushed learning.

Communication pattern

The data from this survey strengthen the assertion that e-mail has replaced face-to-face encounters in the communication between students and professors outside of class. They also show a trend of students using social networks to communicate with peers to discuss schoolwork, especially among the younger students. The use of online communication, however, remains to be used for one-to-one exchanges only (or one-to-many, in the case of professors sending e-mail to the whole class). Many-to-many communication, and hence a tool to facilitate a learning community, has not found a successul flatform to thrive. Despite the fact that Blackboard and equivalent tools are available on most campuses, students simply do not use their class discussion forums to discuss classwork (only 5% reported doing so). This still remains a promising area of technology-assisted collaborative learning yet to be implemented and thrive. Related to the communication habits of students is their need of interaction and discussions in the classroom, which will be discussed next.

Learning engagement and preferences for learning activities

One of the most important findings from the survey is the fact that only slightly more than half of the students think that PowerPoint presentations are sufficient as a learning aid, let alone as a sole instructional tool. As a result, there is a lot to be desired by students in terms of innovative and diverse learning activities, such as in class discussions, group projects, and simulations. This finding clearly demonstrates their need for more interactions in learning, as suggested by previous studies mentioned in the literature review. These interactions can be faciliated and simulated through innovative use of technology in the classroom, as reflected by the students' favor for multimedia learning (such as videos, simulations, and animations).

The key to addressing the interaction, and hence engagement, issue is to diversify the learning experience by utilizing multiple methods and media to deliver the content to students. There might be a reason for the fact that an average student only reads about three books out of maybe eight to ten assigned by their professors every year. They might not want to get all class materials by reading; they want to get it through audio, videos, simulations, discussions. In other words, pushed learning (through instructor-led presentations, book reading) is less effective than pulled learning (when students are engaged and actively put themselves in the context) (Prensky, 2001). Technology, when coupled with solid pedagogy, has a great potential to cause these "bursts" in learning engagement and thus improve learning effectiveness.

Construction knowledge

It was found from the study that in most of the nine areas of construction knowledge under consideration, at least half of the students demonstrate either no to just basic knowledge about the subject areas (corresponding to "remember" and "understand" on Bloom's taxonomy of educational objectives). Around a third of students are at the middle level (corresponding to "apply" and "analyze"), and very few have reached the highest levels, "create" and "evaluate" on Bloom's taxonomy scale. As a result, if teachers are to teach students high-level thinking skills such as creativity, judgment, and decision-making, innovating the current instructional methods is a must. Considering this and the students' low competences in civil engineering specific applications, a skill increasingly desired by the professionals, it might be beneficial for engineering classes to require the use of common commercial software in that area.

Another important trend that is apparent from the data is the tendency of students to strongly prefer a career in project management, which has high requirements for holistic thinking and soft skills (communication, leadership, judgment), to one in engineering/design for which procedural thinking and technical skills are relatively more essential. This poses an educational challenge considering the fact that 1) among the civil engineering students surveyed, there are more sequential/sensing learners (facts, procedures) than there are global/intuitive learners and 2) very few students demonstrate a command of construction knowledge at the high intellectual development levels (evaluating, creating) that is needed for management, decision making, and leadership. This result validates the observation by some researchers of the need to adjust the current engineering curriculum and teaching methods in order to educate engineers with both practical/analytical intelligence and creative intelligence (Arciszewski, 2009).

Differences between grade levels

As students advance in their academic program, they, unsurprisingly, gain more work experience and hence background knowledge in construction and start to have a stronger preference for interactive learning activities such as simulations, discussions, and group projects. They are also more comfortable with activities of high degrees of freedom such as role-playing compared to students in more junior years. The level of comfort, however, is still insignificant with only 19% of graduate students wanting to have role-playing in their class. Because of this, instructors are encouraged to experiment with more complex and open-ended learning materials and format for senior and graduate students. While this might give teachers more options to engage graduate students, it does not mean that graduate students are by default more motivated in class. They in fact can be just as easily distracted as undergraduate students, if not more, as revealed from the analysis of survey data.

4.6 Student background implications for technology-assisted instructional design

As this survey instrument captures student background information in diverse attitude and cognitive aspects, it can be used in various ways to help instructional designers analyze their students, define better learning context, and set appropriate learning goals. In the case of designing technology-assisted learning tools, the data obtained by using this instrument have direct design implications in terms of both instruction and interface. The content of Table 4.8 illustrates how knowledge about student background can be used to design better technology-supported instruction. This understanding should be part of the design framework being developed.

Table 4.8 Design implications of student background

Factor	Trends in data	Design implications
Age (our students: dominantly young, 18-25)	• The younger, the more technology savvy, better game skills, more technology exposed and confident. • The younger, the more wired, accustomed to real time communication • Differences significant even with a few years apart	• More comfortable with complex games and simulations • Less training and orientation required • Big age range: either consider games with average technological sophistication, or make sure adequate training is given to the less savvy group
Gender (our students: 3 to 1 male to female)	• Females less technology savvy and lower game skills • Females have higher GPA • Females slightly less distracted in class, but once distracted learning is more severely disrupted • Females have greater communication need	• If big female audience: engage to avoid first degree distraction. • Also, choose middle-ground technology • Accommodate differences in technology and game skills by training • Have built-in channels for one-to-one and group communication
Technology savvy (our students: savvy)	• The more tech savvy group prefers computer to manual methods, loves simulations • Comfortable with digital, web-based and real time communication • Good game skills	• More tech savvy means less training, more suitable for sophisticated technology, higher expectation for engagement • Built-in communication channels, both asynchronized and real time, to create and support learning community • Exploit games as learning tools
GPA (our students: high GPA)	• Low-scorers benefit more from multimedia-based instruction, discussions and group work	• Choose lower level learning objectives for low-scorers (facts, procedures, etc.) • Select games where frequent feedback is possible

Table 4.8 (continued)

Factor	Trends in data	Design implications
Learning styles & preferences	• Slightly more *active* than *reflective* Moderately *sensing* (vs. *intuitive*) Extremely *visual* (vs. *verbal*) Quite more *sequential* than *global* • Easily distracted • High demand for all kinds of interactions (human or simulated)	• Games with balance of active endeavors and feedback • Fascinated by facts, statistics, sights, sounds • Avoid text-based interfaces • Avoid too open-ended simulations • Diversify delivery methods to engage • Use technology to motivate and support pulled learning • Emphasize interactivity in interfaces
Domain knowledge	• Existing knowledge at lower end to middle of Bloom's Taxonomy	• Define realistic learning objectives • Reinforce background knowledge • Use technology of appropriate complexity • Provide various levels of difficulty

4.7 Conclusions

The technology and construction baseline survey designed was used to study the aspects in the background of civil engineering students that have pedagogical implications for technology-supported instructional design. The objective was to gather facts that could be used to answer the research questions set out at the beginning. The data collected to date reveal important aspects of students' expectations regarding the use of technology and other tools in learning. They had a wide exposure to technology in a wide range of applications, with the most impressive knowledge and skills of web-based tools. Their skills in specific civil engineering and project management applications, however, were a lot more limited, as was their existing knowledge in construction. They had a positive attitude toward technology and were avid gamers. It has been found that students generally prefer to have a variety of learning activities and media, with a strong favor for technology-enhanced learning strategies (such as videos, simulations, animations), interactions (with peers and professors), and relevance to the real world. These preferences suggest that today's students will perform well and benefit from the integration of technology in instruction to improve the level of engagement for the learning experience.

CHAPTER 5: LITERATURE REVIEW AND ORIGIN OF FRAMEWORK

5.1 Focus of literature review

The most important lesson learned from the pilot design of the material management learning module was that a well-designed technology-enhanced teaching tool has to be the result of a knowledge-intensive design process since superior technology knowledge only does not lead to such a creation and neither does mere pedagogical knowledge. A carefully crafted effort is needed to leverage the benefits of technology in every single aspect of pedagogical design to create the most desirable learning conditions (which are expected to translate into learning effectiveness). This is the specific area to which this research aims to contribute. That is to apply the science of instructional design in the context of technology implementation in order to come up with a design framework that helps designers marry the best of both worlds.

The design of the pilot learning module and its evaluation in Chapter 2 helped direct the focus of further literature review on four main areas: 1) student background and readiness for technology (which has been addressed in the survey study in Chapter 4), 2) identification of an instructional design model appropriate for technology implementation, 3) ways to take the best advantage of technological features for the purpose of engaging students, and 4) user interface design principles that enhance pedagogy. Based on these observations, a thorough study of the existing literature was conducted during which further refined research questions could be formulated, as discussed in Chapter 3. This chapter will provide a concise summary of relevant literature from which the envisioned design framework originates. In each of the areas of literature under review, there will be discussions about the current status of knowledge and its direct relevance to the design framework being developed. In the cases where the current existing literature needs to be adapted or expanded to serve the design purpose, these adaptations will also be made within the review. How these areas of knowledge fit specifically into the framework and the extra connections needed to operationalize it will be presented in Chapter 7.

To put the literature review, and subsequently, the framework development in Chapter 6, in context, it is important to restate that the scope of this instructional design framework is for a single unit of instruction with one specific instructional goal under consideration, as opposed to the bigger task of whole course development or curriculum building. Suppose there is a topic to be taught to a specific audience, and the instructor wants to exploit an existing interface template (such as a game, a software program, an online tool, etc.) as the medium and method to deliver the knowledge to the audience. There will be several questions to which the instructor (the designer of this learning tool) needs answers, such as what technology infrastructure and format to use, how to create a pedagogically sound tool that will create favorable learning conditions, whether or not the choice of technology is suitable to the target students, how to instruct students of different learning characteristics and abilities, or what are the most important interaction design features. The objective of the envisioned framework is to help answer these questions in a systematic manner. At the end, what users of the framework will get is a set of structured recommendations that are based on a well-established instructional design model, but at the same time is customized to unique needs by allowing for input that is specific to different populations of students and topics.

In the sections that follow, first will be a review of the literature in active learning and the role of technology, game- and simulation-based applications in particular, in facilitating such a learning condition. Next is a discussion of cognitive, emotional, and psychological processes ignited by games that make them engaging to the players, as well as how these processes are essential to effective learning. The review will also provide a game classification that can be used as a taxonomy for active learning strategies. An important part of the review will be dedicated to describing how Gagne's Nine Events of Instruction can be used as the foundational instructional model for the framework, how designers define high level learning goals, and how Bloom's Taxonomy of Educational

Objectives would help refine these goals. Finally, a review of the relevant literature in user interface design guidelines will be presented.

5.2. Active learning and technology

In recent years, active learning has received enthusiastic support in disciplines across the board because of the benefits educators believe this particular learning method can create. Active learning is defined as any kind of instruction that engages learners in activities that require them to actively take action and think about what they are doing (Prince, 2004). This engagement is the core element of the whole active learning process. Research has shown that simple strategies such as breaking up the lecture into small sessions and having students compare or clarify their notes help boost retention significantly as these small sub-lectures suit the attention spans of students (Bonwell and Eison, 1991, McKinney, 2009, Meyers and Jones, 1993, Prince, 2004). Another tactic is to have students think about what they are learning during the lecture, such as having them write a small essay reflecting on what has been talked about (CULC, 2009). This step effectively promotes student engagement and helps achieve learning objectives of abstract content. A comprehensive review of the literature has found that there is a strong base of supporting evidence for the effectiveness of active learning, although the support is not even for all methods of active learning (Prince, 2004). Table 5.1 provides a summary of commonly used active learning strategies synthesized from multiple resources, many of which can be supported and significantly enhanced by the use of technology. These strategies will be used as an important reference in building a taxonomy of technology-supported learning strategies in Section 5.4. It should be noted that the strategies listed here are not all equivalent in terms of the complexity and scale of the learning activities involved. Some could be part of other broader strategies, and they are not mutually exclusive of one another. Detailed descriptions of the strategies can be found in Appendix E.

Table 5.1 Commonly used active learning strategies in literature

Strategy	**References**
Think-Pair-Share	McKinney, 2009
Games	McKinney, 2009; Thiagi.com
Analysis or reactions to videos	McKinney, 2009
Student debates	McKinney, 2009; ICC, 2009
Student generated exam questions	McKinney, 2009; Thiagi.com
Case study analysis	McKinney, 2009; Meyers and Jones; Hansen, 1987
Journal/log keeping	McKinney 2009
Concept mapping/idea map	ICC, 2009; McKinney 2009; Thiagi.com
Superlatives: reflection on most extreme experiences	Thiagi.com
Role playing	Meyers and Jones, 1993; Shannon, 1986
Simulations exercises/simulation games	Meyers and Jones, 1993
Computer models	Meyers and Jones, 1993
Mind mapping	ICC, 2009
Feedback loop	CULC, 2009
Leading question	ICC 2009
Clarification pauses	CULC, 2009
Concept clouds	ICC, 2009

Despite the fact that educators do not believe in the existence of one universally effective formulated method for teaching, there is a consensus about the critical role of engagement in the learning process, which also happens to be at the core of active learning. Engagement is a key condition that leads to the development of higher-order thinking skills such as analysis, synthesis, and evaluation in Bloom's Taxonomy of Educational Objectives (Chickering and Gamson 1987, Anderson and Krathwohl, 2001). In the study of teaching tools by Nirmalakhandan et al (2007), several methods of instruction that promote active learning were identified, most of which are implementations of technology such as computer-based instructional tools, self-paced computerized tutorials, multimedia presentations, hands-on demonstrations, computer simulation models, and Internet-based instruction, which demonstrates the engaging power of technology. The interactivity of most technological applications gives learners endless opportunities to explore, reinforce, be challenged, be curious, be imaginative, and think critically. Many of the technology-supported learning activities involve some kind of self-paced exploration or simulations that allow for flexibility and accommodation of individual's learning styles and needs.

This engagement, as argued by Prensky (2001), is also the single most important factor in improving learning effectiveness for today's students, gaining a priority over content. While content is always at the core of good instruction, engagement is essential in delivering this content to the students effectively. A lot of this need can be attributed to the fact that this student generation was born and has been growing up in an era where technology has permeated into every aspect of life. They are constantly stimulated, entertained and excited by music videos, computer games, and real time communication. This environment has set higher standards for excitement and engagement in any activity, including learning. Technology, therefore, should be exploited in the learning environment to create similar engagement and effectiveness, as depicted in Figure 5.1.

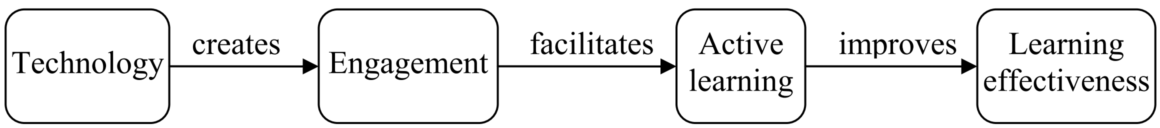

Figure 5.1 Impact of technology on learning

As the result of the ubiquitous abundance of technology in modern life, today's students possess an impressive set of technology skills. The fact that they are very confident with their technology skills, fond of gaming, and enthusiastic about social networks and simulations has been confirmed with the survey study presented in Chapter 4. Overall, students have very a broad range of technology exposure and knowledge, which suggests that they will enjoy the inclusion of technology in the classrooms traditionally perceived as unexciting (reflected by the fact that almost half of students do not stay focused in class). Technology with its engaging power, therefore, seems to be an appropriate resolution to make the best out of the skills students already possess and create the conditions for learning instructors strive to achieve.

5.3 Engaging power of games and simulations

In the survey study conducted, when asked about the learning activities that students wanted to be included in classes, they ranked simulations as one of the two most favorable (together with in-class discussions). They had a very positive attitude toward the use of video and animation technology in class, with more than 75% of students finding it engaging and believing it helped remember and understand learning materials better. As 90% of students played computer games at different levels, the use of simulations of some sort as learning strategies would be welcome and used effectively by students to serve their learning needs.

Game and simulation, from now on, will be defined in this dissertation as any software or computerized tool that is used to create a virtual (learning) experience through an interface instead of a real physical environment. It can be as simple as a computerized version of trivia games, such as a quiz, or as complex as a strategy/management game. It might or might not have a winning state like traditionally designed for conventional "game games." In other words, the range of computerized tools and activities being investigated is not limited to just true games as strictly defined in the technical world.

Computer games are a young industry, yet many games have already reached a high level of sophistication in terms of content and interface. These games come in all forms, fields, and levels and have captured the attention of all ages. There are games for the military and games for the beauty industry, games for farming and games for cooking. For any skill that exists, there is likely a game of some sort that either teaches it or requires the player to have it. The world of games, therefore, offers a wide range of game types that can be used as learning platforms, or as referred to in this dissertation, instructional strategies.

Despite all the differences between commercial and educational games, when it comes to creating engagement in users, the qualities of purely entertaining games can be equally applicable to educational games in the learning context. The reason games can be so compelling is their ability to create intrinsic motivation and satisfaction in so many different ways. Table 5.2 provides a good summary of the emotional, psychological, cognitive and behavioral conditions that games can stimulate and that lead to the voluntary dedication of physical and intellectual energy from users to the learning/playing process. All of these should be and can be replicated for educational games without having to compromise any of the pedagogical principles.

Table 5.2 Why games engage us? (reproduced from Prensky, 2001)

Nature of games	**Condition created/stimulated**
Games are a form of fun.	Enjoyment and pleasure
Games are a form of play.	Intense and passionate involvement
Games have rules	Structure
Games have goals.	Motivation
Games are interactive.	Doing
Games have outcomes and feedback.	Learning
Games are adaptive.	Flow
Games have win states.	Ego gratification
Games have conflict/competition/challenge/ opposition	Adrenaline
Games have problem solving.	Creativity
Games have interaction.	Social groups
Games have representation and story.	Emotion

The conditions created by good games are, in fact, essential to the process of learning in humans. We are first stimulated by observations and thoughts, which create various emotional states and induce feelings. This fundamental process describes how learners get motivated to act upon a situation and is illustrated in Figure 5.2 (reproduced from Arciszewski, 2009).

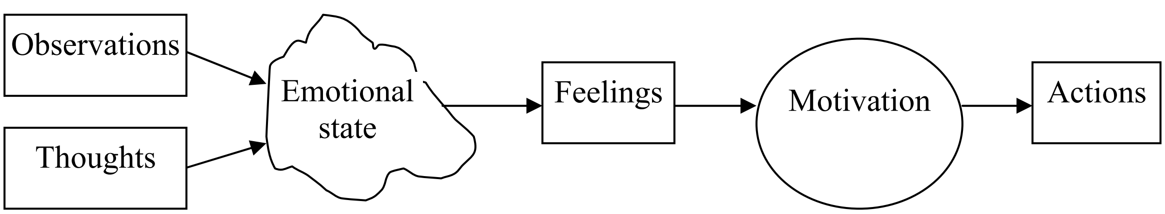

Figure 5.2 From thoughts to actions

The multiple aspects of learning, or intelligence, have long been recognized and emphasized in the study of human learning. Leonardo da Vinci, one of the most diversely talented men that ever lived, had a model for this called "The Renaissance Man." This model is referred to as the da Vinci principles, which happen to explain to a very large extent why the favorable conditions facilitated by games as identified by Prensky can help true learning to occur. In Table 5.3, descriptions of these principles are summarized based on the text by Arciszewski (2009), while the mapping between these and the supporting states and conditions facilitated by games (from Prensky) is created by the author of this dissertation. It can be seen that good games support all but principle number six, which is focused on motor skills and physical wellbeing. This, however, is not likely to be an important objective of formal education at the college level.

Table 5.3 How games support Da Vinci principles – mapping by author

Da Vinci principle	**Supporting states/conditions**
1. Curiosita (curiosity): A constantly curious and open mindset that results in a desire for continuous learning.	Motivation Ego gratification
2. Dimonstrazion (presentation, demonstration): A willingness to verify learned knowledge through persistent experience, learn from mistakes, and be creative	Doing Learning Creativity
3. Sensazione (sensation, feelings): The ability to refine all senses to acquire knowledge, both emotional and rational, abstract and physical.	Emotion Ego gratification Enjoyment and pleasure
4. Stumafo ("going up in smoke"): The willingness to understand and be open-minded about the world's complexity, uncertainty, conflicts, and ambiguity.	Adrenaline Structure
5. Arte/Scienza (art/science, or whole-brain thinker): The balanced approach to life and learning that involves both art and science, artistic and engineering, emotional and rational, logic and imagination, whole picture and details.	Emotion Social groups Creativity Structure
6. Corporalita (corporality): State of being in physical or bodily form rather than spiritual. Awareness of systems characteristics in human body.	
7. Connessione (connection): Awareness and appreciation of the interconnectedness of things and phenomena.	Adrenaline Flow

5.4 Games and simulations as instructional strategies

Section 5.2 reviewed active learning as a highly effective learning method that emphasizes the importance of student engagement. This engagement can be greatly enhanced by technology thanks to its interactive and action-oriented nature. The review also produced a list of commonly used active learning strategies that could be enhanced when implemented with technology. Section 5.3 explained the reasons why games and simulations are so engaging and what principles can be applied to create similar engagement in learning tools. In this following section, discussions will be given to the classification of games and simulations as active learning strategies that could then be used in the framework under development.

Despite the full-blown scale and highly commercial nature of the game industry, there seems to be no consistent classification of games in the literature. As shown in Table 5.4, there have been several classifications of games used in different contexts.

These taxonomies are often based more on the nature of the action involved in the games as opposed to the understanding and knowledge the players acquire in the subject domain of the games. As a result, these lists provide little guidance in terms of what platform would be best for a certain instructional goal under consideration.

Table 5.4 Classifications of games, reproduced from Teixeira *et al* (2008)

Teixeira *et al* (2008)	**Prensky**(2001)	**Battaiolla** (2000)	**Crawford** (1982)
Action	Action	Adventure	Card games
Adventure	Adventure	Education and training	Computer games
Card	Combat	Sports	Table games
Competition	Sports	Strategy	Sports games
Strategy	Strategy	For infants	Children games
Role playing	Interpretation and role playing	Fighting	
Fighting	Puzzle	Leisure	**Caillos** (*in* Anjos, 2005)
Board		RPG	Competition
Leisure	**Johnson** *et al*(1985)	Simulator	Chance
Puzzle	Individual		Simulation
Games of chance	Collaborative		Movement
Simulation			
Educational context			
Sports			
Children			

As in the case with active learning classification, the game types in each of the lists in Table 5.4 are not of the same level of complexity and not mutually exclusive of one another. The development of a taxonomy of technology-supported (game/simulation-based) instructional strategies, therefore, is an effort to marry the forms of active learning strategies (in Table 5.1) with the types of games/simulations (in Table 5.4). The result is the taxonomy presented in Table 5.5. Though the instructional strategies in this taxonomy bear game-like names for a more descriptive distinction, the criteria for classification are based on pedagogical differences between the genres. Each of these game-based instructional platforms also embraces one or more active learning strategies reviewed earlier. The list covers most of the genres that can be easily adapted for educational purposes.

Table 5.5 Proposed taxonomy of game/simulation-based instructional strategies (synthesized and adapted from several sources)

Interactive Case Studies (Horton, 2006, McKinney, 2009, Meyers and Jones, 1993) An effective way to deliver a large amount of information to learners through relevant and meaningful context of real world events, processes or systems. Technology provides rich multimedia presentations to help students digest information better and offer interactive features for decent analyses and application. Can accommodate a wide range of learning objectives (facts, theories, systems, judgment, observation). Case studies are normally quite structured and linear, which is suitable for most students except those with highly global thinking style.
Device Simulations/Virtual Products (Aldrich, 2005, p.5, Horton, 2006, Wang, 2002) Refer to simulated model of a product or device (or a part of it). Widely used for testing a product design for form, fit, performance, and manufacturability, or serves very well as a study or training tool for perspective users of the actual devices/products. Useful in teaching advanced skills that would otherwise unsafe to acquire using the actual product. Students with low or very low technology background mind find these hard and need training.
Math-based Simulations/ Interactive Spreadsheet/ Guided Analysis (Horton, 2006, Aldrich, 2005, ICC, 2009, McKinney, 2009, thiagi.com) Refer to all interactive analyses that involve complex behind-the-scene mathematical calculations and an interactive interface for results with tools to aid analyses and decision-making. Users input data through relevant variables, the program calculates the desired functions, and results are displayed mostly visually. Suitable teaching accounting, economic problems, structural stability, process systems, physics, etc. Adequate prerequisite knowledge in subject is a must as interface is mostly visual.
Skill Building Simulations (Wohling and Gill, 1980) Involve a simulated environment in which students operate virtual equipment and carry out procedures to learn some desirable skills, mostly technical (as opposed to soft skills, which can be learned through role playing and other management/strategy games and simulations). Used primarily to develop skills in specific procedures, methods and techniques.
Design/ Invention Games (Horton, 2006) Provide the basic building blocks for creating an object or a system that serves a predefined function. The interface provides a wide range of options for basic elements from which users can choose, enforces the most important design principles (such as science), and visualizes as well as evaluate the creation. Usually highly visual and emphasizes impact each component/element has on the whole system. Good for creativity and learning about scientific systems.
Role-playing (Wohling and Gill, 1980, Horton, 2006, McKinney, 2009) Role-playing is an unrehearsed dramatization in which individuals improvise behaviors that illustrate acts expected of persons involved in defined situation. Participants are presented with a realistic or hypothetical situation, in which each of them assumes a role and puts himself/herself in the shoes of that character. They will then have to act and interact with the assumed perspectives and views of the character they are playing. Role-playing helps students understand the perspectives and feelings of different stakeholders in a complex situation of conflicts of dilemmas. Role-playing has two major uses: 1) training people in attitudinal areas, and 2) integrating and applying learning from a variety of sources to deal with problem situations. Students with strong preference for facts (sensing) over intuition might need extra help in role-playing.

Table 5.5 (continued)

Strategy Games/ Management Simulations/ God Games (Aldrich 2005) Refer to the most complex and technologically elaborate simulation platform of all. Can be highly sophisticated in the visual interface, highly interactive and engaging, and cognitively comprehensive. In a game of this type, "learners manage the concepts of exploration, building, defending, logistics and conquering. They need long-term philosophies, not just minute-to-minute reactions. They balance short-term vs. long-term goals. They have to move between the small and big picture, juggling a bigger task of distraction or destruction of a key facility." Students need strong technology skills and good domain knowledge to be ready for this learning method.
Concept/Mind Mapping (Novak and Canas, 2006, Horton, 2006) Concept mapping is a method to create, explore, present, and structure knowledge graphically. In many cases, concept/mind mapping is considered a better alternative to outlines and purely textual hierarchy of ideas. It helps the visual brain process the information and grasp both the meaning of details and the big picture of relevant concepts in a context. Mind mapping is a less fluid version of concept mapping in the sense that it is more like a tree-branching map. Mind mapping are better suited for topics that are more descriptive, while concept mapping works well for more abstract topics. Concept and mind mapping is a simple and useful tool in a wide range of learning activities, such as note taking, brainstorming, idea generation, documenting and tracking team input.
Quiz-show Games (Horton, 2006) Similar to TV game shows, can be used in place of tests official quizzes and exams to test students' knowledge. This will make the task of taking tests less intimidating, more engaging, and more motivating if games are played prior to teaching the subject. Quiz-show games are good for testing factual knowledge, and if done right, will encourage and motivate to learn and improve.

It is important to note that there might be a significant amount of overlap between some of the games, and some are much more complex than others. In fact, some games can be completely submerged in a more sophisticated one, for example a strategy game might have a math simulation embedded in it. Some are simply the enhanced version of the non-computerized method, such as Interactive Case Studies, or Concept/Mind Mapping. In the middle of the complexity/sophistication scale are Device Simulation, Skill Building Simulation and Design/Invention games where the non-simulated forms (real device operations or manual design methods) exist but are not always available for learning purposes. In this case a simulated tool is a great alternative that might be able to offer additional features to support the learning process. At the other end are instructional tools/strategies that are only feasible because of technology such as complex Management/Strategy Games.

The role of this taxonomy of instructional strategies in the framework being developed is to provide options for the instructional designers/teachers to identify one or more forms of game/simulation-based strategies that meet their needs and are suitable for their students. To help users of framework make a better informed decision as to which strategy is best suited for their task, it is necessary to provide more information on the applicability of these strategies and how to implement them in different situations. Detailed descriptions were therefore generated for each of the strategies in terms of their structure, qualities, typical uses, best suited learning objectives, most important aspects of design, and examples of existing educational applications in that particular platform. These can be found in Appendix F.

5.5 Instructional goals and Bloom's taxonomy

The very first step in the instructional design process, even before any decision is made on what learning strategy to be used, what activities to include, and how to build all these into an interface, is to determine what students are expected to learn. This includes both the broader instructional goal (such as what type of knowledge to be taught) and the more specific instructional objectives (what skills/knowledge students are expected to demonstrate and how to assess their performance). This is consistent with the backward design principle by Wiggins and McTighe (2005) introduced in Chapter 2. This section will review the relevant literature in instructional design that makes the execution of this task logical and systematic.

5.5.1 Definition of instructional goals

In general, knowledge can be categorized into fifteen areas as shown in Table 5.6. This taxonomy of instructional goals is the expanded version of the original classification by Prensky (2001). These categories, though broad and high-level, are important in making one think about the nature of the learning experience one wants to create. In this table, the categories for learning goals and supporting game types were taken directly from Prensky with minor modifications to a few goal categories. Also provided for each category are examples of common topics in civil engineering and construction management that generally fall into that category and some learning activities that can be used to achieve each goal. Some of these specific examples and learning activities were taken from Prensky, while most of them were substantially revised and expanded by the author to make them more relevant to the construction management domain (with the examples) and create more links to the active learning instructional strategies and game types reviewed earlier.

Table 5.6 Taxonomy of instructional goals with examples and suggested learning activities (adapted and expanded based on Prensky, 2001, p.156).

Goal	Examples	Learning Activities	Possible game types
Judgment	Ethics; interpretation of laws, regulations, and codes; assessing impact of changes; hazard analyses; evaluating change orders; resource allocation; dispute avoidance and resolution; negotiation; jobsite inspection; hiring; community/public relations.	Case studies, asking questions, discussions, making choices (practice), feedback, coaching	Role-play games Detective games Multiplayer games Adventure games Strategy games
Calculations/ Analyses	Apply theories, formulae, procedures to do calculations (engineering, economics, etc.); estimating; cash flow analyses; evaluating economic alternatives.	Reviewing theories, realizing components, substituting variables, comparing results	*Not in original Prensky*
Creativity	Apply existing and new knowledge to create a product: marketing; public image; sustainable design.	Play, experimentation, exploration, challenges, idea generation	Puzzles Invention games
Facts	Product specifications; laws, regulations and codes; insurance bonds and requirements; licensing requirements; cost accounting formats; policies; punch lists;	Questions, memorization, association, drill	Game show competitions, flash cards, mnemonics, sports games
Physical Systems	Components of a systems in the physical world and the physical and logical relationships among them: spatial relations; site development/organization; product details; machines; site work/excavation; mechanical/electrical systems.	Recognizing components, understanding components and relationships, exposure to various systems	*Not in original Prensky*
Procedures	Carry out a certain sequence of activities to achieve a goal: assembly techniques/equipment; steel erection; pipe lining; concrete curing; payment request.	Demonstration, imitation, practice	Timed games Reflex games
Language	Technical terminologies; acronyms; negotiation language; press release protocol; project documentation	Imitation, continuous practice, immersion	Role-play games Reflex games Flashcard games

Table 5.6 (continued)

Goal	Examples	Learning Activities	Possible game types
Theories	Structural mechanics; economics; organizational behaviors; management philosophies; how people learn; marketing principles	Logic, experimentation, questioning	Open-ended simulations Building games Construction games Reality testing games
Technical skills	Estimating; budgeting; interviewing; technical drawing; surveying; crane operation; pipe connection; machine operation; scheduling.	Imitation, feedback, coaching, continuous practice, increasing challenge	Persistent state games Role-play games Adventure games Detective games
Behaviors/ Soft skills	Leadership; facilitation; supervision; self-control; team building	Imitation, feedback, Coaching, practice	Role-play games
Reasoning/Decision Making	Strategic and tactical thinking; quality analysis; idea evaluation; risk analysis;	Problems, examples	Puzzles
Process	Bidding; procurement; auditing; scheduling; training; strategy creation	System analysis and deconstruction, practice	Strategy games Adventure games Simulation games
Systems	Supply chain; partnership; business organization; refineries; markets.	Understanding principles, graduated tasks, playing in micro world	Simulation games
Observation	Moods, morale, inefficiencies, problems	Observing, feedback	Concentration games Adventure games
Communication	Appropriate language; meeting facilitation; public speaking; face-to-face vs. online communication	Imitation, discussions, practice	Role-play games Reflex games

The knowledge areas classified in this taxonomy are not meant to be exclusive of each other; for example in order to be creative, one needs to know some basic facts, but teaching facts is not the ultimate goal. In addition, one basic principle of instruction is to not try to teach too many things at once, ideally a unit of instruction should have only a single learning goal. More often than not, a topic can be taught in more than one way, emphasizing different aspects of the topic that might be characterized by different goals. Going through the process of defining the overall instructional goal helps designers prioritizing the specific knowledge and writing the instructional objectives. The choice of instructional goal is the first decision the designer has to face when creating instruction; once decided, it cannot change. Objectives are iterative and refined in an ongoing fashion, but a goal is stable or else teaching is done to a moving target. It is expected that this taxonomy of learning goals can be built into the framework under development to guide designers to the next step that is choosing the right option from the game-based instructional strategy taxonomy developed earlier for the base design of their instructional tool.

5.5.2 Bloom's taxonomy of educational objectives

Once the high-level instructional goal has been determined, specific instructional objectives have to be defined. Meyers and Jones (1993) identified "clarifying course objectives and content" as one of the four elements essential to the active learning environment. The failure to define good learning objectives often leads to failure, especially in e-learning (Clark and Mayer, 2003). While the instructional goal taxonomy in Table 5.6 is useful in defining the scope of instruction, it is not specific enough to be used for learning assessment purposes. It is necessary to have more fleshed-out learning objectives that can be translated into learning activities, and consequently, learning assessment metrics. For this purpose, Bloom's Taxonomy of Educational Objectives has long been used as a practical guideline that helps define a specific level of understanding in a subject matter to be taught. Bloom's Taxonomy is a framework used to classify learning activities in the order of cognitive complexity. It was first created in 1956 by Benjamin Bloom and a group of educational psychologists as a way to assist teachers in designing instructional activities, defining learning objectives, and measuring learning outcomes. Table 5.7 lists common action verbs that can be used to define learning objectives at each level of the Bloom's taxonomy.

This taxonomy is supposed to be a linear model; a learner moves up from lower level thinking to higher ones: it is easier to remember an equation than to apply it to a problem; in order to analyze a context, one has to know the facts and/or the theory. The first pyramid in Figure 5.3 represents this original taxonomy. During the 1990s and the 2000s, the APA (American Psychological Association) revised the taxonomy and created a new version, as shown in the second pyramid of Figure 5.3 (Anderson and Krathwohl, 2001). While the pyramid reflects the hierarchy of the model and has clearly endured the test of time, its linearity has not gone unchallenged, especially for the higher levels. It is not always clear whether creating is more complex than evaluating, or analysis really has cognitive superiority over application. To make the taxonomy more comprehensible and hence easier to use in this research, three broad levels were introduced to the revised version; each consists of two of Bloom's levels: basic (remember, understand), intermediate (apply, analyze), and advanced (evaluate, create). Both the specific and the broad levels will be used to characterize the instructional goals and strategies when making connections between the components of the design framework being developed.

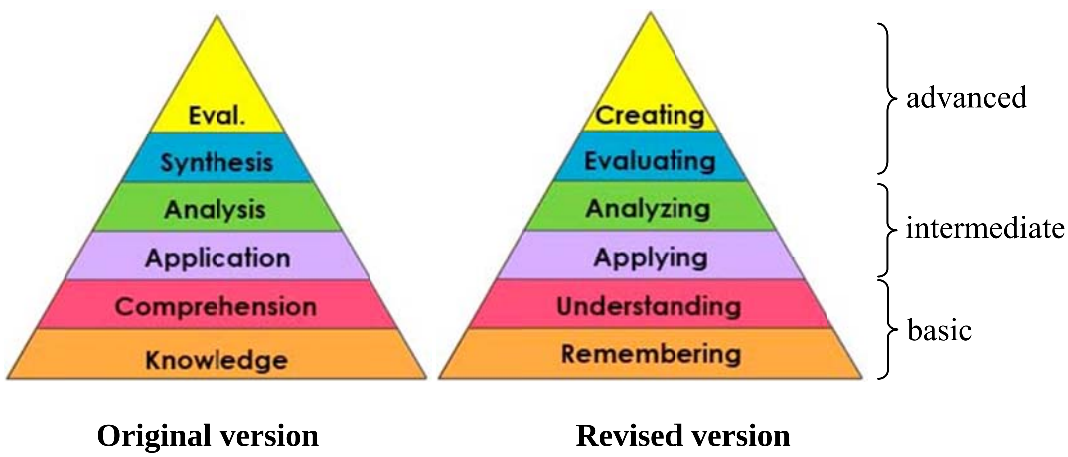

Figure 5.3 Bloom's taxonomy of learning outcomes for the cognitive domain (reproduced from Overbaugh and Schultz, 2010)

Table 5.7 Bloom's action verbs (synthesized from Overbaugh and Schultz, 2010)

Bloom's level	Action
Remembering	Arrange, define, duplicate, label, list, memorize, name, order, recognize, relate, recall, repeat, reproduce,
Understanding	Classify, describe, discuss, explain, express, identify, indicate, interpret, locate, paraphrase, recognize, report, restate, review, select, translate
Applying	Apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use, write
Analyzing	Analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, distinguish, examine, experiment, question,
Evaluating	Appraise, argue, assess, choose, compare, defend, estimate, evaluate, judge, predict, rate, select, support, value
Creating	Assemble, compose, construct, create, design, develop, formulate, plan, propose, write

5.6 Instructional design model: Gagne's Nine Events of Instruction

The taxonomy of game/simulation-based instructional strategies in Table 5.5 provides instructional designers with general ideas for a technology-supported learning format that is potentially intriguing to learners. While games and simulations are often designed with several characteristics inherently supportive of the learning process, they may not be intentionally purposed to achieve a set of pedagogical objectives. As the goal of this research is to explore ways of taking the best advantage of technology in creating learning/teaching tools that facilitate effective active learning, it is important to base the design framework on a solid instructional design model, as "pouring a solid foundation of good pedagogical design before adding on the layer of technology can become a critical factor in the success rate of technology integration" (Ziegenguss, 2005).

There are two important qualities that are sought after in an instructional design model to be used as the guiding structure for the design of a technology-enhanced teaching tool. First, the model should be pedagogically sound and based on established research in cognitive processes involved in the human learning process. This assertion is particularly important as when learning with technology, learners have to handle more stimuli than simply listening or reading. These stimuli require simultaneous responses from several senses and might become overwhelmed when not handled correctly. Second, the model needs enough actionable details so that linkages can be made between the various components of technology design and instructional design embedded in the framework under construction. Gagne's Nine Events of Instruction model seems to fit the bill as 1) it has been around long enough to be validated by experts in the field and 2) it is event-based, which is a great match for the event-based operations of computer applications. Not only does Gagne's model remain "one of the most significant contributions to instructional design today" (Van Eck, 2007) and is widely used to ensure teaching effectiveness, its framework and details can also be fully supported in good games, and hence in good game-based instruction (Becker, 2007).

The Gagne model (Gagne et al, 1992) identifies nine instructional stimuli or events that create favorable conditions for learning through the activation of various internal mental processes (Figure 5.4). This model is based on the theory of information processing, which treats the human brain as a computer. The model focuses on intellectual skills and suggests that various types of tasks and learning activities should be included in instruction. The order of the nine events might suggest a hierarchy of learning events for a learning module, which is typically followed in a conventional learning sequence. However, this is not a requirement for applying the model. In fact, some instructional events should be repeated several times throughout the learning experience (such as providing feedback or gaining/retaining attention). This repetition is especially true in instruction designed with the support of technology thanks to its additional capacity to automate certain system responses that help users learn better.

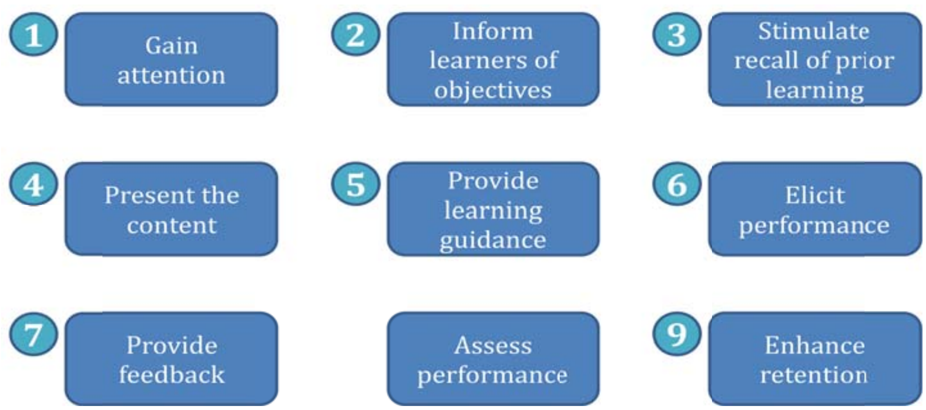

Figure 5.4 Gagne's Nine Events of Instruction

The role of each of these nine instructional events in the learning process is described in Table 5.8. For each of the events, suggestions are also given as to which multimedia elements in a game-simulation platform can be used to create the conditions that facilitate that learning event. Though some of these details were taken directly from Van Eck (2007), most of them were generated by the author through a comprehensive analysis of the literature. All of these elements can be translated into interface features for the technology-supported learning tool being built.

Table 5.8 Gagne's nine events of instruction (expanded by author from Van Eck, 2007)

Event	Descriptions	Game/simulation elements
1) Gain attention	(Stimuli activate receptors). To get students ready for learning and participation. To make them curious and want to learn more about the topic.	• Persistent animations to allure users into clicking • High quality demo videos • Pop-up suggestions
2) Inform learners of objectives	(Creates level of expectation for learning). To create the internal process of expectancy and helps motivate learners to complete the lesson. Also to set *benchmarks* for learning assessment.	• Back-story, context setting • Advertising, show case of games/simulations prior to start • Rule setting • Winning state/score definition
3) Stimulate recall of prior learning	(Retrieval and activation of short-term memory). To establish links between knowledge to be learned with prior knowledge and personal experience. This is believed to help code information in long-term memory.	• Physical/mental resemblance of interface stimulates recall of prior knowledge about the real world counterpart • Short quizzes prior to start also trigger thinking and recall prior knowledge
4) Present the content	(Selective perception of content). Present new content to learners. This is key to engagement. Content should be chunked and organized meaningfully, and typically is explained and then demonstrated. To appeal to different learning modalities, a variety of media should be used if possible, including text, graphics, audio narration, and video.	• Define goals • Provide support when needed • Offering a hint • Response to a negative action, reward a positive one
5) Provide learning guidance	(Semantic encoding for long-term memory). Additional guidance to facilitate long-term information coding, includes use of examples, non-examples, case studies, graphical representations, mnemonics, and analogies.	• Game players do not use manuals – provide "on site" just-in-time coaching: in terms of guidance and extra materials • Provide examples (multimedia rather than text) • Visual or auditory mnemonics • Metaphors/analogies • Get help from other online users/community
6) Elicit performance (practice)	(Responds to questions to enhance encoding and verification). Learners to practice new skills or behaviors. Eliciting performance provides an opportunity for learners to confirm their correct understanding, and the repetition further increases the likelihood of retention.	• Offer lots of practice with varying content/format

Table 5.8 (continued)

Event	Descriptions	Game/simulation elements
7) Provide feedback	(Reinforcement and assessment of correct performance). Provide specific and immediate feedback of learners' performance. Exercises and tutorials are used for comprehension and encoding purposes, not for formal scoring (formative feedback).	• Displays, scores, • Queries • System response messages: verbal feedback • Goal reminder: status update
8) Assess performance	(Retrieval and reinforcement of content as final evaluation). Post-test of final assessment of student performance upon completion of learning period, completed independently without additional coaching, feedback, or hints.	• Through scores or expected outcomes • Through definition of winning/pass state
9) Enhance retention	(Retrieval and generalization of learned skill to new situation). Encourage application of newly learned knowledge in different contexts. Develop perspective understanding of subject matter (in relation with other knowledge areas, with the world).	• Graduated challenges and increasing level of complexity/difficulty help retain long-term knowledge • Themes and context in games and simulation support long term retention of materials

A technology-supported learning tool has to be built on the concrete actions that allow learning activities to be carried out through an interface. These learning activities should be more specific than the generic conditions prescribed by Gagne's learning events. For example, to help students recall prior knowledge in a subject area (an instructional/learning event), quizzes or case studies can be used to set the context and provide background information. These quizzes and case studies are specific learning activities that make up the event "stimulate recall of prior learning". Bloom's Taxonomy and the action verbs described in the previous section are particularly helpful in defining these learning activities. In the design framework that was being developed, these would be generated for each of the game-based instructional strategies under consideration. They will be specific to the nature and format of the strategy and detailed enough to be translated into computer features and actions for the instructional tool designed. More of this will be discussed in Chapter 6, framework development.

5.7 Design implications of student background

Also affecting the choice of instructional goal and strategy is the background of the students. Not only is learning influenced by what a student already knows when instruction begins, but learning is also influenced by learner traits and characteristics. As found from the Technology and Construction Baseline Survey study in Chapter 4, age and gender do make a difference in terms of the technology skills students possess as well as their attitude toward games. Low-scoring students might benefit greatly from multimedia-based instruction but might need significant orientation or training prior to the lesson and frequent feedback (Issa *et al*, 1999). An audience that is not technology-savvy might not feel comfortable handling a complicated simulation, or students with a global approach to constructing knowledge will find a structured game boring and limiting. While all these are not definitive or absolute in any sense, they are realistic observations with research implications that will help make instruction more supportive and effective to all groups in the student audience. In-depth discussions about the design implications of student background for instructional design have been presented in Chapter 4 and summarized in Table 4.8.

5.8 Principles of interface design

The major difference between a traditional learning method (such as an instructor-led lecture) and a technology-enhanced learning tool is the way information is delivered to the students. In a traditional lecture, information is usually given by the instructor; students do not have significant control of their learning pace or method, at least not in the classroom. In a technology-supported learning environment, learners do not have that human factor when interacting with the medium; however, the sources of information are much more diverse (multimedia) and learners are much more in control of their learning activities. Good technology-enhanced instruction should be able to both compensate well for the lack of human interaction (as it is to a large extent a self-taught experience) and take advantage of the extraordinary capabilities of technology to sharpen learners' senses and support their cognitive processing in order to provide a stimulating learning experience. Besides good content, such instruction can only be achieved when a well-designed interface is in place. The existing knowledge in the user interface design world, naturally, is the most reliable resource for such wisdom.

Several guidelines exist for graphical user interface (UI) design and have been widely embraced by most well-known industry software and hardware designers such as Apple and Microsoft. While most of these guidelines are not specifically developed to guide the design of learning tools, many of them will inherently lead to the creation of interactive, friendly and flexible interfaces which are extremely supportive learning conditions. For any interface, there are qualities that are commonly desired such as readability, aesthetic integrity, or reliability. For an educational interface, extra attention should be paid to the interaction design principles that help create tools that are particularly engaging, stimulating and cognitively supportive of the learning process.

Table 5.9 describes twelve interface design principles that are believed to have important implications in instructional design. The descriptions for these guidelines are brief, generic, and synthesized from various sources available (Horton, 2006, APPLE, 2010, Asktog, 2010, IBM, 2010, Microsoft, 2010). A more detailed version of this list can be found in Appendix G.

Table 5.9 Proposed high-level user interface design guidelines (synthesized by author)

Guidelines	Examples
1) Consistency	• Visual consistency: Icons, size boxes, scroll arrows, etc. need to appear the same throughout the application • Make objects consistent with their behavior. Make objects that act differently look different.
2) Provide psychological/emotional comfort	• Appeal to all senses with sounds, visuals, texts, dialogues, feedback. • Use voice/narration where appropriate to create a sense of dialogue. • Allow enough time for users to response.
3) Support cognitive processing of information	• Small number of rules applied throughout. Use generic commands wherever possible. • Reduce memory load. Front load menu entries. • Use visuals effectively: color codes, design theme graphics,
4) Simplicity	• Prioritize: most important components must be most visible and prominent. • Modularity of topics: break complex tasks into simpler ones. • Simplicity means visibility. • Focus attention on content delivery, not on fancy media.
5) Efficiency of users	• Prioritize: optimize for most important tasks, use large objects for important functions. • Typical use cases
6) Aesthetic integrity	• Graphics: keep simple. Interface should look pleasant on the screen, even when viewed for a long time. • Conventionality: don't change the meaning or behavior of standard items. Try to use metaphors. • Legible text.
7) Accommodate individual differences	• Vision: avoid confusing colors to the color blinds; flexible font size. • Add sound where appropriate • Content: adapt to different expertise levels of users.
8) Feedback and communication	• Confirmations: confirm upon receiving input from users. • Informing of progress • Use a mix of verbal (textual or audio) and visual feedback
9) User control	• User control: Allow the user, not the computer, to initiate and control actions. • Help users avoid dangerous, irreversible actions. • Consequences of actions should be immediately visible.
10) Forgiveness	• Make most actions reversible. Create safety nets, such as the Undo and Revert to Saved commands. • Anticipate common problems and give warnings.
11) Explorable interfaces	• Stable visual and structural elements to give users a sense of "home" • Level of flexibility: depends on frequency of use for the task. • Menu: should be broad, not deep with many layers of options.
12) Use of metaphors	• Take advantage of people's knowledge of the world by using metaphors • Use metaphors that represent concrete, familiar ideas, and make the metaphors obvious.

It should be noted that these high-level guidelines are not completely distinct from one another. Similar to the classification of learning objectives or learning strategies, some of these guidelines do overlap, or one can be a cause for another quality. For example, good feedback and communication are certainly correlated to a high efficiency of users. For this reason, a recommendation to focus on one interface design quality (guideline) might indirectly lead to the achievement of another quality. When applied to a specific instructional design problem where a learning topic is defined, learning format focused, and student characteristics known, these high-level guidelines will have a much more specific meaning and practical consequences. This approach will be explained in more depth in Chapter 6.

5.9 Chapter summary

In this chapter, a thorough review of literature was conducted in the areas of active learning, impact of technology on learning, instructional design theory, and user interface design guidelines. Guided by the vision for the design framework being developed, the author had consciously expanded and made adaptations to the relevant literature where appropriate to create initial connections among these otherwise disconnected these pieces of knowledge. Specifically, this literature review has:

- Reviewed literature in active learning and engaging power of games/simulations; mapped games' engaging qualities to daVinci principles of learning;
- Reviewed Bloom's Taxonomy of educational objectives: useful for defining learning objectives and guiding learning activity design;
- Reviewed Gagne's Nine Events of Instruction, expanded list of supporting game/media elements based on Van Eck's original list;
- Created a new taxonomy for game-based instructional strategies;
- Reviewed and expanded Prensky's taxonomy of instructional goals;
- Proposed a list of user interface design principles with important pedagogical implications, based on existing principles from various sources.

It is expected that this revised and updated literature will be used as the starting point in building an effective design framework for creating technology-enhanced teaching tools.

CHAPTER 6: FRAMEWORK DEVELOPMENT

Chapter 5 reviewed relevant literature that formed the origin of the framework being developed and generated preliminary details for some of its components. The goal of this chapter is to formalize the final conceptual framework, define the rules that dictate framework operations, develop a design sequence to operate the framework, create the missing linkages between framework components, and build a computerized version of the framework for easy implementation. A detailed walkthrough of the framework will also be presented.

6.1 Research question revisited and early framework development

It is important to restate that the mission of this chapter is to answer the first part of the second research question: ***How can the distributed knowledge in instructional design, interface design, and student background be systematically embedded in the design process***? The first part of the answer to this question is to identify the distributed knowledge, as suggested by the sub research questions:

- Is there a classification of educational games and simulations that can be used as a taxonomy for technology-aided instructional strategies?
- What existing guidelines in user interface design have important pedagogical implications?
- How can we use our knowledge about the students to improve the effectiveness of technology-aided instruction?

Answers to these sub questions have been obtained from the survey study in Chapter 4 and literature review/early framework development in Chapter 5, from which several key components of a potential framework for designing technology-supported learning tools have been identified, adapted, and developed. Figure 6.1 is the visual summary of these components, in which a cloud represents an area of literature that was modified, adapted, expanded or newly created by the author of this dissertation while a circle represents knowledge directly obtain from the literature. The components include:

- A taxonomy of instructional goals with examples and suggested learning activities;
- Bloom's taxonomy for defining instructional objectives;
- Gagne's Nine Events of Instruction model for creating effective instructional activities;
- A taxonomy of game-based instructional strategies;
- A set of key user interface design principles with potential pedagogical implications; and,
- A set of student background parameters and data to be incorporated into the framework.

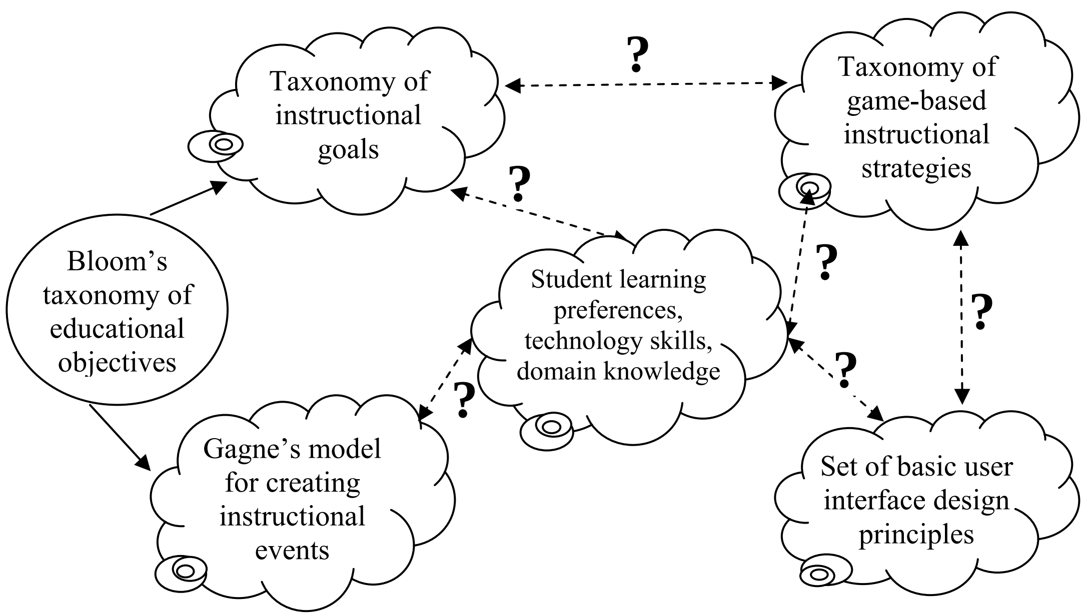

Figure 6.1 Key components of framework from the literature and the missing links

These pieces of distributed knowledge, however, are not of much use without the links that connect one to another in a logical manner. For example, given a subject matter to teach, how does one choose a game-based strategy that suits the nature of the subject? How should the interface be designed? What instructional activities can be implemented effectively on such an interface? How does one make sure the design is appropriate for students' technology skills and actually supportive of their learning preferences? Before these questions can be answered in detail, hence addressing the main research question, a structure is needed to put the building components in perspective with one another, formalize the framework and determine all the rules required to operate it.

6.2 EDDE – the conceptual framework

The conceptual design framework is founded upon the key components identified from the literature and depicted in Figure 6.1. The structure of the proposed framework consists of four major steps: Explore, Design, Develop, and Evaluate (EDDE, Figure 6.2). This conceptual framework will be materialized into a design sequence that takes instructional designers through a step-by-step process, starting with an instructional goal, then navigating through the body of knowledge in interface and instructional design in a structured and purposeful way and arriving at a conceptual design of a game-based learning tool that has enough concrete details to be turned into an effective interface. By relating interaction design principles and game-based active learning strategies in a structured manner, the framework provides users with sensible and logical choices and enough background information to make good design decisions.

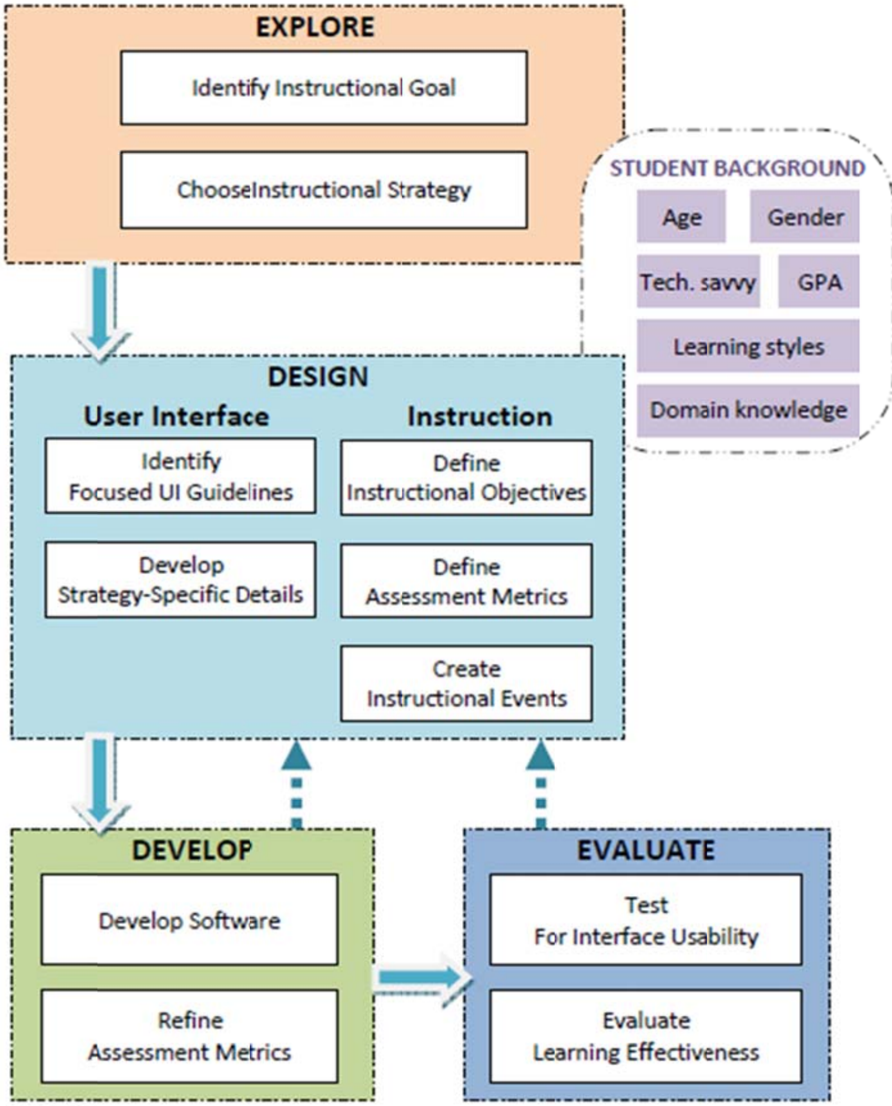

Figure 6.2 The EDDE framework

6.2.1 EXPLORE

The EDDE design process starts with EXPLORE, in which the instructor has to decide what the overall instructional goal is for the topic to be taught and then choose an appropriate game-based instructional strategy to be the format of the learning tool they are designing. As discussed earlier, the instructional goal is the answer to the question of what type of knowledge the students are to learn, e.g., facts, theories, procedures, language, creativity, communication, etc. A learning goal can be multifaceted and might include more than one type of knowledge. The taxonomy of instructional goals previously developed during the preliminary research and literature review phase (Table 5.6) provides designers with a comprehensive list of goal categories from which they can determine an appropriate goal for the topic they are teaching.

In order to be able to decide on an appropriate instructional goal, instructors need to conduct audience analysis during this EXPLORE stage. It is essential that students' backgrounds in the subject domain, their preferences for learning, and their technology skills be taken into account when deciding what should be taught to them and how. Analyses from the survey study suggested several ways in which student background data can impact the choice of interface features and learning strategies/activities, as summarized in Table 4.8. It is expected that the framework can enforce a mechanism that makes instructional designers aware of this impact at every decision point so they can take action to address it where necessary. Details of how this mechanism is enforced will be discussed in Section 6.4.4.

6.2.2 DESIGN

Once the instructional goal has been defined and a game-based instructional strategy chosen, the next step of EDDE is DESIGN, where most of the conceptual and content design is conducted, in terms of both instruction and user interface. For creating instruction, this is where specific instructional objectives are defined based on the high-level instructional goal determined in the first step. During this process, Bloom's Taxonomy can be a useful guide. As the framework does not know the specific topic that the learning tool is supposed to teach, it cannot automatically produce the instructional objectives for it. These can only be created by the designers themselves. This marks the first point in the flow of the framework where the designers have to generate their own content for the design they are creating instead of just making a choice based on the options provided by the framework. For each of the game-based instructional strategies, the framework would have a set of recommendations for instructional activities based on Gagne's Nine Events of Instruction model. The development of these recommendations will be discussed in Section 6.4.3. Preliminary learning assessment metrics are also created at this stage, though they are likely to be modified during the course of interface implementation and design refinement.

In terms of user interface design, the choice of instructional strategy will dictate what the framework suggests as important user interface (UI) design features, with considerations given to the student background. In other words, both instructional and interface design recommendations produced by EDDE are specific to the game-based instructional strategy selected. The focused UI guidelines are chosen from the list of basic UI design principles provided in Table 5.9 in the literature review. More concrete interface features are also provided to further explain the high-level UIs in the context of the instructional strategy chosen. Details of these features and how to map instructional strategies to UI guidelines will be discussed in Section 6.4.2.

6.2.3 DEVELOP

The third step in the design process of technology-supported instruction is DEVELOP where software development takes place. This is the only stage in which EDDE is not directly implemented; development has to be done and software created by a technical team. The role of EDDE in this stage is to provide the conceptual design to guide implementation. There might be revisions to the detailed instructional events and specific interface features during interface development when all sorts of constraints start to reveal themselves, such as time, budget, and difficulties in content presentation. Revisions might also be made to add more features that only become feasible because of the additional capacity of technology, such as assessment metric refinement. For example, by using screen shots, recording mouse clicks, vocal or visual expressions of users, some aspects of learning performance can be assessed in a way that has never been possible with traditional instruction. With these captions, non-performance metrics can become good indicators for learning effectiveness and should be added to the overall learning evaluation. It is therefore common for designers to go back to the first two steps and update the design features during software development.

6.2.4 EVALUATE

The last step of designing a technology-supported learning tool is EVALUATE, where testing is done to assess the achievement of learning effectiveness, learner perceptions, as well as the technical usability of technology. This process is done after the software has been designed, but some preliminary evaluation metrics should be initiated during development so that the software is designed in a way that it can be tested later on. The most important indicator of a successful design is the satisfactory achievement of the desired learning outcomes. If the tool fails to achieve the outcomes, the designers have to go back and re-evaluate decisions at every step after the definition of learning outcomes. Failure might lie in the game format, the outcome measurement design, or the design of the interface itself.

It is expected that the EDDE framework will be helpful in providing theoretical guidelines to the conceptual and content design of an effective technology-enhanced teaching tool. This help lies mainly in the first two stages of the framework, EXPLORE and DESIGN, which are operationalized and made easy by the software EDDEaid (which will be described in Section 6.6). For the last two stages, DEVELOP and EVALUATE, the involvement, and therefore contribution, of EDDE will be indirect: it helps development by providing theoretical concepts and design requirements and helps evaluation by providing the initial benchmark of what to be expected for the final product.

6.3 EDDE – the design sequence

The EDDE process depicted in Figure 6.2 and described in Section 6.2 represents the conceptual structure of a design framework for technology-supported teaching tools from start (with an idea) to finish (with a working product). For completeness, the process also includes phases that are beyond the scope of this research, such as software development and user testing. For clarity purposes, the framework in the context of this dissertation refers to the process of creating a conceptual design of a technology-supported tool with substantial content that will be used to produce the learning tool.

To operationalize this conceptual framework, its components and concepts are broken down into a relatively sequential design sequence, as illustrated in Figure 6.3. The framework imposes a structure on the design process, as reflected in this sequence by a series of decision points at which designers have to make a choice in order to proceed. This is an interactive process in which the framework (the tool) and the designers (the users) alternately provide choices and making choices. Table 6.1 describes in detail which actions to be taken by designers at which point and EDDEaid's responses triggered by those actions. User actions highlighted in bold denote response-triggering actions. In order for the framework to give appropriate output for specific user input, a few sets of rules need to be established to operationalize this process. Figure 6.3 points out three connections in the framework that require these rules to operate. First are the rules that provide instructional strategy options for a certain instructional goal. Second is the choice of user interface design principles for a specific strategy. Third are the recommendations for instructional events and activities corresponding to a selected strategy. There is a fourth set of rules that work behind the scene and are not illustrated in Figure 6.3 (but are visible at several points in Table 6.1): those that reflect the design implications of student background characteristics. These four sets of rules/recommendations are the missing connections that need to be generated to complete the EDDE framework.

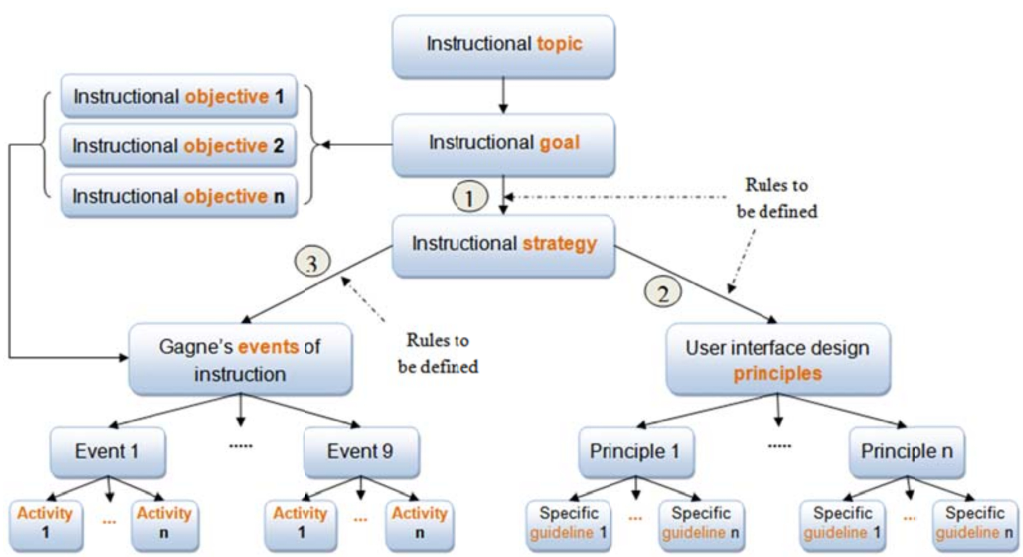

Figure 6.3 Design sequence

Table 6.1 Interactions between users and EDDE

User's input	EDDE's output
Define instructional topic **Provide student background data** **Select instructional goal**	
	Provide warnings/comments on choice of goal based on student background data Recommend instructional strategies
Choose best suited instructional strategy	
	Recommend focused UI guidelines Provide strategy-specific UI recommendations Provide suggestions/comments on interface features based on student background data Recommend strategy-specific instructional activities for Gagne's events Provide suggestions/comments on instructional activities based on student background data
Define instructional objectives Select desirable instructional activities from the recommended Create other instructional activities based on recommendations Review the design	

Throughout the process, at every decision point, the framework offers some specific recommendations and in many cases provides comments regarding the impact that student background might have on the decision. These recommendations and comments, however, are not structured in a rigid manner that would prevent users from proceeding if they do not agree with what is being recommended. Their purpose is to make designers aware of potential consequences and/or implications of the decisions they are making and not to dictate what choice they can make. To make the framework flexible, which is a must given the dynamic and subjective nature of instructional design, users are allowed to deviate from the recommended options and make their own choice as they wish. It is believed that by having to provide input for their own design problems, instructional designers give more thought to the process and have a better sense of ownership of the results, which will make the framework as a decision support tool more effective. Besides, every instructional design problem is unique; even with the same topic and the same audience, each teacher will have a different approach and philosophy to determine exactly what content should be taught, at which level, and what is considered a success or a failure of learning (or teaching). The design framework can only guide users to keep them on track by pointing in the right direction with the right tools; it cannot presume where they want to go ultimately. The use of this framework, thus, requires a great deal of input from the users' end to make sure the ideas they get out at the end help solve their problem. It is therefore not meant to be an automated procedure.

6.4. Making the missing connections

6.4.1 Mapping instruction goals to instructional strategies

The literature review provided a taxonomy of instructional goals (Table 5.6) and a taxonomy of game/simulation-based instructional strategies (Table 5.5). The descriptions of these goals in Table 5.6 provide reasonable guidelines for instructors to make a sensible decision on the learning goal they want to achieve. There are, however, no direct links between instructional goals and instructional strategies. The taxonomy of game-based instructional strategies was newly developed from the various studies in the literature, and hence there was no research findings directly mapped to it.

To create the links between instructional goals and game-based instructional strategies, the following methods of analysis were used:

- Use the possible game types suggested in the original Prensky's instructional goal taxonomy (last column of Table 5.6) and translate these game types into equivalent instructional strategies (in Table 5.5). For example, Prensky suggested using puzzles and invention games to teach creativity. In the new taxonomy of instructional strategies, this would fall into the category of design/invention games.
- Use the examples and suggestions for learning activities in the revised taxonomy of instructional goals (third column of Table 5.6) to trigger connections. For example, one of the learning activities that is used to teach creativity is idea generation, hence the recommendation to use concept/mind mapping as an instructional strategy for teaching creativity.

- Based on the descriptions of the instructional goals, they can be classified as belonging to certain levels in Bloom's taxonomy of educational objectives. For example, teaching "facts" as an instructional goal is equivalent to teaching at the lowest levels on the Bloom's taxonomy: basic (remembering, understanding). A similar classification of instructional strategies can also be done, for example quiz-show games are mostly used to test recall of facts or recognition of prior knowledge, and hence they generally belong to "remembering" on Bloom's scale. Because of this matching in terms of Bloom's level, quiz-show games is one possible instructional strategy that can be used to teach facts.
- From the previous example, it can be seen that the hints for these links can be found right in the definition of the instructional goals and strategies.

This process was done elaborately for all instructional goals and strategies. The results were the mapping presented in Table 6.2. Similar to instructional goals, the boundaries between game types or instructional strategies are far from written in stone. One type of game might focus on certain aspects, but it has a lot in common with several other genres. This overlap is why choosing an instructional goal, and hence a game type, should be a flexible and explorative process in which the instructional designer reinforces and refines his or her teaching scope and teaching goals. For a single instructional goal, one or more instructional strategies might be suitable, for example math simulations are considered a good fit for teaching calculations and analyses, while concept/mind mapping and design/invention games are well suited for teaching creativity. These games can be at any level of technology sophistication; for example, mind mapping is generally considered simple, but some design games can get quite complex. It is, therefore, not an intention to rigidly map a certain learning objective to a certain game. As the way an instructional designer defines a learning goal can be very subjective, the framework just offers recommendations and provides detailed descriptions for each type of game. It leaves it to the designer to decide which game type or learning strategy works best for the nature of the topic to be taught and the learning goal to be achieved. It explains why this is an exploration process in which the instructional designers can try out different scenarios and find the best (initial) solution to their problem.

Table 6.2 Mapping of instructional goals and instructional strategies by author

Goal	Suitable learning strategies/game styles	Blooms' level
Judgment	Interactive case studies, role-playing, strategy/management games	Advanced (evaluating, analyzing)
Calculations/Analyses	Math simulations	Intermediate (applying)
Creativity	Design/invention games, concept/mind mapping	Advanced (creating)
Facts	Quiz-show games, case studies, concept/mind mapping	Basic (knowing, understanding)
Physical Systems	Device simulations, skill building simulations, design/invention games	Basic(understanding)
Procedures	Skill building simulations	Intermediate (applying)
Language	Role-playing, quiz-show games, concept/mind mapping	Intermediate (applying)
Theories	Device simulations/Virtual products, strategy/management games, interactive case studies, role-playing, design/invention games	Intermediate (analyzing)
Technical skills	Skill building games, role-playing, device simulations	Intermediate (applying)
Leadership/Supervision	Role playing games	Advanced (evaluating)
Reasoning/Decision Making	Strategy games	Advanced (evaluating)
Process	Strategy/management games	Advanced (evaluating, creating)
Systems	Strategy/management games, interactive case studies	Intermediate (analyzing) Advanced (evaluation)
Observation	Role playing games, interactive case studies, concept/mind mapping	Advanced (analyzing, evaluating)
Communication	Role playing games, concept/mind mapping	Intermediate (applying)

6.4.2 Mapping instructional strategies to user interface design guidelines

The second missing set of connections from Figure 6.3 is the rules that map instructional strategies to user interface design guidelines as out of the twelve high-level user interface design principles presented in Table 5.9, some are more relevant to a certain game-based instructional strategy than others and hence are highlighted as the focused interface features for that strategy. In the literature there are several separate studies of individual strategies that provide best practices in user interface design for these game types (Horton, 2006, Prensky, 2001, Aldrich, 2005). Through synthesizing and identifying those that have the most pedagogical relevance, a list of best interface design qualities was created for each of the game-based instructional strategies on the taxonomy used in this framework (Table 6.3). This will be used as the mapping that governs the choices of focused user interface design guidelines for a specific strategy in EDDE. It should be reminded that this selection does not mean only recommended guidelines are valuable for the instructional interface being developed. All the twelve high-level UI principles are good guidelines for any interface. The focused principles are those with more important pedagogical impact for the game-based instructional strategy being examined and therefore should be the foundational interface design principles to start with in conceptual design.

Table 6.3 Mapping of learning strategies and user interface design guidelines by author

Learning strategy	**User interface guidelines (high-level)**
Interactive Case Studies	Feedback and communication, Accommodate individual differences/Provide emotional comfort, Explorable interfaces, Support for cognitive processing of information, Simplicity
Device Simulations/Virtual Products	Consistency, Feedback and communication, Efficiency of Users
Math-based Simulations/ Interactive Spreadsheet/ Guided Analysis	Support cognitive processing of information, Forgiveness, Simplicity, Explorable interfaces
Skill Building Simulations	Efficiency of users, Use of metaphors, Feedback and communication
Design/ Invention Games	Simplicity, User control, Feedback and communication, Efficiency of users
Role-playing Games	Simplicity, User control/Direct manipulation/Forgiveness, Feedback and communication, Provide emotional and psychological comfort
Strategy Games/ Management Simulations/ God Games	Use of metaphors, Simplicity/Efficiency of users, Feedback and communication, Explorable interfaces/Forgiveness
Concept/Mind Mapping	Simplicity, Support cognitive processing of information/Efficiency of users
Quiz-show Games	Accommodate individual differences, Forgiveness, Simplicity, Feedback and communication

To make these high level UI guidelines more practical and relevant to the context of the instructional strategy under consideration, strategy-specific explanations were created. For example, “feedback and communication” is an UI guideline deemed important to several learning strategies, but its specific meaning when applied for each strategy might be different. For strategies that are more structured in terms of activity choices and sequence (such as device simulations or quiz-show games), feedback is more for validation of actions and instruction for next steps. In contrast, for open-ended learning strategies such as role-playing or management/god games, feedback is more suggestive and given as a tool to trigger thinking and offer options. These are not just user interface guidelines; they are also pedagogical guidelines. Details of specific user interface recommendations for all strategies are provided in Appendix H.

6.4.3 Developing instructional events for a specific strategy

The generic instructional design model used in this framework is Gagne’s Nine Events of Instruction. This model suggests that instruction should be designed to have nine types of events that trigger different critical learning conditions for students. The descriptions of these events and what general game/media elements can be used to create them were discussed in the literature review of Chapter 5 (Figure 5.4 and Table 5.8). To make the framework more useful to the users, for each of the instructional strategies, a set of specific instructional activities were developed to address each of the nine event groups in Gagne’s model. These provide the users with a pool of ideas to adopt and develop from. These specific instructional activities were generated by the author through a thorough synthesis of best practices in the literature (Horton, 2006, Van Eck, 2007, Lee and Owen, 2000, Aldrich, 2005) and a conscious effort to include as many active learning strategies (list in Table 5.1, descriptions in Appendix E) as possible.

When using EDDE, it is up to the designers to adopt these suggestions, ignore them or modify them to suit their needs. As discussed before, it is not always required to include all nine of Gagne’s instructional events in a learning module, as some events might be infeasible to be implemented for some topics. The events can occur in any order that fits the nature of the learning activities, and some events might take a much more central role than others in the learning experience. In many cases it might be best to use Gagne’s instructional events in a recursive manner (Van Eck, 2007). Details of events developed for each of these strategies are provided in Appendix I.

6.4.4 Integrating student background into the framework

In this framework, it is an assumption that the designers have basic information on their student audience and provide that as an input to the process, based on which the framework will provide feedback or warning messages for choices of instructional goals or strategies that might have conflicts with the current status of their students. As reflected in Figure 6.3 and Table 6.1, student background, though it does not dictate the choices for instructional goal or strategy, it in fact has design implications in many different ways. For example, with an audience of superb technology skills or substantial existing knowledge in the subject domain, low-level learning objectives such as facts and physical systems or simple learning strategies such as quiz-show games might not be the most efficient or exciting ways to teach additional knowledge. Similarly, students of low to very low technology skills might not be ready for highly sophisticated learning strategies such as strategy/management games, in which case adequate training is advised if the instructor wishes to adopt the strategies. Similar concerns exist for the choice of user interface features and instructional events. Table 4.8 provides the general ground rules for tailoring the choice of instructional goal and instructional technology for a specific student audience. These are translated into specific considerations at the key decision points as summarized in Table 6.4. When applied to each specific case, these considerations can be made more concrete and relevant to the design problem at hand. In the software tool EDDEaid (which will be described in Section 6.6), these ground rules are further refined to suit the case they are applied to. They are then programmed into the interface to be displayed as checks/warnings/comments when the user interacts with the tool. It is in the EDDEaid interface that these features of the framework work best. A sample list of the checks programmed in EDDEaid can be found in Appendix J.

Table 6.4 Student background implications at key decision points

Decision	Student background considerations
Define instructional goal	Goal should be appropriate for background in the domain. • If students have limited prior knowledge, high level goals (judgment, leadership, reasoning/decision making) can be challenging. If must use, make sure to provide lots of background knowledge. • The opposite is true: low level goals (facts) create boredom and demotivate students with substantial background knowledge.
Select instructional strategy	• Students are technology-savvy: avoid simple games like quiz shows. Students are low tech: complex games like device simulations or strategy games might be too challenging. Provide lots of training if must use. • Students with none/limited domain knowledge: avoid or provide enough background knowledge when using strategies that require prerequisites such as math simulations. • Sensing and/or sequential students prefer facts and procedures. Open-ended game requiring intuition such as role-playing and strategy games might create challenges. Include enough instructions and background facts if must use.
Design user interface	• Teaching students with substantial domain knowledge and/or teaching high-level goals: emphasize interactive features and exploration. Provide feedback to challenge or trigger thinking. Teaching students with limited domain knowledge: provide lots of information and educational feedback as instructions. • Sequential students: provide clear/well-structured action sequence. • Low-scoring students: use diverse multimedia. Give lots of feedback. • Reflective students: provide pauses and user control. Active students: encourage actions. • Visual students: icons, buttons, actions should be highly visual, intuitive, metaphorical. Light in text. • Teaching complex subjects to sequential/sensing students: balance user control/explorability with imposed structure. Break down into small steps. • Technology-savvy students: multitasking is possible.
Design instruction	• Low-scoring students: demonstrations are helpful in setting expectations and recall prior knowledge. Also benefit from explicit guidance and teamwork. • Young students have high expectations for engagement: include milestones and attention-grabbing events throughout the lesson. • Experienced or students with substantial domain knowledge: content with real world connections will be engaging. Encourage knowledge sharing and collaborative work. Goal-oriented instruction could be helpful. • Students with limited/no prior knowledge: engage by create curiosity or controversies. • Provide tools to encourage interactions, both in-person and simulated. This is good for all students. • Students with diverse domain background: include tasks of different levels of difficulty.

6.5 Assembling the framework

Now that the missing connections have been created, the EDDE framework is ready to be assembled and finalized into an operational process. Figure 6.4 summarizes the framework structure and operational principles with detailed references to component content as well as governing connections among components. To demonstrate how the framework is used to conceptually design a technology-supported instructional application, a walkthrough of a specific design problem will be presented in Section 6.6. This walkthrough will be discussed in conjunction with the description of the EDDEaid software – the computerized version of EDDE – to enhance the walkthrough with visual representations of the process.

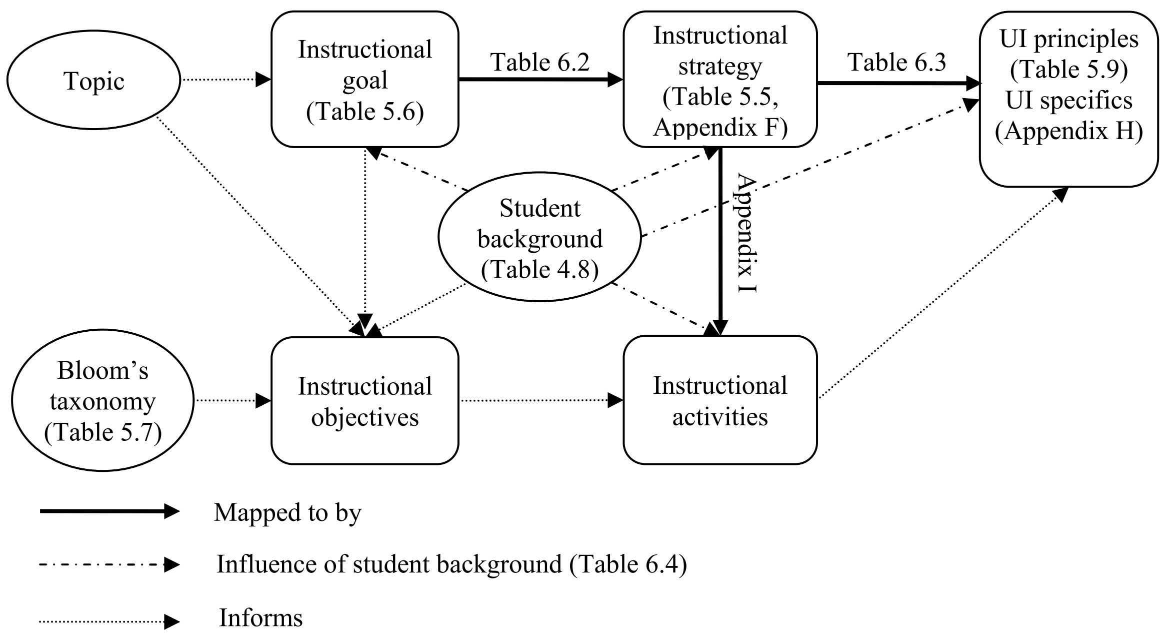

Figure 6.4 The fully assembled EDDE framework

6.6 EDDEaid development and framework walkthrough

6.6.1 EDDEaid overview

As the EDDE framework draws knowledge from multiple fields to address this interdisciplinary design problem, applying it to address a specific problem at hand might be overwhelming due to the sheer amount of information involved in this process. To make this task easier for the users of this framework, a design support software application called EDDEaid was created to help them use the framework efficiently without having to organize and juggle too many pieces of information at one time. All the content and logic of the framework are hardwired in the backend of the application. Relevant information is presented only where necessary when prompted by users. It is also designed to be interactive to help trigger the thought process of users and incorporate their input (learning topic, student background, etc.) in the final outcome of the tool.

The interface of EDDEaid has five different interactive screens that are numbered to guide users through the design sequence. The Home screen is where a typical user starts, with options to go to reference materials, demo video and other general information (Figure 6.5). Screen #1 is dedicated to the EXPLORE stage where users provide student background input and select the instructional goal and strategy. Screen #2 guides users through the user interface design requirements, and Screen #3 provides a template for creating specific instructional events. All decisions made by users are recorded in a summary in Screen #4 where they can review, edit and save the output to be used outside of the EDDEaid interface.

6.6.2 Context of walkthrough

To further illustrate the decision-making points in the design process and what output should be expected from the design framework, let us revisit the design problem in the original pilot design: creating a virtual jobsite with mobile technologies to teach materials management. The assumption is that students have very limited background knowledge in construction and site management, that they are highly visual learners, and quite technology savvy although they have not been much exposed to sensing technologies. In the EDDEaid interface, these student background data are the first input designers have to provide to the application, as shown in the left panel of the Explore screen in Figure 6.6. When these data are unavailable, default data obtained from the baseline survey study are used instead. These student background parameters will be used to validate and evaluate design decisions made throughout the process.

6.6.3 Defining instructional goal

In this example, the goal is to design a learning module that teaches students about construction materials on a jobsite and the task of monitoring and managing these materials for proper execution of a provided construction schedule. To determine the high-level instructional goal for this learning module, the taxonomy of instructional goals from Table 5.6 is used as a reference. From the list of 15 categories, "physical systems" seems to best reflect the goal of this module (students need to know how a construction jobsite is laid out and understand the critical physical components of it), although "procedures" can also be part of it (students needed to master certain tasks such as identifying and locating materials, knowing what they were needed for, monitoring availability or managing schedule). As it is recommended that an instructional unit have only one goal, "physical systems" is chosen as the primary goal for this exercise. The vision is that the learning module would be some kind of a simulated jobsite that could be used in class or in an environment rather than a real jobsite.

In the EDDEaid interface, the taxonomy is displayed in the middle panel of the Explore screen, as shown in Figure 6.6. For clarity only goal titles are permanently visible on the screen. Descriptions and additional information about each instructional goal will be provided via hover tooltips or popup windows upon mouse-overs or mouse clicks on information buttons by users. This method of customized information delivery prevents users from being overwhelmed by too much information and encourages exploration, which is a great advantage over the pen-and-paper way of using the framework. Instructions on what to do at this step in the design process are also always available at the users' fingertip.

6.6.4 Selecting instructional strategy

Once the instructional goal has been defined, the next step is choosing a suitable game-based instructional strategy to be used as the format for the learning module. This is done by using the mapping created in Table 6.2. Among the instructional strategies suggested by the framework (device simulations, design/invention games, skill building simulations), “skill building simulations” seems to be the best option as it provides both a simulated reality and convenient conditions for procedural practice, which is desirable in skill building. To make a better-informed decision, designers are advised to study the detailed descriptions of game-based instructional strategies provided in Appendix F.

In the EDDEaid interface, the recommended instructional strategies for a certain goal will be highlighted in the right panel (Figure 6.6). From these, the users will choose the one that they think is the best for their case, and proceed to the next stage. Similar to the instructional goal panel, additional information about each of the strategies is provided upon request. If users want to deviate from the recommended instructional strategies, they can click on “Show all strategies” to activate all other strategies and choose as they desire. At this point, they can review what they did on this screen and move on to the next step by clicking on the tab “Design User Interface”.

In some cases a pop up message will appear when users select a certain instructional goal or strategy. This happens when EDDEaid checks against the background of the students and finds that their choice might have some important consequence or meaning that is noteworthy. This message is to make users aware of the perceived incompatibility (or an important but not obvious compatibility) between the students’ characteristics and the choice the designer is making. This by no means is absolute, and it does not prevent the designer from proceeding with selections. However users are advised to keep these thoughts in mind when designing the next features for their learning module.

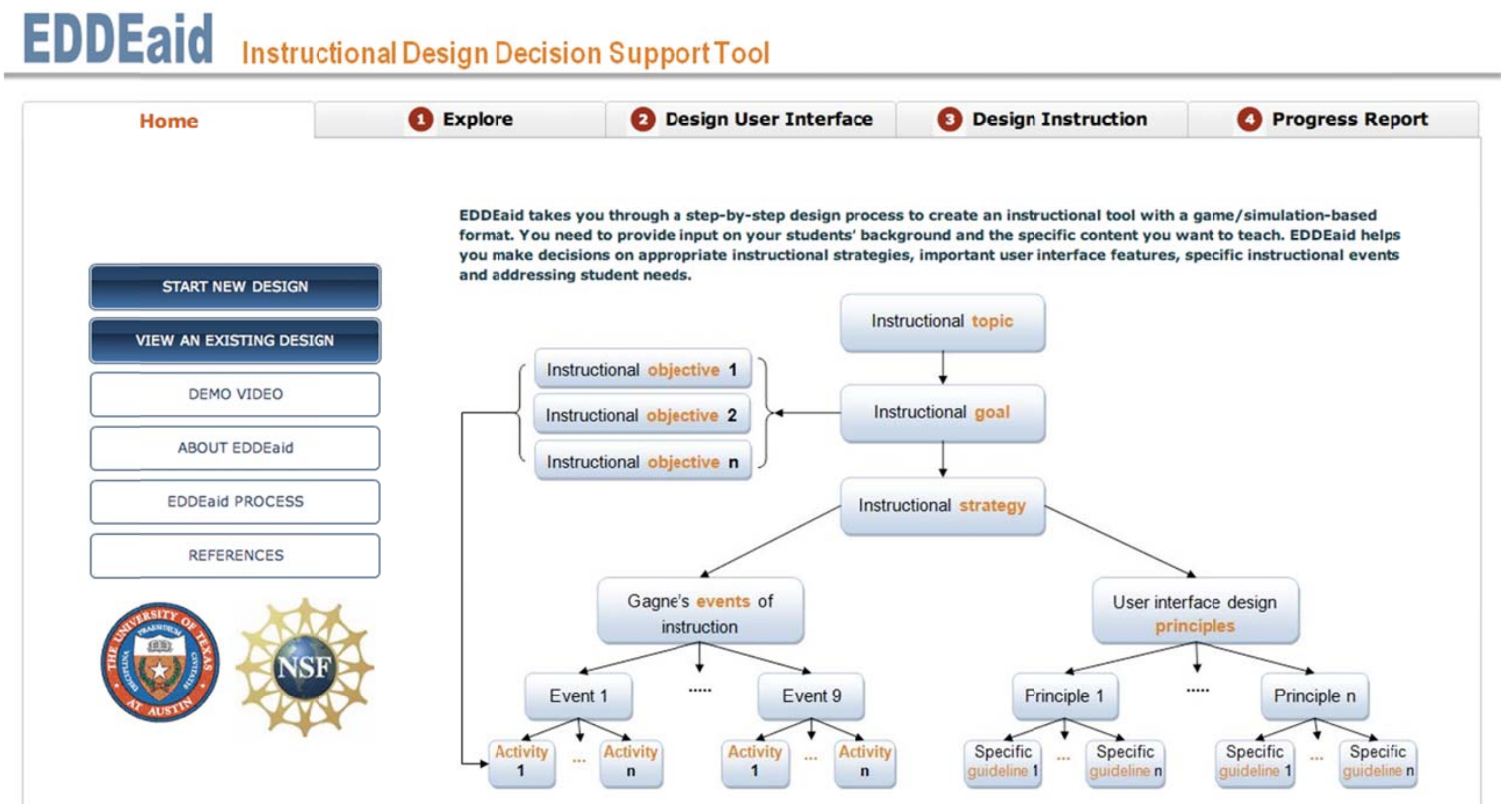

Figure 6.5 EDDEaid Home screen

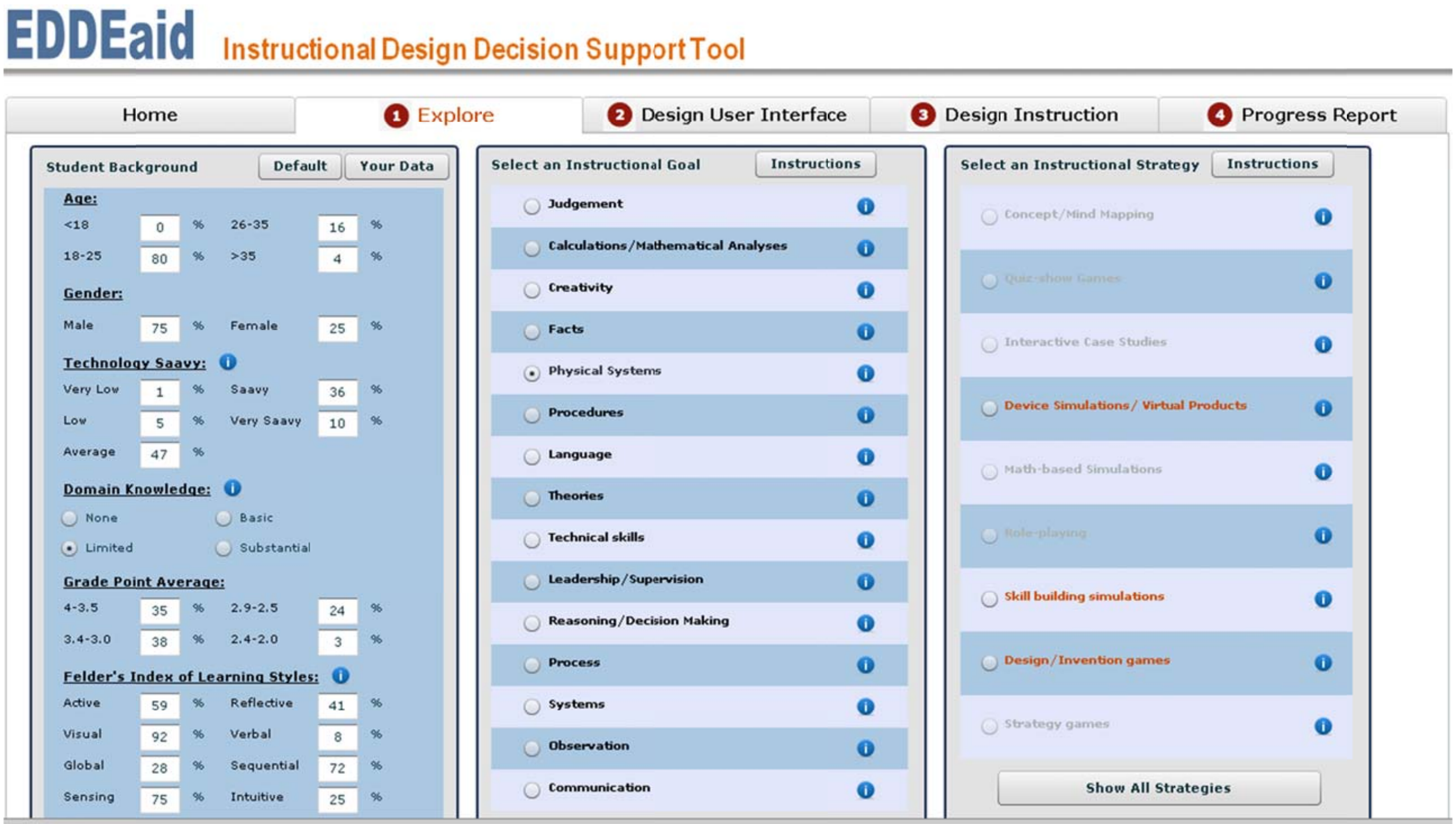

Figure 6.6 EDDEaid's Explore screen

6.6.5 *Design user interface*

By using the mapping between instructional strategies and user interface design principles in Table 6.3, the framework suggests that there are three user interface design principles that are critical for a skill building simulation interface: efficiency of users, use of metaphors, and feedback and communication. These principles are highlighted in the corresponding panel on screen #2 of the EDDEaid interface, as shown in Figure 6.7 (the selections of instructional goal and strategy are carried over from screen #1 and displayed in the first two panels of this screen). This part of the program helps users narrow down the most important interaction features that they should focus on for a skill building simulation interface. This does not mean that other principles do not apply to this design; they are just not as important as the highlighted ones. Users can learn more about any user interface design principle by using the built-in information button. However, they are not able to choose any other principles other than what is recommended.

The last column on this screen is where detailed descriptions of the recommended high level design principles are provided. These are specific to the instructional strategy chosen. The use of metaphors, for example, will mean different things for a skill building simulation and a case study. Users are to select the points they find most relevant.

To get these user interface design features without EDDEaid, Table 6.3 and Appendix H can be used for the mapping between instructional strategies and user interface principles and specific interface features, respectively. The results are presented in Table 6.5. In addition to features that are specific to the skill building simulation strategy, there are also a few notes on how to account for student background in the design. In EDDEaid these are displayed at the bottom right corner and are generated based on the student background data provided on the previous screen.

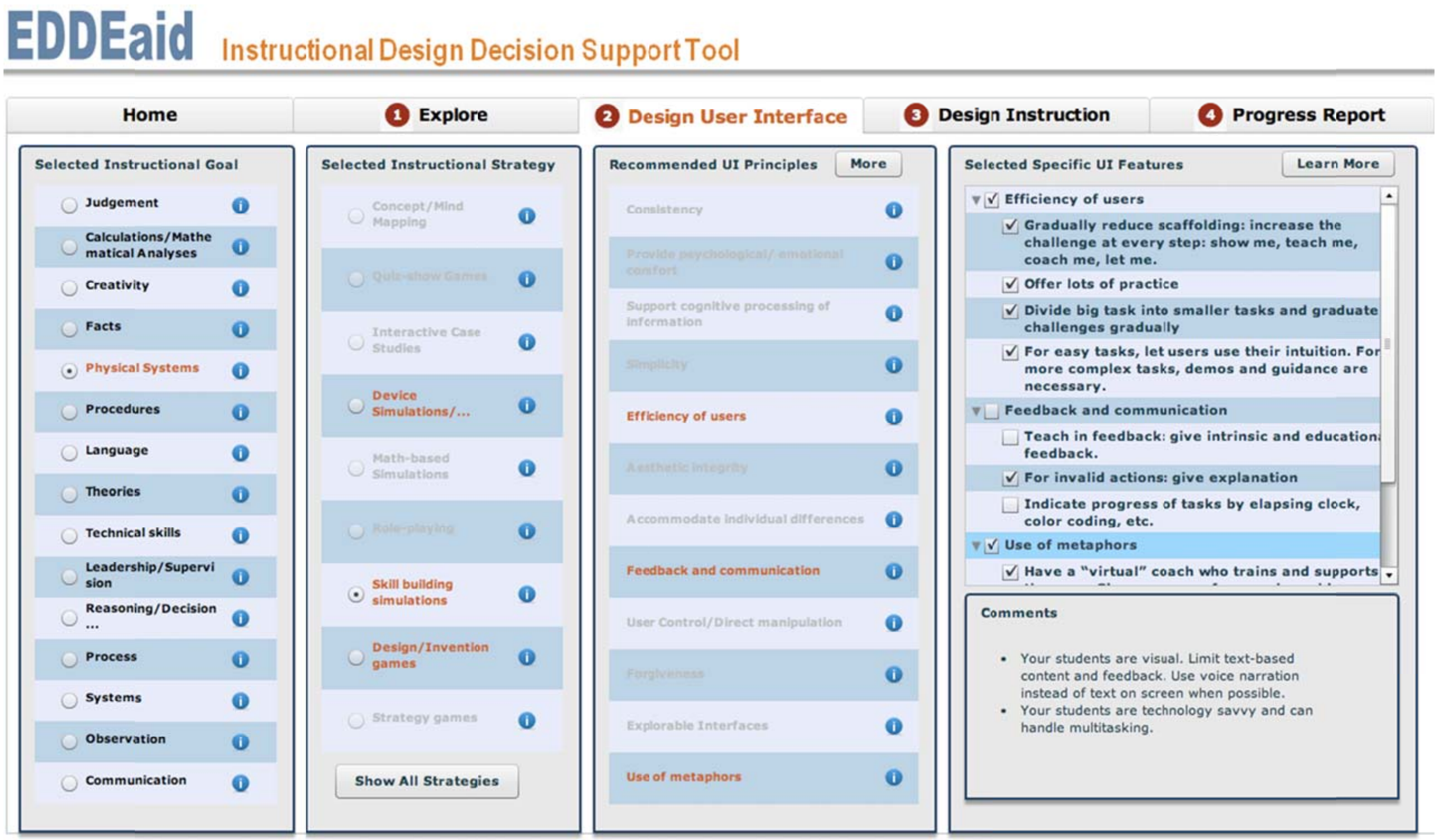

Figure 6.7 EDDEaid's interface – Design User Interface

Table 6.5 Specific user interface design guidelines for Skill building simulations

Efficiency of user
• *Gradually reduce learning support: increase the challenge at every step: "show me, teach me, coach me, let me."**
• Offer lots of practice
• Divide big task into smaller tasks and *graduate challenges gradually*
• For easy tasks, let users use their intuition. For more complex tasks, demos and guidance are necessary.
Use of metaphors
• Have a "virtual" coach who trains and supports the user. Give a name, a face, and pop him up when feedback is given. But don't be annoying.
• Interface should have moderate fidelity with the real world, but does not have to be total fidelity (simplifications are desirable to avoid distractions and focus on the skill being learned).
• Use visual metaphors for command/action buttons (that mimic/represent the physical action, such as drag and drop for locating, associating, attaching)
Feedback and communication
• *Teach in feedback: give intrinsic and educational feedback.*
• For invalid actions: give explanation
• Indicate progress of tasks by elapsing clock, color coding, etc.
<u>Extra notes relating to student background:</u>
• Your students are visual. Limit text-based content and feedback. *Use voice narration instead of text on screen when possible.*
• *Your students are technology savvy and can handle multitasking*

* *italic items* indicate features that were not implemented in original pilot design

6.6.6 Design instruction

Up to this point, the only instructional design task that has been done is the definition of the instructional goal at the beginning of the process. The next step in designing instruction is to flesh this goal out into more concrete and measureable objectives. This is where Bloom's taxonomy in Table 5.7 becomes handy in shaping these objectives. To be consistent with the pilot design in Chapter 2, instructional objectives for the hypothetical learning module are: 1) practice spatial/time reasoning, 2) identify materials, 3) comprehend construction resources, 4) practice logical reasoning, 5) recognize technology potential and limitations, and 6) develop operation skills. On the EDDEaid screen #3 (Figure 6.8), a permanent part of the interface to the left is dedicated to giving examples and providing Bloom's action verbs to make this task of defining instructional objectives easier for users. It would become a convenient reference for creating specific instructional activities for Gagne's events later on in the process.

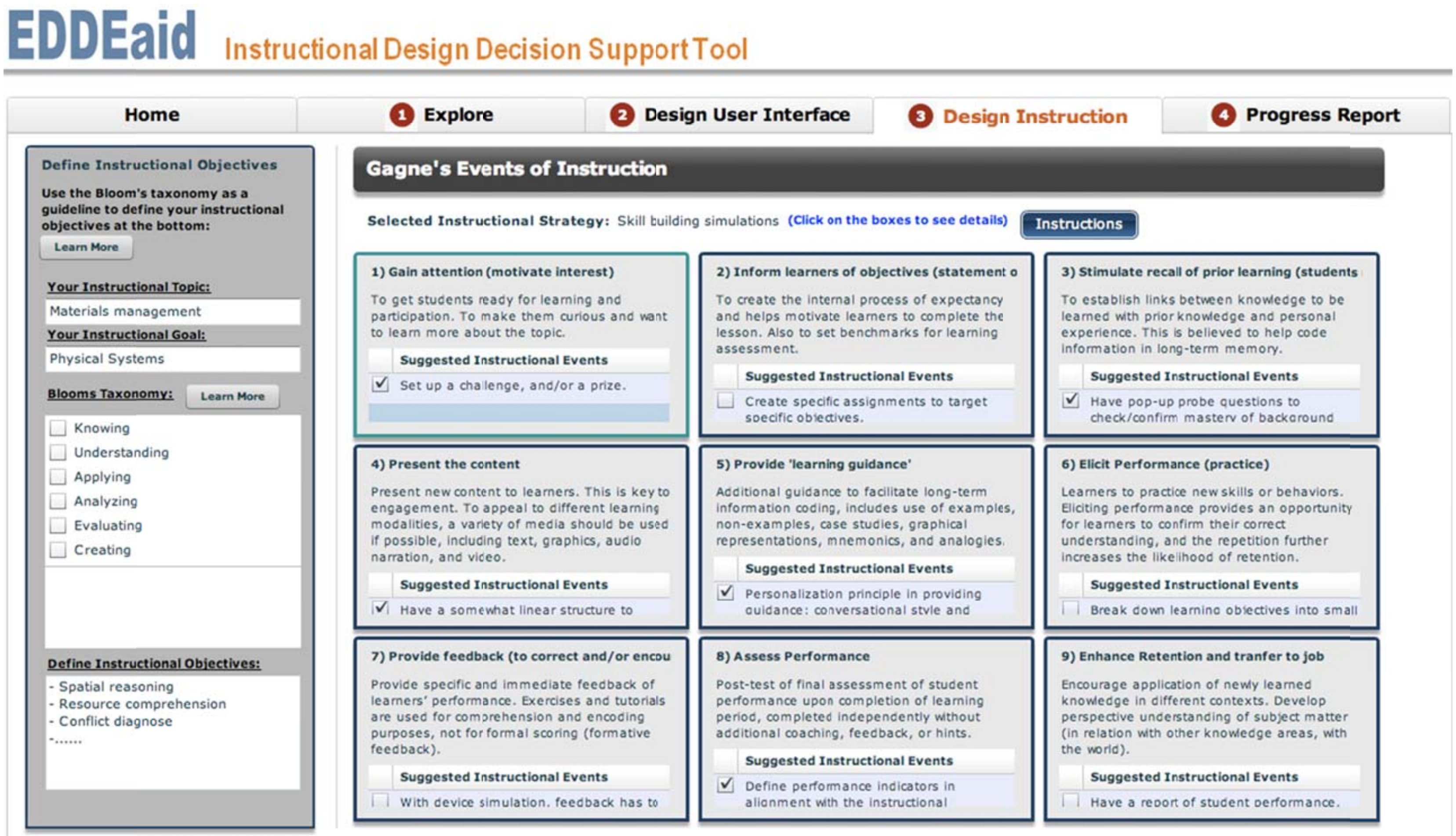

Figure 6.8 EDDEaid interface – Design Instruction

As implied by the name, "Design Instruction" is the part where users create all of the content for their learning module. It also requires the most of their effort. Similar to the user interface design features, detailed instructional events were created specifically for each of the instructional strategies in the framework. The general guidelines are provided by Gagne's Nine Events of Instruction model. For each of the strategies, detailed learning activities for the nine instructional events were created and documented in Appendix I. For the skill building simulation strategy being considered, specific recommendations for instructional events are presented in Table 6.6. Comparing this hypothetical to the actual pilot design, there are several ideas suggested by the framework that did not exist in the actual learning module. These are the points in italic in Table 6.6. Other points either already existed in the pilot design or are not very relevant to this particular learning topic.

Table 6.6 Instructional events for "Skill building simulations"

Instructional event	**Events**
Gain attention	• *Set up a challenge, and/or a prize*
Inform learners of objectives	• Create specific assignments to target specific goals
Stimulate recall of prior learning	• *Have pop-up probe questions to check/confirm mastery of background knowledge during the process, especially after an important decision*
Present the content	• Have a somewhat linear structure to content presentation to provide information gradually. • For highly visual applications that focus on operations: only display the most relevant information on the current task to be carried out. • For complex tasks: provide tools for further research (browsing, searching), or background information
Provide "learning guidance"	• *Apply the personalization principle in providing guidance: conversational style and virtual coaches, rather than text-based information* • In providing feedback and guidance, make explicit references to prior knowledge as well as potential future consequences
Elicit performance (practice)	• Break down learning goals into small assignments • Trigger thoughts: ask questions, or prompt users to self-ask questions. • Have different levels of difficulties of tasks • Offer much practice, but make it optional so that students can

	choose how much practice they do (to accommodate students with different learning curves)
Provide feedback	• With device simulation, feedback has to be prompt and accurate right after action is taken • *Provide comfort: the modality principle – add sound, narration is generally better than text. This creates a sense of conversation* • Use short quizzes, multi-choice questions as educational feedback and learning guidance.
Assess performance	• Emphasize learning, not acting: the goal is to learn the skills to be learned, not to go through the exercise in the shortest amount of time or the fewest mouse clicks. • Procedural actions can be recorded and use as one assessment criterion • *Provide comprehensive assessment at the end for reflection.*
Enhance retention and transfer to the job	• *Have a report of student performance, what they did well and what they did not do well.* • Relate/compare student performance to expert performance
<u>Student background concerns</u>	• Your students are visual learners. Avoid too much text, or using graphics, diagrams, figures to summarize text content. • Your students are more comfortable with content that is structured than too open-ended. Break content into sub-topics, have summaries, reviews, process charts to help them understand the material better.

* *italic items* indicate features that were not present in original pilot design

Because of the large amount of information presented and generated during the task of creating instructional activities, it is dedicated the majority of real estate in the EDDEaid interface for the "Design Instruction" stage the process (Figure 6.8). Each of the nine Gagne's instructional events is represented by a box that can be expanded into a big window when clicked upon (Figure 6.9). This box acts as an interactive work window where users can select from the recommended instructional activities for this particular event or jot down their own ideas in the blank box provided. If there is anything that users have to pay attention to in this event group regarding the background of the students, it will be displayed in the box "other notes" at the bottom of the screen.

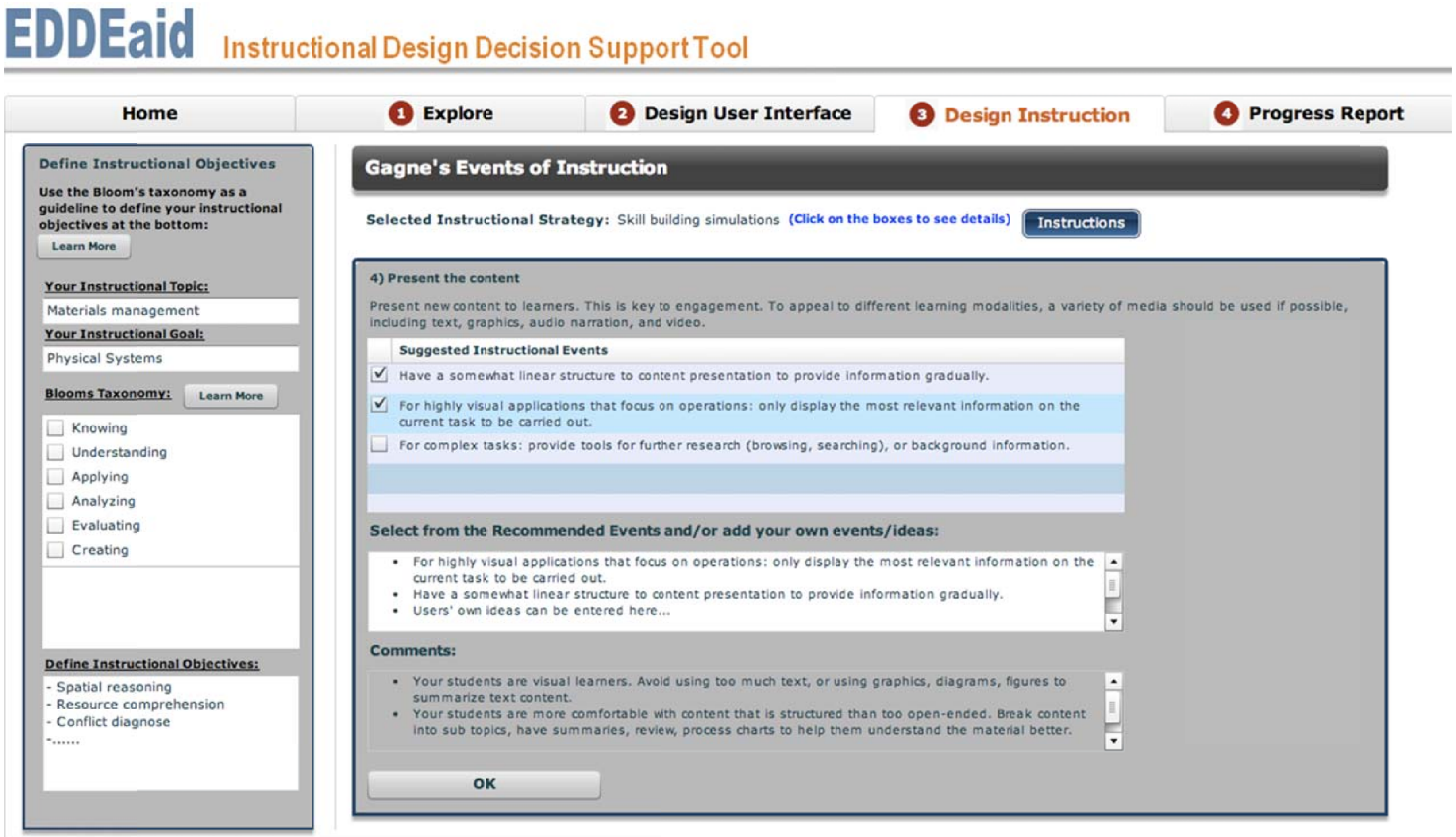

Figure 6.9 EDDEaid interface –interactive box for creating instructional activities

A user can go through the process of creating the nine events of instructions in any order, although the suggested order works well for most cases. They can always go back to a previous box and change the content as they wish. They might find that they have less content for certain boxes than others, which is normal. As long as they make a deliberate effort to go through all nine boxes, they will have a reasonably comprehensive list of potential instructional events that can be used for the learning module. Many of these events translate well into operational events for the user interface of the learning module they are designing.

6.6.7 Design summary

By applying the design framework developed, these are the take-away features for the hypothetical materials management learning module:

- Topic: materials management on virtual jobsite;
- Instructional goal: physical systems;
- Instructional objectives: 1) practice spatial/time reasoning, 2) identify materials, 3) comprehend construction resources, 4) practice logical reasoning, 5) recognize technology potential and limitations, and 6) develop operational skills;
- Instructional strategy: skill building simulation;
- User interface features: as in Table 6.5;
- Instructional activities: as in Table 6.6.

Figure 6.10 shows the summary of the hypothetical design created in EDDEaid. At the top of the page is the basic important information about the learning module, such as the topic, the type of knowledge being taught, the learning strategy chosen, etc. The default summary screen is a display of all user interface design features in the left column, and all instructional event design features in the right column, including both the program's recommendations and those that users created. The text in these two panels is editable. Users can take extra notes or print the summary table to a text file for their future reference outside of the software interface. If there are existing designs in the database other than the one they have created, users can compare theirs to one of those existing designs.

6.6.8 Product packaging and maintenance

EDDEaid was created to be a stand-alone computer application. The installation package includes an AdobeAIR installer provided by Adobe, and the EDDEaid installer. A user's guide was also created with specific and to-the-point instructions on how to use EDDEaid to accompany the software but is not included in this dissertation. This user's manual is only limited to addressing practical issues of using EDDEaid and a concise glossary of terminology used in the program. Extensive research discussions and references can only be found in this dissertation.

Besides the coding, the content and logic of EDDEaid are input to the backend of the applications in the form of html files. Should the need to update content and logic arise for EDDEaid, this can be done by updating the html files and re-feeding this to the program in the backend with minimal coding effort required. This will make it convenient to refine and expand the content of EDDEaid as the result of evaluation. Both the software and the user's manual are made available on a CD but not in this dissertation.

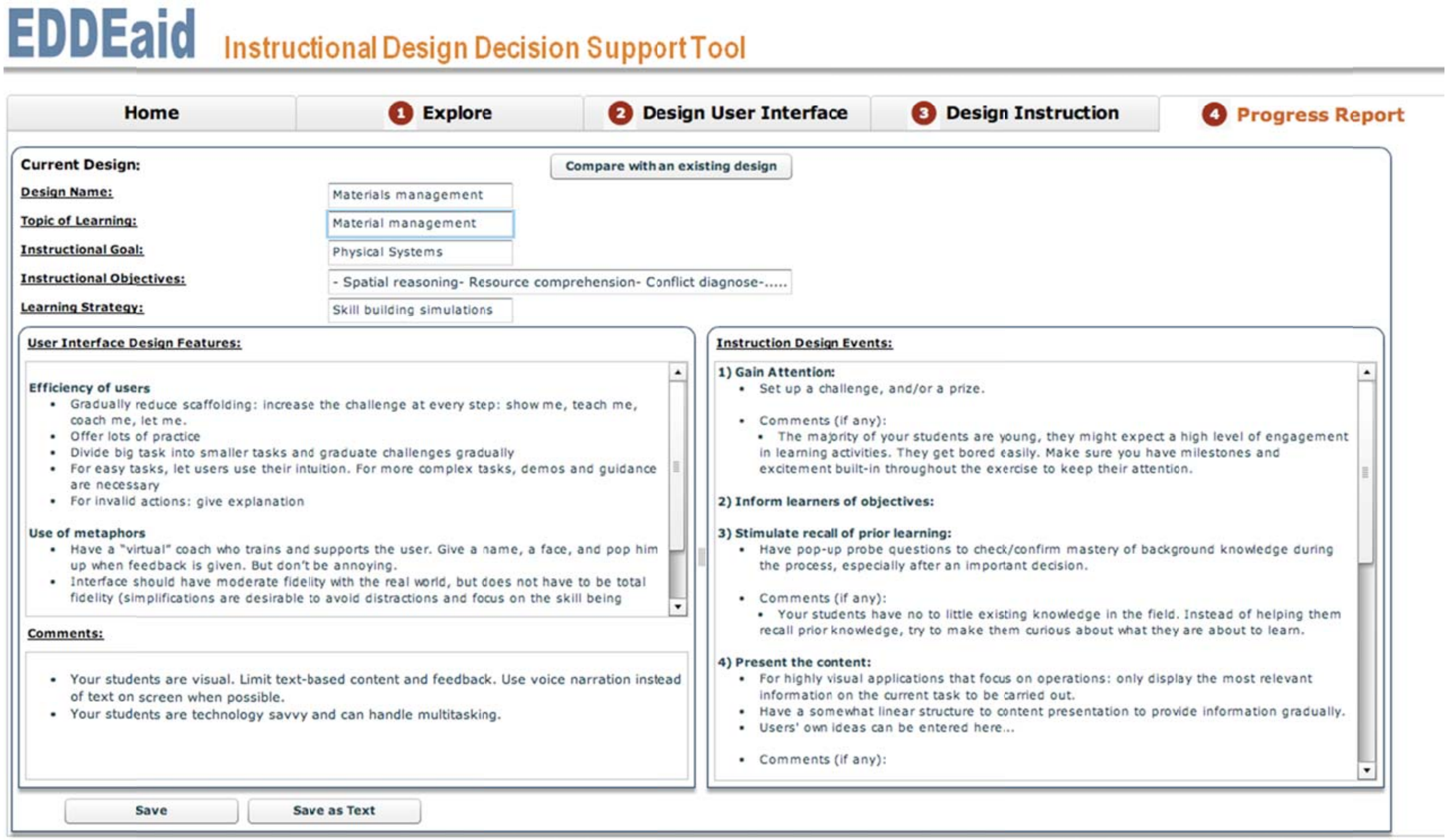

Figure 6.10 EDDEaid interface – Progress Report (Summary)

6.7 Re-evaluation of pilot design

The beginning of this research endeavor began in Chapter 2 when a pilot design was created for a materials management learning module. This module was designed without the guidance of any formal framework and was used as the exploratory study to inform the subsequent literature review and help scope the design framework to be developed. The module was tested in November, 2007.

In the walkthrough of the newly designed framework EDDE (and its tool EDDEaid), the exact same design problem as that of the pilot design was used as the input and starting point of the design process; that is, using EDDEaid to create a technology-supported tool that teaches materials management on a virtual jobsite. By using EDDEaid, a set of interface and instructional design recommendations was produced for the hypothetical tool. This set of recommendations was then used to compare against the pilot design for a re-evaluation of the learning module according to the standards set by the newly developed framework.

6.7.1 New features suggested by EDDEaid

The learning module created in 2007 was an interactive interface that allowed students to process live material data as they were detected when students walked around the virtual jobsite. The three main learning activities were: 1) to locate materials, 2) to associate materials with construction activities and 3) to validate the construction schedule based on material availability. The module was tested by eight students in the tests of two versions. The feedback was positive; however, there was room for potential improvements.

The italic points in Tables 6.4 and 6.5 are interface or instructional design features that were produced by using EDDE/EDDEaid but did not exist in the original pilot design of the materials management learning module. These new ideas were then translated into desirable features as shown in Table 6.6. Due to time and resource constraints, only the features in italic were added to the learning module. The refined version was re-tested to validate the value of the new additions.

Table 6.7 Additional features for learning module recommended by EDDE

#	Feature	Description
1	Material location information	• Identify material locations as (x,y) coordinates. Define a square/circle for tolerance.
2	Validation for schedule changes	• Give feedback as a pop-up message when an illogical change is made to the schedule
3	Give landmarks for task completion	• When all activities located or associated, display message in popup to inform learners of task completion and direct them to the next step.
4	*Make visual feedback more informative and educational*	• *Change color code for schedule bar to yellow, light green, dark green with check mark to reflect status* • *Change background color for schedule when locked/unlocked* • *Stronger visual cue to remove pins* • *Upon pin removal, simultaneously remove association and change schedule status color*
5	*Performance statistics*	• *Number of materials to be located and correctly located (x/y materials located)* • *Number of materials to be associated and correctly associated (x/y materials associated)* • *Number of activities ready to be executed with all materials: x/y activities ready* • *Time on task*
6	Confirmation message for unlocking schedule	• When button lock/unlock is clicked, display message "You are about to make changes to the schedule. Please review material availability and locations before proceeding. Pay attention to spatial conflict when changing the schedule."
7	*Hoover tooltips*	• *Display information in text boxes when mousing over certain icons (this is already there for the schedule bars)*
8	*Add user info box*	• *To save name/id*
9	*Add Help function*	• *When clicked upon, display a large popup window with brief instruction*

6.7.2 Testing of revised learning module

The testing of the newly updated materials management learning module was done in October 2010 with seven test participants. It followed the same procedures as those used in the testing of the original version in 2007. These were discussed in detail in Chapter 2. In the new testing, additional questions were added to the post-test survey to get users' specific feedback on the newly added features.

6.7.2.1 Student performance

Table 6.7 summarizes the performance of seven participants in the testing. For easy comparison, student performance from the 2007 testing is reproduced from Chapter 2. The most significant improvement noticed by the author was the much shorter time on task for all of the 2010 participants. Participants also showed a greater level of enjoyment and less frustration than those in the 2007 testing. This might be the reason all seven participants completed the task with relative ease and six out of seven made correct observations of material availability and appropriate adjustments to the schedule (only one out of three test participants in the 2007 testing was able to complete schedule validation). Overall performance for the 2010 cohort was also more consistent.

Table 6.8 Student performance in October 2010 testing

Participant #	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**
Task completion	Completed	Completed	Completed	Completed	Completed	Completed	Completed
Conflict diagnose	4/4	3/4	3/4	3/4	3/4	4/4	4/4
Representations of material availability and status	3/3	3/3	3/3	3/3	3/3	3/3	3/3
Understanding of RFID communication	2/4	2/4	4/4	4/4	4/4	4/4	2/4
True/False questions on RFID and wireless communication	8/8	7/8	8/8	8/8	8/8	7/8	6/8
Time on task	22 min	30 min	27 min	25 min	30 min	24 min	25 min
Schedule validation	*Validated*	*Not validated*	*Validated*	*Validated*	*Validated*	*Validated*	*Validated*

Table 2.4. Student performance in November 2007 testing (reproduced from Chapter 2)

Participant #	**1**	**2**	**3**
Task completion	Completed	Substantially completed	Completed
Conflict diagnose	2/4	¼	4/4
Representations of material availability and status	3/3	3/3	3/3
Understanding of RFID communication	3/4	2/4	4/4
True/False questions on RFID and wireless communication	8/8	5/8	8/8
Time on task	40 min	1 hour	25 min

6.7.2.2 Student feedback

In addition to the questions in the post-test questionnaire used in the November 2007 testing, test participants were also asked to rate the usefulness and effectiveness of nine interface features on the scale from “0” to “10” with “0” being “not useful/effective at all”, “5” being “neutral” and “10” being “very useful/effective”. The results are shown in Table 6.8. The shaded rows indicate newly added/improved features, while the rest were features present in the previous version of the learning module.

The best rated features among those surveyed were features number 1, 2 and 6, all of which were purely visual feedback and communication. The participants responded strongly (and positively) to the very visible color coding for activity status and the flow of logic when a corrective action was taken, such as the way the association icon and activity status changed when a previously found and associated material was removed. This suggested that the recommended feature number four in Table 6.6 made a noticeable impact on the way students interacted with the learning module.

Table 6.9 Student’s rating of interface features

#	Participant	#1	#2	#3	#4	#5	#6	#7
1	Color coding for pins (red for "unfound", green for "found")	10	10	8	10	10	10	7
2	Color coding for activity status (yellow, light green, dark green with check mark)	10	9	8	10	6	10	7
3	User performance statistics	NA*	7	10	NA	6	8	6
4	“Instruction” button	NA	5	10	NA	6	6	6
5	Ability to “lock/unlock” schedule	0	5	10	10	7	7	8
6	Visual feedback (schedule panel changes color when locked/unlocked, activity status changes when pins removed or disassociated)	10	10	10	10	6	8	7
7	Ability to move/remove pins on map	10	9	0	2	7	7	5
8	Hover tooltips	8	9	3	10	10	9	7
9	Ability to sort materials	NA	8	3	NA	10	8	7

*NA: participant did not use the feature. 0 = not useful at all. 10 = very useful.

Another interesting observation was the extreme differences in the way test participants rated some features; features #7 and #5 got both “10” and “0” scores from different users. Two out of seven subjects did not use features #3 and #4, but subject #3 used them and thought they were very useful. For certain tasks the interface offers more than one way to get them done, such as having both the "instructions" button and hover tooltips to explain the functions of the icons, or adding "user performance statistics" to track progress on top of the permanently visible but not easily assessable visual representation. Because of this reason, some features, though useful to those who use them, might not be relevant or even appear useless to those who do not find they need to use them. While avoiding redundancies and noise in an interface is desirable, it is also important to offer various ways to do some key tasks as learners have different preferences and tend to learn in different ways.

In conclusion, the testing of the newly improved materials management learning module demonstrated that EDDEaid could be used to create a new conceptual design of a technology-supported learning tool of decent quality. When used to evaluate an existing design, it was also capable of making sensible recommendations for improvement. This is an early validation for the potential of EDDEaid to be useful tool. More rigorous and structured testing is needed to evaluate the value of the framework at a larger scale. This will be the content of the next chapter.

6.8 Chapter summary

Chapter 6 detailed the development of the EDDE framework from organizing framework components to creating the design sequence and developing the missing connections that would make the framework actionable. It also described the development of the software tool EDDEaid and provided a complete walkthrough of the framework using the design problem used in the pilot design as an example. This walkthrough produced a set of design recommendations for the conceptual design under investigation, which included some design features that were not originally in the pilot design. Some of these suggested design features were added to the revised version of the pilot design. The testing of the revised version demonstrated that the newly developed framework was capable of producing valuable design recommendations that led to considerable improvement of a technology-supported learning tool.

CHAPTER 7: EDDEaid EVALUATION

7.1 Introduction

Chapter 6 described the development of EDDE as a framework that supports the design of technology-supported teaching tools in four areas: 1) exploring the context of the design problem to set direction for development, 2) conceptual design of the learning tool in terms of both user interface requirements and instructional activities, 3) technical development of the tool, and 4) evaluation of the tool in terms of teaching/learning effectiveness. The framework is a structured process that guides the design of such tools from the initial step of defining instructional objectives and setting up a model for the interface to the detailed creation of specific instructional events and establishing preliminary standards for interface design. This is a systematic integration of critically synthesized literature and newly developed linkages among the key aspects of design. By laying out a formalized procedure and providing relevant information for each step, EDDE helps instructors make well-informed generic design choices while being able to create instructional details for the specific topic the tool is supposed to teach. Both the synthesized literature and newly developed knowledge that go into the framework have been reviewed by domain experts in instructional design and technology design (Dr. Kathy Schmidt, Senior Research Associate, The Schreyer Institute for Teaching Excellence, The Pennsylvania State University and Dr. Randolph Bias, Director, Information eXperience Lab, University of Texas at Austin).

The design of technology-supported instruction is a complex and knowledge-intensive process. As a result, the amount of content in EDDE is quite significant, which makes the actual implementation of the framework difficult without a support tool. In addition to that, the quality of designs produced by EDDE partly depends on how much engagement and dedication the users put into to using it. The pen-and-paper approach, understandably, is not the best medium in which this kind of interaction can be effectively facilitated. This gave rise to the need for a semi-automated tool that helps instructors implement EDDE with ease. EDDEaid, therefore, was created to meet this need and make EDDE more appealing and useful to potential users.

EDDEaid is a stand-alone computer program that captures the procedure and content of EDDE in the backend of the application, while initiating and supporting user interaction in the frontend of the interface. The logic of the EDDE framework is reflected in the way EDDEaid is modularized into a sequence for users to follow. Information is spread out and only presented when needed. This reduces the memory load, makes the process easier to follow, and helps users focus their effort on the interactions that shape the final outcome of the tool. In other words, EDDEaid is EDDE in a much more user-friendly form. An evaluation of EDDEaid, therefore, is also an evaluation of the quality and usefulness of EDDE. This evaluation process will be the content of this chapter.

There are three main objectives in the evaluation of EDDEaid: 1) to validate/confirm the usefulness and efficiency of EDDEaid as an instructional design support tool, 2) to explore potential strength and long-term value of EDDEaid, and 3) to identify weaknesses of EDDEaid and ways to improve the framework/tool. The method used for validation is exploratory research in which several test participants are asked to use the tool to design a technology-supported learning tool to teach a topic of their choice. Evaluation is then made based on users' perception of EDDEaid, their satisfaction with the designs produced by the tool, their concrete evaluation of specific EDDEaid recommendations, as well as the researcher's observations of users in progress.

The next section of this chapter will discuss in a greater depth the specific research questions to be answered in this evaluation as well as a description of the research methods used to address them. A summary of findings for individual test cases is provided in Section 7.3, while Section 7.4 focuses on cross-case analyses and comparisons for broader implications. The last section is devoted to further discussions of the value of EDDEaid, its strengths and weaknesses, as well as its potential long-term impact as a research and practical tool.

7.2 Research questions and methodology

7.2.1 Research questions

The overall research objective set out at the beginning of this research endeavor is to develop a framework to aid the development of technology-supported instruction. The first part of this objective has been addressed in Chapter 6 with the creation of EDDE/EDDEaid, which detailed how existing distributed knowledge can be embedded in the design process and how missing links are created to tie things together. This chapter seeks to answer the second part of the research question: "*Is EDDE/EDDEaid helpful in facilitating better creation of technology-aided instruction?"*Specifically, the evaluation of EDDEaid will provide insight into the following aspects:

- Does EDDEaid help make the design of technology-supported instruction pedagogically solid? How?
- Does EDDEaid help users make better choices for the technology platform to be used for instruction and design good user interfaces? How?
- What are other added values of EDDEaid for the target audience?
- How can EDDEaid be improved?

7.2.2 Research methodology

The evaluation of EDDEaid is designed as exploratory research conducted via several intensive pilot tests with individual target users. Specifically, university faculty members from different construction programs in the United States with different backgrounds in instructional and technology design were invited to use EDDEaid for its intended purposes. The faculty can either use EDDEaid to do a hypothetical design for a technology-supported tool to teach a topic they are interested in or use EDDEaid to critique or improve an existing tool they already designed. Test participants will then reflect on their experience with EDDEaid and provide the researcher with their subjective assessment of the validity, effectiveness, and usability of the application. The final evaluation is a combination of structured interviews, user performance, in-depth user feedback, and researcher's observations of the testing process.

The testing procedure starts with a structured pre-test interview in which test participants are asked about their college teaching experience, their background in formal instructional design training/education, and their approach to creating instruction and addressing student's learning needs. The participants are also asked to discuss their experience in teaching with technology, the challenges in designing effective technology-supported instruction, and their interest in it. During this interview, each participant is encouraged to envision and describe an instructional topic for which they would want to build a potential technology-enhanced learning module. This topic and initial idea will be used as the design problem when they use EDDEaid later on. The pre-test interview can take between 20 and 40 minutes, depending on how much experience the participants have and how much insight they want to share. The detailed interview guide used can be found in Appendix L.

Next, the test participants are given an orientation session in which they discuss with the researcher the potential topics of instructional design that will benefit from EDDEaid. Participants are asked to form the general idea before watching a demonstration video that takes the viewers through a step-by-step process of using EDDEaid and makes them aware of the available features. This orientation process helps establish expectations and prepare them for the design task they are about to execute. Participants also spend time to explore the actual EDDEaid interface to familiarize themselves with the tool and get further explanations from the researcher until they are ready to start their design problem.

Once the test participants started their EDDEaid session, they were encouraged to go through the design task independently without the help of the researcher. While the researcher was always available throughout the session, participants were expected to carry out the task on their own and only consult the researcher for verifications, technical assistance, or real-time comments. There was no time limit to the test; the users could take as much time as they needed to make the best out of the tool. They were also clearly informed that there was no grading or ranking of their final output so that they did not feel they had to conform to some standard and produce results to be measured against some benchmark. The ultimate purpose of this testing is to evaluate the effectiveness of EDDEaid in helping them design better technology-aided instruction. Although the actual output from the design session is an indicator of the usefulness of EDDEaid to the users, the testing is essentially for users to evaluate EDDEaid for its intended purposes rather than for assessing users' instructional design capability or technical performance in using EDDEaid.

The last part of the evaluation process is a structured post-test interview. Users are asked to provide feedback on the ease of use of EDDEaid, both technically and logically, its usefulness for the intended design, and the effectiveness of different features in the program. In retrospect, the users are asked to reflect on the perceived added value of using EDDEaid to carry out the design compared to the task done without EDDEaid. For users who use EDDEaid to design new instructional tools, they can base their comparison on their general experience of creating instruction. Those who use EDDEaid to improve and critique existing designs also use these existing tools as an additional important benchmark for their assessment. Participants provide concrete evaluations on specific EDDEaid recommendations, such as whether a certain EDDEaid suggestion resonates or conflicts with their existing knowledge of instructional design or how EDDEaid helps them address the challenges encountered in such a task.

Besides the feedback on the specific tasks that they carry out, participants are also asked to reflect on the thought process facilitated by EDDEaid and how it impacts their instructional design knowledge, habits, and approach. Their thoughts and opinions on the long-term potential of EDDEaid are discussed together with their critical feedback on the limitations of the program and how it can be improved. In addition to open-ended questions, the post-test interview also has a number of Likert-scale questions to which participants give exact numerical ratings for the statements presented about EDDEaid. As a whole, this post-test reflection session provides critical in-depth assessment of EDDEaid's usefulness and impact as an instructional design support tool from the perspective of actual users.

It is important to acknowledge and address the biases that might be present in the evaluation of EDDEaid. As this is exploratory research based on user feedback and opinions, it might seem quite subjective. This subjectivity, however, should be put in context of the research problem to fully understand its impact on the validity of the evaluation. First of all, this is not first-degree subjectivity. The evaluation data are obtained from test participants as independent evaluators; tests are not done by the researcher. Second, while there is inherently some level of subjectivity in the way the testing is designed and data interpreted, this can be minimized by using structured interviews to avoid inconsistencies that tend to be caused by reflexive behavior of the researcher. Third, in order to achieve absolute scientific objectivity as defined by standard texts, it would require that every single independent variable affecting the end product has to be accurately benchmarked and consistently controlled for all test cases, including the participants' instructional and interface design experience, their background in the topic they are teaching, and the level of interest and confidence in the tool. As this expectation is not realistic, being able to establish a purely objective measure is unlikely. The best alternative is to make sure that test participants' assessments of EDDEaid are relatively objective by providing enough context, imposing structure to the tests, and encouraging them to be perceptive and critical.

7.3 Findings

7.3.1 Test participants' background

The evaluation testing was conducted with nine faculty members in eight different schools. Two of the testing sessions were conducted in person. The other seven were conducted via the telephone. In all cases, the testing sequence and interview questions were exactly the same. The time on tasks for most tests was 1.5 to 2 hours, including the interviews, the orientation process, and time interacting with EDDEaid. Technical problems occurred for two cases in which extra time had to be spent on fixing the issues. However this was purely technical (software incompatibility with operating system) and did not have any significant impact on the outcome of the test. A summary of all participants' background is shown in Figure 7.1. Detailed information for each test case can be found in the individual summaries in Appendix K. This section will be focused on the background of the test participants, while Section 7.3.3 will summarize the output of the actual testing and post-test interviews.

Table 7.1 Background of test participants

Number of test participants: 9
Title: 1 professor, 8 assistant professors
Domain: construction engineering and management (CEM), building construction
Teaching experience: 1 starting, the rest 1-17 years of college teaching

The amount of formal training or education in instructional design these participants had was either nothing or limited to the basic orientation sessions that schools held for new teaching assistants and faculty. Participant #1 was the only exception in this regard with a solid background in instructional design education of a formal two-year teaching certification program, another 6-month teacher education program, and a dozen 2-day workshops on teaching effectiveness. All participants stated that they either had used some type of technology-assisted teaching, mostly simulations, in their classes at some level. The simplest forms include a quiz-like game on PowerPoint or a calculation-based simulation in Excel. Some used Monte Carlo or commercial applications to teach their topics. In the most advanced case, participant #5 designed a construction safety game to help students recognize hazards on job sites. All participants expressed the interest in employing more technology to enhance their teaching and confirmed students' positive response to technology-aided learning. They also raised some concerns about teaching with technology, including the learning curve involved in learning to use an application, the emphasis on playing rather than learning, or the research rather than learning orientation in some existing tools.

As a whole, this group of faculty represents the biggest target audience of EDDEaid: instructors with typical (limited) background in instructional and interface design who are interested in exploring ways to incorporate technology in their teaching. The more senior faculty in the group help investigate the value and performance of EDDEaid among the more experienced instructional designers. While there is nothing in EDDEaid that limits its suitability to instructors of any background, its structure and comprehensiveness is expected to prove particularly useful to those who have the most challenges in both generating the content and ensuring its pedagogical effectiveness at the same time. The test results will also reveal how useful EDDEaid is in helping instructors address major user interface issues when designing technology-supported instruction.

7.3.2 Summaries of test cases

Figure 7.1 is the summary of pre- and post-test interviews for a test user (interview summaries for all other cases can be found in Appendix L). The information has been edited only for clarity; no other modifications or manipulations were made. The background part captures the essence of the pre-test interview; all of which has been described in Section 7.3.1. The next part is a brief description of technology-supported learning tool(s) designed by that participant using EDDEaid (details of these conceptual designs are provided in Appendix M). The last part, which is also the most important, is the user's critical evaluation of EDDEaid obtained from the post-test interview. The overall assessment of EDDEaid reflects the degree to which test participants agreed with positive statements about EDDEaid (details in Section 7.3.3). Further discussions of these evaluations will be included in the next sections.

7.3.3 Overall assessment of EDDEaid

In addition to open-ended questions that allowed participants to provide feedback on various important aspects of EDDEaid, the post-test interview also included a list of positive statements about the qualities of EDDEaid for which participants were asked to give a response. The response is a 5-point Likert-scale rating that indicates the level to which they agreed with the statement being made, with "1" being "strongly disagree" and "5" being "strongly agree". The numbers in the last column of Table 7.2 are the average ratings for individual qualities of EDDEaid, and those in the last row are the average ratings of EDDEaid across different dimensions by each participant. These are also the numbers at the end of summaries in the previous section. It can be seen that participants were very appreciative of the fact that EDDEaid made the design process of technology-supported learning tools systematic, solid, and efficient, and that it provided important insights into the process of designing instruction and user interface that they had not been aware of before. In all other aspects, EDDEaid also earned high ratings, which proved that users were satisfied with and positive about the value EDDEaid added to their general knowledge as well as their specific task. More implications of these assessments will be discussed further in Section 7.4.

BACKGROUND

- *Position/title*: Assistant professor, Construction
- *Teaching experience*: 2 years as faculty, 4 years as teaching assistant
- *# of courses designed*: 3
- *Formal instructional design training/education*: Basics through TA and faculty orientation.
- *Approach to instructional design*: Depending on the class. Adopt some curriculum standards to meet requirements.
- *Challenges/most important aspects in instruction design*: 1) Most construction students are visual, how to teach them best. 2) The flow of instructional sequence is very important.
- *Student background data collected*: Experience in construction, special learning needs, baseline knowledge.
- *Experience in teaching with technology/simulated learning*: As a TA: simulations. As a faculty: developed a construction safety game to recognize hazards on job sites.
- *Pro/con or challenges of technology-supported learning*: How to make it a learning instead of playing tool. The ultimate goal is learning, not winning.

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Evaluate an existing technology-supported teaching tool.
- *Instructional topic*: Simulation of construction equipment site operations
- *Instructional Goal/Type of knowledge being taught*: Procedures
- *Instructional objective(s)*: 1) Recognize different tools for creating models of construction equipment operations. 2) Recognize when each tool can be used depending on the specific job site
- *Technology-supported instructional strategy*: Skill building simulations

EVALUATION OF EDDEaid

- *New concepts/insights*: A lot of instructional design knowledge and insights that I might not have thought of before.
- *Perceived value of EDDEaid*: 1) Provides an efficient checklist of things I might not have thought of, but when I see them, I know I need them. 2) Helps review and enhance my design. 3) Helps me address some of the challenges in instructional and game design that I ran into before. 4) I can compare EDDEaid insights with my own observations and student feedback. 5) If I had not previously designed the game, I would probably have taken everything from EDDEaid.
- *Ease of use*: Very easy to use
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable
- *Comments/recommendations*:1) 1st time users might be unclear about what instructional goal to choose in step 1. 2) List of 7 or more items are hard to remember and compare.
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 4.3/5.0

Figure 7.1 Sample summary of user interviews

Table 7.2 Specific assessments of EDDEaid

	Statement/Quality	P1	P2	P3	P4	P5	P6	P7	P8	P9	Avr
1	The classification of instructional goals is valuable and helps you define better learning goals.	5	5	4	4	4	5	3	4	5	**4.3**
2	The classification of instructional strategies (game/simulation types) is useful and helps you make better decisions.	5	4	5	4	4	4	4	4	4	**4.2**
3	The notes/comments about the potential impact of student background on the choice of instructional goals, instructional strategies and instructional events are useful.	4	5	3	3	5	5	4	5	4	**4.2**
4	The user interface design principles provide a good overall picture of how interaction features can be used to support learning.	5	5	4	4	4	3	3	3	3	**3.8**
5	The use of Gagne's Nine Events of Instruction model ensures that the conceptual design created is pedagogically sound.	4	4	5	4	4	4	4	5	4	**4.2**
6	The way information is spreadout and presented to users only when needed (through mouse-overs, information icons, pop-up windows, notes boxes) reduces the memory load and helps me process information better.	5	5	4	4	5	3	3	4	4	**4.1**
7	I get important insights about instructional design and interface design with EDDEaid that I have not been aware of before.	4	5	5	5	4	5	4	5	4	**4.6**
8	Compared to the unguided design experience, EDDEaid helped you create a better and more solid learning module.	5	5	4	4	4	4	4	5	4	**4.3**
9	EDDEaid provides a framework that consolidates the literature in instructional design and user interface design to make the design process of technology-supported learning tools systematic, solid and efficient.	5	5	4	5	5	5	4	5	3	**4.6**
	Average	**4.7**	**4.8**	**4.2**	**4.1**	**4.2**	**4.3**	**3.8**	**4.7**	**3.9**	**4.2**

1 – Strongly disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly agree

7.4 Discussion

Section 7.3 summarized the results from the nine test cases and highlighted a number of important overall observations. In this section, the obtained data will be analyzed in depth to provide answers to the research questions defined at the beginning of the evaluation process.

7.4.1 Question 1

Does EDDEaid help make the design of technology-supported instruction pedagogically solid? How?

Given the test participants' limited background in instructional design, it was expected that most of the knowledge in instructional model and design procedure was new to them, as reflected in the feedback. In particular, none of them had heard of Gagne's Nine Events of Instruction model before EDDEaid, and they all agreed that using this model as the backbone of the design process ensures that the instructional tool created is pedagogically sound (earning a score of 4.2 for #5 in Table 7.2). They also highly appreciated the new insights about teaching and instruction EDDEaid provided (reflected in the 4.6 score given for #7). Participants believed that designs produced using the framework would likely to be more solid than an unguided design (score of 4.3 for #8). As participant #1 put it, "EDDEaid helps you formalize and verbalize your thinking in planning and creating instruction, starting with learning objectives then content building then syllabus development, instead of the other way round (which most of us faculty tend to do.)" Participant #7 in particular found that Gagne's model was very helpful in creating better lesson plans, especially in incorporating assessment in instruction.

The structured process that EDDEaid affords also triggers instructors to reflect on the way they create instruction. [It] "makes you think about the whole process at different levels from broad to specific makes, things you might not be thinking about otherwise" (participant #3). With EDDEaid's classification of instructional goals and strategies, this "broad to specific" (participant #3) process is easy to maneuver, as indicated by users' appreciation reflected in the evaluation (4.5 for #1 and 4.3 for #2). The instructors also become more aware of the difference between the way they teach and the way students learn. "I get to put myself in the shoes of students and think along the line of how they learn" (participant #3). In addition to these big picture values, EDDEaid also "provides a lot of ideas on how to teach better, how to motivate students to learn, such as having a competition or an award" (participant #4). Participant #5 pointed out that one of the challenges of designing technology-supported instruction is to make sure the emphasis is on learning, not playing, and EDDEaid helped address this. All this user feedback suggests that EDDEaid helps create technology-assisted instruction that is pedagogically solid through both a structure that is based on a formal instructional model and the specific ideas and recommendations it provides.

Table 7.3 provides a list of concrete feedback from the test participants on how specifically EDDEaid helped them create better designs by pointing out at certain recommendations (taken from their EDDEaid design output) and explaining how they triggered their thinking, how they resonated with their own understanding of the design task, how they made them reflect on what they were doing, and how they challenged them to innovate. These are ideas that were considered most valuable by the participants and are top priorities for implementation, among other ideas that they selected from EDDEaid. These are just a subset of all the design features they produced from using EDDEaid to design their conceptual tool. All points on the list except for those in italic are ideas that participants were most excited about – their takeaway lessons from the EDDEaid session. The ideas in **bold** are things they had never thought about and found interesting and useful. Table 7.3 includes the feedback of seven out of nine test participants. Participants #2 and #6 were unavailable for further follow-up.

Table 7.3 Concrete recommendations from EDDEaid best rated by participants

Participant #1 – Design 1: 4D Building Information Models (Goal: Procedures. Strategy: Skill building simulations) • **Add sound/audio feedback in form of "virtual coach"** • Provide intrinsic and educational feedback • Breaking content into modules, specific assignments to target specific goals • Emphasize learning, not acting.
Participant #1 – Design 2: BIM Case Studies (Goal: Facts. Strategy: Interactive case studies) • **Reward student achievement** • **Virtual field trip as a demo/expectation setting tool.** • **Use classic/historic events to motivate and trigger thinking** • Provide interactive feedback and discussions
Participant #3: Estimating (Goal: Calculations/mathematical analyses. Strategy: Math-based simulations) • **Use short quizzes as educational feedback and learning guidance** • **Emphasize simplicity for the interface** • Ways to gain attention

***Bold**: things never thought of before

Table 7.3 continued

Participant #4: Earthwork (Goal: Reasoning/decision making. Strategy: Role-playing) • **Dramatize on the method of creating challenges for roles (a press conference, an alert, a newspaper headline, etc.)** • **Use a current event or an interesting demo video to gain attention and trigger thoughts** Pay attention to student diversity and match roles to skills
Participant #5: Safety (Goal: Judgment. Strategy: Role-playing) • **Present the situation as a conflict, a crisis, a controversy, a dilemma, a comedy.** • Align each major stimulus with a learning objective • Students are visual: avoid using too much text, using graphics to summarize content (especially with construction students). • Students are more comfortable with structured content rather than open-ended. • Give in-depth feedback of actions and consequences. Provide opportunities to take corrective actions. • EDDEaid helps address challenge: emphasize learning, not playing in games.
Participant #7: Request for Information cycle (Goal: Procedures. Strategy: Skill building simulations) • **Gagne's model helps design lesson plan better, especially how to incorporate assessment in instruction.** • Have a somewhat linear structure to deliver content gradually. • EDDEaid's recommendation for instructional strategy confirmed own choice • Emphasize retention and transfer to job: relate to real world practice, detailed performance report to students. • Bloom's taxonomy helps address challenge in terms of what level of depth to teach
Participant #8: Decision and risk analysis (Goal: Reasoning/decision making. Strategy: Interactive case studies) • **Gagne's model: interesting and useful** • Help rethink student background and skills: how to make learning effective for a diverse student audience
Participant #9: Risk management (Goal: Theories. Strategy: Interactive case studies) • **Enabling feedback affordable only through technology** • EDDEaid suggests several ways to communicate with students and makes instructors may more attention to how people learn • EDDEaid opens up options when you start designing courses • Learn more about the design task as the moment right now is confined with what data are available now.

***Bold**: things never thought of before

It can be seen that many of the recommendations participants found valuable emphasized the importance of a good pedagogical design. The participants' feedback confirmed the importance of addressing student background and skills in designing instruction. Participant #4 commented on the importance of accommodating student diversity when using role-playing as a strategy: "Sometimes this is an ignored issue, but it will dismantle the whole learning design. Putting students in an appropriate role is important to make the learning smooth and without interruptions. A bad choice can create snowball effectives, and eventually all students lose interest." Participant #5 found the recommendation to use more graphics than text and to organize content in a structured manner particularly appropriate when designing a construction safety game for the construction students given their background and learning preferences. Participants #8 and #9 both had very diverse students audience (one with mature students of 1-25 years of work experience, the other with students from various cultural and educational backgrounds), and they both agreed that EDDEaid helps them think more deeply about how students learn and suggests effective ways to communicate with them.

Another matter of common interests found among the participants was the ability to gain attention and motivate student interests. Participant #1 was particularly excited about the suggestion to use a virtual field trip as a demo for a case studies class where students were to conduct individual case studies on topics of the same themes. Several participants embraced the idea of using current events to engage students or employing dramatic introductions to a subject with challenges or controversies, especially when role-playing was used as the learning strategy (participants #1, #4, #5). Participant #1 also pointed out that rewarding students with prizes or other forms of recognition is a great way to encourage and engage students in the learning process.

Many participants pointed out how EDDEaid regularly reminded them of the importance of giving feedback and providing learning guidance to the learners. As suggested by EDDEaid, participant #1 planned to give immediate verbal feedback to students performing skill building tasks instead of only providing written feedback as previously planned. This participant also planned to include more in-class discussions for the interactive case studies class. Participant #5 echoed EDDEaid's recommendation to give in-depth feedback of actions and consequences when implementing role-playing.

In the pre-test interviews, a few participants mentioned the challenges of using technology to teach domain knowledge. According to these participants, EDDEaid could help address some of these challenges. Participants #1 and #5 observed that the consistent implementation of Gagne's model ensured the focus of technology-supported instruction was on learning, not acting or playing, especially when a game was employed as the learning strategy. Participant #9 found EDDEaid to have many ideas for instructors to communicate learning content to learners of different backgrounds effectively, an issue of major concern for this participant because of the diverse student body this instructor had to teach. To participant #7, one of the biggest challenges in instructional design was to determine what level of depth the knowledge should be taught at for a specific student audience, and the participant believed that the classification of instructional goals and implementation of Bloom's taxonomy would help instructors do this task better.

7.4.2 Question 2

Does EDDEaid help users make better choices for the technology platform to be used for instruction and design good user interfaces? How?

One of the first, and arguably the most significant, decisions users have to make in EDDEaid is to choose an instructional strategy, or a type of simulation-based application, to be the model for their technology-supported learning tool. According to participant #3, EDDEaid "provides a more complete and structured view of the instructional strategies in the form of simulation/game-based applications." To accommodate the subjective and fluid manner in which an instructor defines the instructional goal, EDDEaid does not impose rigid instructional strategy recommendations on users. Instead, they are free to deviate from the suggested strategies and explore to choose one that best suits their need. This flexibility seems to resonate well with the users as it helps them see the possibilities of each option. "EDDEaid is comprehensive and diverse: choosing a different strategy or goal takes you down a very different path." In particular, participant #3 found the mapping between these strategies and major user interface design guidelines "a new and good" idea. According to participant #9, EDDEaid "opens up options when you start to design the course", while participant #7 commented on how EDDEaid suggested skill building simulations as the strategy suitable for the topic being taught, which was “exactly what I thought.”

According to the test participants, the user interface design guidelines introduced in EDDEaid to a large extent were considered valuable in terms of providing a good overall picture of how interaction features can be used to support learning, earning a 3.8 score for the overall assessment from Table 7.2, a slightly lower level of confirmation from the participants compared to the pedagogical value EDDEaid offers. The tool, however, proved to be providing useful recommendations in specific instances. Participant #3 found that “simplicity” was a very good guideline for designing a math-based simulation so that the most important analysis task could be at the center throughout the exercise and students would not forget what they were doing analysis, not calculations. Another value of these guidelines is that they make users aware of the importance of doing it right, both in terms of preventing problems and making the best out of the technology being used for teaching; as participant #4 described it: “[EEDEaid] informs users of potential problems, traps or issues that might lie ahead.” Many of these might not be obvious to a person of limited background in interface design. Because of this, EDDEaid also serves as “an efficient checklist of things I might not have thought of, but when I see them, I know I need them” (participant #4). It is evident from the positive feedback that the test participants enjoyed exploring instructional strategies and were comfortable with taking EDDEaid’s suggestions for user interface design as the starting point for the design of their technology-supported learning tools.

7.4.3 Question 3

What are other added values of EDDEaid for the target audience?

The in-depth interview sessions with test participants yielded insightful feedback on what value EDDEaid had for each of the test cases involved. While each participant might have had different specific observations and assessments of the tool, there were some themes that could be recognized from the feedback. Table 7.4 provides a concise summary of the test participants’ evaluation of the value EDDEaid contributes to their own knowledge in instructional design. The biggest consensus was to consider EDDEaid an effective tool that helped formalize the complex process of instructional design. This was made possible first of all by the way EDDEaid enforces a structure to the process that helps prevent design errors. The framework was also able to trigger thinking and visualizing the big picture of instructional design from the broad starting point to the specific instructional creation. EDDEaid was proved to facilitate critical thinking and reflections through which instructors became more aware of their role and perspective in the learning process of students.

Table 7.4 The value of EDDEaid to target audience

Value added	**Confirmation from user feedback**
Help formalize instructional design process	Enforce structure and process, help prevent design errors • Help formalize and verbalize thinking and instruction planning and creation • Help design better lesson plans and assessment • Provide complete and structured view of instructional strategies in form of simulation/game-based applications • Inform users of potential problems/traps/issues that might lie ahead • Provide guidelines for user interface design Facilitate thinking • Thought provoking and systematic: makes you think about the whole process at different levels from broad to specific • Provide an efficient checklist of important and useful ideas, things you might not think of otherwise Trigger reflections and critical assessment of instruction • Help understand learning from student's perspective • Make aware of difference between instructor and student perspective • Help review and enhance existing design by comparing EDDEaid insights with my own observations and student feedback.
EDDEaid: A good practical tool	Informative and educational • Rich information, lots of ideas on how to teach better • Information buttons • Most content new (and important) to most users Comprehensive and diverse • Covers a wide range of instructional goals and strategies • Multiple paths to explore Flexible • Allows users to add own ideas • Allows users to explore different paths before deciding • Can be used at different points in the iterative design process Versatile/generic: • Applicable to different domains • Wide range of instructional goals, not just limited to calculations and technical areas

Another important consensus resulting from the evaluation was the recognition of EDDEaid as an effective and practical tool that is both flexible and educational. All of the participants found the tool comprehensive and generally easy to use (Table 7.5). Four out of six thought the amount of knowledge in EDDEaid was reasonable, and the other two found it a little bit overwhelming. Most of the knowledge was new to the users, especially in the instructional design area. As a design support tool, EDDEaid was flexible in the way it allows users to explore multiple options before proceeding and add their own thoughts to customize the design. Despite the fact that the examples provided in EDDEaid are mostly construction-related and the participants are all in the construction domain themselves, they realized the generic scope of the tool and commented on the applicability of EDDEaid in other domains.

Table 7.5 Overall assessment of EDDEaid

	Ease of use	**Amount of info/knowledge**	**User's effort**	**Flexibility**
P1	Very easy	Comprehensive & reasonable	Reasonable	Reasonable
P2	Easy	Comprehensive, a bit overwhelming	Reasonable	Reasonable
P3	Average	Comprehensive & reasonable	Reasonable	Reasonable
P4	Very easy	Comprehensive & reasonable	Reasonable	A little structured
P5	Very easy	Comprehensive & reasonable	Reasonable	Reasonable
P6	Average	Comprehensive, a bit overwhelming	Reasonable	Reasonable
P7	Easy	Comprehensive & reasonable	Reasonable	Reasonable
P8	Easy	Comprehensive & reasonable	Reasonable	A little structured
P9	Very easy	Comprehensive & reasonable	Reasonable	Reasonable

7.4.4 Question 4

How can EDDEaid be improved?

Table 7.6 summarizes the feedback made by the test participant to address the limitations they observed in EDDEaid and suggest ways to improve the software. The feedback is divided into three main categories: content and logic, interface, and usability. The last part is dedicated to a major recommendation to expand EDDEaid into a knowledge building and sharing tool.

Table 7.6 Suggestions to improve EDDEaid by test participants

Feedback/suggestions	**Notes on how to address**
<u>Content/logic/structure</u>	
• For student data, use headcounts instead of percentage	• Might not adopt. Calculating percentage is an easy task.
• Values of fields under student background do not automatically add up to 100%, users have to make sure they have it all correct.	• Already considered. This would pose more severe problems.
• 1st time users might be unclear about what instructional goal to choose in step 1	• Instructions already exist. To be made more specific
• More examples, more information buttons	• Addressed: use a handout outside of interface
• Include case studies and success stories of EDDEaid uses	• To be considered for future research
• Add ability to choose strategy based on class size	• To be considered for future research
• Add ability to align instructional events with certain accreditation requirements	• Out of scope
• Visualize idea progressions: real-time achievement of learning goal/objectives	• To be considered for future research
• Provide guidelines on how to communicate these features with the design team (software designers).	• To be considered for future research
• Add a diagram visualizing relationships among the terms/concepts in EDDEaid	• Addressed.
<u>Interface</u>	
• First time users should have local access to instructions and reference materials so that they don't have to go back and forth. Or add a button on every screen for reference materials.	• Addressed: a user's manual created. Future refinement: add a "Help" or "Q&A" button to all screens to address users' specific questions
• Screen #3 is a little bit overwhelming, should be broken into two screens	• To be considered for future research/development
• After users minimize an event box on screen #3, there should be some visual feedback in the way it looks to tell users "I got what you wrote".	• To be considered for future research
• Add direct link to survey on Home screen.	• Might not be needed. Currently survey is in references.
<u>Usability</u>	
• Installation procedure: package Adobe AIR with EDDEaid into one file for easier installation.	• Future research/development
• Display problems for some Windows 7 users	• To be investigated
• List of 7 or more items are hard to remember and compare.	• Might not address. Lists must be comprehensive.
<u>EDDEaid as a knowledge building and sharing tool</u> Build this into an Instructional Design Information Management System. • EDDEaid as a centralized place for collecting and synthesizing ideas. • Might organize designs by topic, keywords and make them searchable. • As a new user works with a design, they can see what others have done before.	Future research/development

In terms of content and logic, some of the comments were about additional automatic functions of EDDEaid to calculate the input for students' background information. While these are legitimate suggestions, they require a significant amount of extra coding and additional precious real estate to do tasks that are too basic and can be done by the users with minimal effort. In some cases the logic had already been there originally but was then taken out because it created a worse logic problem. On the other hand, some other suggestions can be simply addressed by providing supplemental material without making significant changes to the interface.

There are two major comments that fall under the Interface category. One participant suggested having a button for the reference materials on all screens so that users do not have to go back and forth when they need to refer to some literature or instructions, or providing users a local access to those materials in one document. To address this comment, the author created a complete user's manual document that is to be packaged with the EDDEaid software itself as a finished product. The same user questioned the validity of the information in EDDEaid because of the lack of direct references for every recommendation/feature given. For clarity, all references were taken out of the interactive screens of EDDEaid. With the existence of a more elaborate user's manual, these references can now be reintroduced back into the EDDEaid package for completeness. A "Help" or "Q&A" button can also be added to all screens to answer most common questions that users might have. Some other issues that were found to be unique to a single case and did not create any significant problems were not addressed immediately but put under consideration for future research and development of EDDEaid.

The only technical usability problem that was found during the testing was a display error on some (not all) machines with a Windows 7 operating system. This problem is being investigated further so that the bug can be fixed in the future development of EDDEaid. Another usability comment concerns the packaging of the whole EDDEaid software, running environment, and documentation as a single installation package. While this is a reasonable suggestion, it was not taken and addressed as of now because of its limited added value compared to other content and interface modifications given the resource constraints of the research team.

The most significant suggestion for improving EDDEaid, or rather for expanding EDDEaid and taking it to the next level comes from participant #4. This suggested idea was to develop a more sophisticated interface for EDDEaid so that it can be used as a knowledge building and sharing tool. If EDDEaid allows user inputs to be stored, organized, and searched within the interface with minimal effort, EDDEaid's pools of ideas will quickly multiply and bring enormous benefits to its users. This piece of feedback reinforces the researcher's vision of EDDEaid as a continuous knowledge creation portal. While the implementation of this idea is beyond the scope of this dissertation, it certainly is an important consideration for potential future research and development.

7.4.5 Other observations

Among the instructors who used EDDE for the testing, there was a consensus about EDDEaid's helpfulness in facilitating the creation of effective technology-supported instruction. The framework was, however, not useful in the same way for all instructors. It was observed that some appreciated the richness and diversity of the tool more than anything else. Others found its depth to be the most attractive quality. Understandably, those with more extensive background in instructional and technology design and those who were more devoted to the design exercise tend to see the qualities that were not the most obvious, such as the importance of defining good instructional objectives or the subtlety of the comments that tie design recommendations to students' background.

It was evident from the feedback that most participants were enthusiastic about the prospect of EDDEaid. Participant #5, who already designed a game to teach construction safety, commented: "*If I had not previously designed the game, I would probably have taken everything from EDDEaid*." All of them were willing to use EDDEaid again in the future and recommend it to other colleagues (except participant #6 who was positive but neutral and would be completely convinced if success stories exist). As EDDEaid is an interactive tool, the products it produces are only as good as the combined quality of what EDDEaid has to offer and how much effort the users put into it. Because of this nature, it is important that EDDEaid get users excited and therefore become engage in the process. Most of the current limitations of EDDEaid could be eliminated if extra orientation or guiding support was provided. A user's manual to address common specific questions first time users might have will effectively increase the visibility of EDDEaid qualities and features. As this is envisioned to be a tool of multiple uses, most of these problems might essentially disappear by the second or third try.

It was observed from the testing that the level of participant engagement in the process influenced the robustness and comprehensiveness of the design output. Participants #1, #3, #5 and#6 were the most thorough users: they spent lots of time exploring more features, reading instructions and following examples. As a result, the designs they produced were richer in details and more customized to their own topics. For example, participants #1 and #6 defined the most elaborated instructional objectives of all, and made an effort to generate more ideas beyond what was suggested by EDDEaid. Although participant #6 was slightly more critical of EDDEaid than other participants, the effort this participant put into using EDDEaid resulted in a deep understanding of the tool, what it does and how to improve it.

In usability testing, the concern over the impact the researcher might have on a subject (test participant) cannot be ignored. Just because subjects know the researcher is present in the room while they are doing the test, their behavior might change. In the four cases that were conducted via Skype, this impact might be somewhat less significant as at least the tester was not physically in the room with the subjects and hence appeared less interfering. To reduce this impact for all test settings, however, the author was systematic and consistent in informing users of the context and expectations. The fact that time was not a constraint, their deliverable would not be graded, and it was them who was with the authority to do the evaluation instead of the author assessing their work should have made the participants more comfortable to go through the process without feeling pressured.

7.5 Conclusions

To evaluate the usefulness and effectiveness of EDDEaid as a design support tool for technology-supported instruction, tests were conducted with six participants who were university academics in different construction schools. The evaluation was then derived from the users' assessment and opinion of EDDEaid. While this exploratory research method inherently had some subjectivity bias, it was nevertheless a legitimate way to produce reasonable validation of the tool's value under the circumstances. All testing followed a structured format with well-documented materials.

In general, the users' feedback confirmed that EDDEaid was effective and valuable as a technology-supported instructional design support tool thanks to its systematic and structured process as well as comprehensive and flexible content. It helped produce pedagogically solid instruction by formalizing the process based on instructional design theories. The users were also positive about EDDEaid's ability to help make better choices of simulation-based instructional strategies and shapes good initial user interfaces for the learning tool. Users' evaluation of EDDEaid recognized its significance as a new framework that formalizes and structures an otherwise complex and error-prone process and the software itself as a comprehensive, flexible, educational and versatile tool that has the potential to serve as a knowledge building and sharing portal for instructors across domains. In addition, users of EDDEaid found it helpful in both guiding the design of new learning tools as well as facilitating critical assessment of existing tools. The test participants provided several suggestions for short-term refinement of EDDEaid as well as its long-term development. Some suggestions have already been addressed in the current version of EDDEaid, while some others are considered for future research.

CHAPTER 8: CONCLUSIONS

8.1 Dissertation summary

The goal of this research was to create (within the construction education domain) a framework that would guide designers through the commonly complex and confusing process of creating an effective technology-assisted learning tool. The research endeavor started with a pilot design of a materials management learning module which was a stand-alone software program run on a tabletPC platform and supported by hardware infrastructure consisting of pre-programmed sensors. This program was carefully designed and went through several refinement cycles. In the tests done in August and November of 2007, the module was well received and generated a high level of interest among participating students. This design served as the motivational study that revealed the critical aspects involved in the creation of a technology-supported instructional tool as well as the needs to do further research on several issues that had not been adequately addressed in the current body of knowledge. These insights helped focus the literature review on identifying relevant findings in instructional design, interface design and technology-supported learning that could be used as the foundation for the envisioned framework.

Initial literature review provided an overall profile of today's college students, especially in areas related to technology adaptation and learning expectations. The data that existed, however, were neither in the form that could be easily incorporated in the instructional design process nor were they representative of civil engineering students. For this reason, the Technology and Construction Baseline Survey was created to assess students' technology skills and attitude, learning preferences, and baseline construction knowledge for the civil engineering student audience. From the 280 data points collected, it was found that today's students were exposed to a wide range of technology applications. They had a positive attitude toward technology, were enthusiastic gamers, and strongly preferred learning activities that involved interactions, whether these interactions were face-to-face or simulated by technology. These findings suggested that technology-assisted learning would excite and engage students, especially in several areas of construction management to which their exposure was limited. These data would then be incorporated in the design framework being developed to ensure the creation of instruction that is truly student-centered.

The most important part of the dissertation is the framework development. Through synthesizing and expanding current literature in instructional and interface design, meaningful connections were revealed and developed which would establish the ground for assembling the various components of the framework into a systematic and operational process, EDDE. In its final form, EDDE (Explore, Design, Develop, Evaluate) takes users through a step-by-step procedure, starting with a high level instructional goal, narrowing down with suitable choices for a game/simulation-based instructional strategy, enforcing with basic interface design features, and finally customizing the design with relevant instructional activities.

Because of the sheer amount of interconnected knowledge and information embedded in this framework, a computerized design support tool (called EDDEaid) was created. EDDEaid embodied the framework and all of its contents in an interactive and easy to use manner. This tool also created an added value to the EDDE conceptual framework as the result of more effective content delivery and visual aids. The evaluation of the framework was done through the testing of EDDEaid. A group of nine construction management professors with varying teaching and technology experiences were asked to use the tool to either create a new conceptual technology-aided teaching tool, or to improve/critique an existing tool. Their feedback was used to evaluate the usefulness and effectiveness of the framework. The feedback confirmed the value of EDDEaid as a flexible yet formalized and systematic approach to technology-supported instructional design. Test participants also highly appreciated the richness and comprehensiveness of EDDEaid's content as well as its educational value. A re-evaluation of the materials learning module created as the motivational study was also conducted based on the newly developed framework.

8.2 Research contributions

8.2.1 Academic contributions

This research has made both academic and practical contributions to the body of knowledge in technology-assisted instructional design and construction education. To the best of the author's knowledge, there has been no operational design framework for technology-supported tools that effectively combines the knowledge in instructional design and interface design prior to this research. The student background data that existed were either not specific to civil engineering students or not directly implementable in such a complex design process. This research has made an important step forward in filling these gaps by adequately answering the two main research questions below, and hence making the following contributions:

Can we synthesize existing knowledge in user interface design and instructional design into a framework that aids the development of technology-supported instruction?

- The research demonstrates that distributed research findings in separate studies in instructional design and interface design can be systematically incorporated in a design framework that leads to the creation of technology-improved teaching/learning tools. The research offers a method for creating this framework by first of all identifying the critical design components from a large amount of literature in instructional and interface design. By ways of content analysis and synthesis, it also provides the method for revealing previously implicit links between these components and hence developing the missing connections necessary for making the framework actionable. This research provides an effective way of turning useful but unrelated wisdom abundant in the world of technology design and pedagogical design into concrete design actions that can be implemented in the process of creating technology-supported instruction.
- The process of creating the EDDE framework is also a process of expanding, enriching and adapting current literature in related areas to serve the purpose of designing technology-enhanced instruction. Upon completion of framework development, the research has generated useful additional knowledge in these

areas, including: 1) a game/simulation taxonomy for educational purposes that did not exist prior to this research, 2) a list of high-level user interface design principles with important pedagogical implications, 3) several design recommendations for different design scenarios, from the choice of game types to specific instructional events suitable for each type, and 4) the logical connections among these aspects of design.

- EDDE puts a structure to an otherwise overwhelming and error-prone design process. It formalizes and divides the process into distinctive phases and focuses design effort on the decisions that are critical at each step. The balance between flexibility (giving several design choices for each problem as well as an option for designers to come up with their own specifics) and structure (formalized design process) ensures the applicability of the framework to a wide range of instructional design problems. The generic nature of the knowledge that goes into the framework makes it viable for applications in any domain of education.
- The value of the framework developed in this research has been demonstrated through applications in the construction education domain. The evaluation results suggest that EDDE has been accepted and perceived by professors in construction management and building construction as a useful and effective process to create technology-supported instruction for their own topics and students. This acceptance by the target audience confirms the vision of EDDE as an effectively integrated design process that guides the development of technology-assisted instruction.

What is student knowledge with respect to technology and construction, and what are the implications for pedagogical design?

- This research has conducted a study of technology skills, learning preferences and domain knowledge of today’s civil engineering students. This study provides a new and updated understanding of students’ skills and needs with regard to technology’s role in improving the learning environment. It helps directly fill the gap in the current literature of audience analysis for technology-supported instructional design. The new study focuses on students' characteristics and attributes that have explicit implications on pedagogical design as well as explores the more implicit implications that might exist in the data collected. All of this knowledge can be helpful in raising instructional designers' and professors' awareness of their audience's strengths and weaknesses, hence making instruction designed more student-centered.

- The incorporation of student background data at several decision points in the EDDE framework demonstrates how knowledge of students' strengths, technology skills and learning needs can be used to make technology-assisted instruction more relevant and effective for the student audience it serves. As technology has become an important part of today's students' skill set and learning expectations, this knowledge should and could be among the decisive factors that shape the design of technology-enhanced learning tools.

8.2.2 Practical contributions and research products

Apart from the academic contributions, this research has also made practical contributions that are valuable to teachers of the construction education and other domains. Among these are the three research products that can be used in conjunction with or independently from the dissertation: EDDEaid (the computerized version of EDDE), the Technology and Construction Baseline Survey, and the materials management learning module.

- **EDDEaid** makes the implementation of this design framework more effortless. EDDEaid has turned hundreds of pages of document into an interactive interface with just a couple of screens to navigate. The software has been tested by several faculty users and refined to become a product that can be used independently from this dissertation. This light-weight (only 2MB) stand-alone application comes with a demonstration video and a user's manual, which greatly improves the tool's accessibility and helps it reach a large number of potential users with ease.

- The **Technology and Construction Baseline Survey** is available both online and in paper form for easy distribution and a long-term growth of the database. This will enable further analyses of student technology maturity and learning expectations. It can also be used for students of other disciplines besides civil engineering as most of the questions are not domain-specific. The particular assessment of students' existing knowledge in the seven knowledge areas in construction management can be replaced by the subjects more relevant to the field under consideration.

- The process of creating, testing and refining **the materials management learning module** demonstrates how mobile technology can be deployed in a flexible manner to create a virtual learning environment. This example can be used as a reference and template for creating a technology-enhanced teaching experience. The module has practical value beyond being a mere research tool. It can be used in almost any classroom setting with minimal infrastructure requirements to provide a meaningful simulated experience of monitoring materials and managing activities on a construction jobsite. It can also be used as a tool to introduce students and workers to the versatility of mobile and wireless technologies in construction.

In addition to these practical research products, the EDDE framework and EDDEaid tool produced in this dissertation can be used as an educational tool outside of the area of technology-supported instruction. Thanks to the large amount of important literature embedded in the framework/tool and the structure it enforces, EDDE/EDDEaid is useful in enhancing general instructional design, and hence teaching effectiveness, as much of its content is based on generic pedagogical design principles. The feedback from the user testing of EDDEaid confirmed the value of EDDEaid as a comprehensive and educational tool for teachers/professors in general.

8.3 Recommendations for future research

This dissertation has provided a structured framework for choosing an appropriate interface and useful instructional events for a game/simulation-based learning tool. The framework helps designers make better informed design decisions by matching pedagogical objectives with desirable characteristics afforded by technology. This matching is the result of synthesizing distributed literature on the uses of games in learning and identifying educational qualities of several game elements. To make this process more useful and comprehensive for the target audience (professors/teachers with less-than-commercial-scale development resources), it is recommended that future research efforts focus on conducting a thorough analysis of pedagogical values for each of the game type considered in this framework, as well as how different elements of such a game support the learning conditions in Gagne's Nine Events of Instruction model. Specific existing games should be used for this analysis to provide concrete examples and visions, similar to what was done by Amory et al (1999). A library of visual game/interface elements with specific pedagogical values can be produced from such an analysis and would be a valuable addition to the current EDDE framework and EDDEaid tool.

On the practical side of EDDEaid, the process of conducting this research and testing the tool has triggered a number of worthy ideas that, though valuable, were not implemented. Most of the time the reason was the ideas being out of scope of the project, and occasionally because of time and resource constraints. Among these, ideas well suited for future practical improvements of EDDEaid include more visual feedback for the design instruction screen, design recommendations for specific class sizes, and the inclusion of case studies and success stories of EDDEaid uses as inspiration and guidelines for new users. The more EDDEaid gets used, the more valuable user feedback can be fed back into the tool to refine, enrich and expand the content of the framework. If a critical mass of users can be reached, EDDEaid can evolve into a knowledge sharing tool among interested faculty who have a desire to create innovative learning tools supported by technology.

Appendix A: Pre-test Questionnaire for Pilot Learning Module Testing

Informed Consent

TITLE OF RESEARCH:	CI-TEAM: Educating a Competitive, Cyberinfrastructure Savvy Engineering and Construction Workforce
CO-INVESTIGATORS:	**Dr. William O'Brien**, Asst. Prof., Civil, Architectural, and Environmental Engineering, PI **Dr. Christine Julien**, Asst. Prof., Electrical and Computer Engineering, Co-PI **Dr. Kathy Schmidt**, Director, Faculty Innovation Center, Senior Personnel

We are asking you to participate in a small study. This specific study will explore how usable and useful a construction management learning module is to the user. The learning module is designed as a self-contained computer application. The participants will use this application on a TabletPC to complete a construction scheduling exercise. The total duration of this study is expected to be approximately 60 minutes, with 15 to 30 minutes of direct interaction with the application, and 30 minutes of feedback and questionnaires. The information collected will be analyzed to propose ways to improve the usability and usefulness of the application. No sensitive or private information will be collected or recorded as part of the study. This research study is part of a construction workforce education research project conducted at the University of Texas at Austin.

If you agree to participate in the study, you will be asked to provide some basic information on your demographic background and your familiarity with mobile computing tools as well as your experience with construction work and educational experience. You might also be asked to answer a questionnaire to determine your learning preference. You will then use a TabletPC to explore the application interface and features, and then complete the exercise. During the exercise, the supervisor will make observations of your interaction with the learning module. If you have any technical questions during this time, you may address them to the supervisor. After you complete the exercise, you will be asked to turn it in and answer a questionnaire to give feedback on your experience with the learning module. The purpose of this research is to study the usability of the application, and not to examine your performance in the task.

There is no anticipated physical risk to the participants as part of the study. Similarly, no risks are otherwise anticipated other than a minimal risk of confidentiality loss as the researchers will have direct interaction with the participants in terms of training and observing use of the technology.

The primary potential benefit to you as a participant involved in testing the education modules is that you could gain exposure to and understanding of advanced technologies for the intelligent jobsite, which may help you in your future career.

The decision to take part in this study is ultimately your choice. You can refuse to participate anytime, before or during the test, without any penalty.

If you have any questions, concerns, or complaints about the research or research-related issues, please ask the supervisor. If you experience any discomfort as a result of the study or have any questions after the study is over, please contact co-investigator Dr. Kathy Schmidt at (512)-232-1536 or k.schmidt@mail.utexas.edu

.

Your signature below indicates that you have read the information above and agree to participate in this study. You will receive a copy of this signed document.

____

Signature of Participant Date

____

Signature of Supervisor Date

Pre-Test Questionnaire

Instructions:

The overall purpose of this study is to look at an integrated learning environment using mobile devices to read sensor data. This specific questionnaire is designed to capture 1) your demographic and background information, and 2) your preferred methods of learning.

You will be asked to provide your UTEID (or student ID for non-UT students). This ID is used purely to classify participants' background and is not linked to any of your UT profile or record. You may choose to not answer any questions.

The data gathered in this study will be reviewed by Kathy Schmidt, Director of the College's Faculty Innovation Center. Should you have concerns please contact the Office of Research Support and Compliance at 471-8871.

ID ____________________

Age group:
- ☐ 18-25
- ☐ 25-35
- ☐ 35-45
- ☐ Over 45

Gender:
- ☐ Male
- ☐ Female

Current academic standing:
- ☐ Not in college
- ☐ Freshman
- ☐ Sophomore
- ☐ Junior
- ☐ Senior
- ☐ Graduate school

Current academic major area (be specific; if not yet have a major please specify intended major):
- ☐ Structural Engineering
- ☐ CM/CEM/CEPM
- ☐ Geotechnical Engineering
- ☐ Environmental & Water Resources Engineering
- ☐ Architectural Engineering
- ☐ Transportation Engineering
- ☐ Building Construction
- ☐ Architecture
- ☐ Other (please specify):

Targeted job location after graduation:
- ☐ USA
- ☐ Others

How many years of construction work experience do you have?
- ☐ None
- ☐ Less than 2 years
- ☐ 2 to 5 years
- ☐ More than 5 years

Current or intended (after graduation) work area:
- ☐ Management (executives)
- ☐ Support (technical, estimating, sales, accounting, etc.)
- ☐ Supervision (foremen and superintendents)
- ☐ Labor (skilled and unskilled)
- ☐ Other (please specify):

English proficiency:

	Oral	Written
No skill	☐	☐
Limited	☐	☐
Sufficient	☐	☐
Fluent	☐	☐
Proficient	☐	☐

Appendix B: Post-test Questionnaire for Pilot Learning Module Testing

Post-Test Questionnaire

Instructions:

The overall purpose of this study is to look at an integrated learning environment using mobile devices to read sensor data. This specific assessment questionnaire asks you to provide feedback on your experience with the learning module as part of data that support the study.

The assessment is designed to determine how well the learning module served as a learning/teaching tool. Your performance is not relevant.

You will be asked to provide your UTEID (or student ID for non-UT students). This ID is used purely to classify participants' background and is not linked to any of your UT profile or record. You may choose to not answer any questions.

The data gathered in this study will be reviewed by Kathy Schmidt, Director of the College's Faculty Innovation Center. Should you have concerns please contact the Office of Research Support and Compliance at 471-8871.

ID ____________________

Learning module recap

1. How often do you use a tabletPC?
   - ☐ Never
   - ☐ Rarely (a few times a year)
   - ☐ Occasionally (once or twice a month)
   - ☐ Often (weekly basis)
   - ☐ Often (weekly basis)

2. How did this exercise improve your tabletPC skills?
   - ☐ Did not help
   - ☐ A little
   - ☐ Considerably
   - ☐ Significantly
   - ☐ Not applicable, as I've already mastered the skills.

3. Were you aware of RFID technology before? ☐ Y ☐ N

4. Were you aware of any RFID applications on construction jobsites? ☐ Y ☐ N

5. You are holding the tabletPC (with the receiver attached) and walking through the site when you see a material palette a few yards away. However you cannot find this material item on the list under RFID data. Which of the following might be the reason for this? (check all that apply)
   - ☐ This palette does not have an RFID tag attached to it.
   - ☐ This palette might have an RFID tag but the tag is not working therefore it is not detected and shown.
   - ☐ This palette does have an RFID tag. The tag is working (radiating radio waves) but the receiver (attached to the tabletPC) is too far away so it is out of range for that tag.
   - ☐ There might be too much obstruction that reduces the working range for the RFID tag.

6. Refer to figure 1:
   - List the material palettes (IDs only) that have been found and located on the map:

   - List the material palettes (IDs only) that have been associated with some activities:

   - List the material palettes (IDs only) that have been detected but not yet found and located:

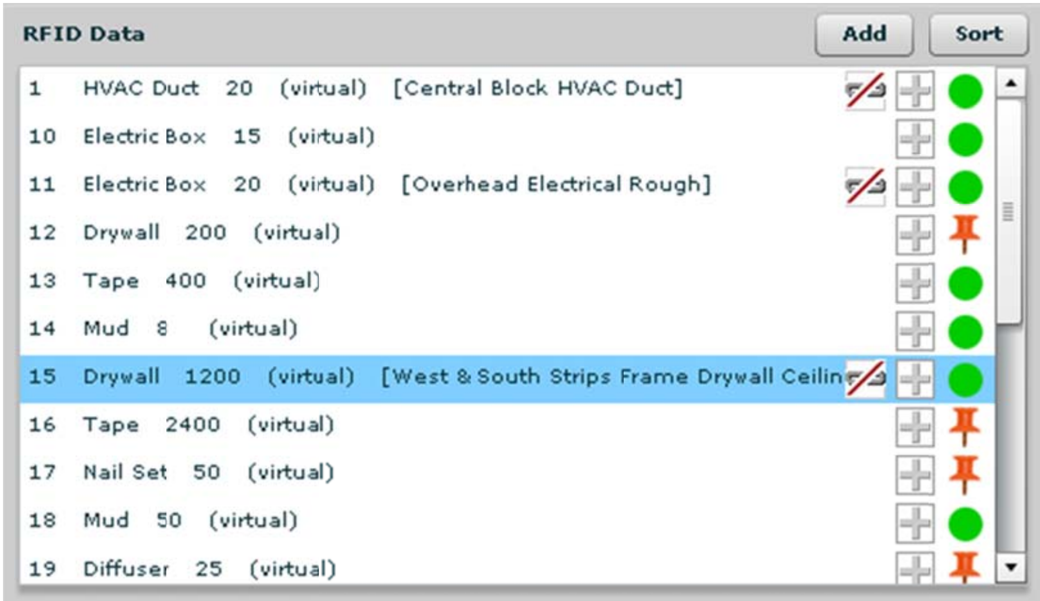

Figure 1: RFID Data Panel

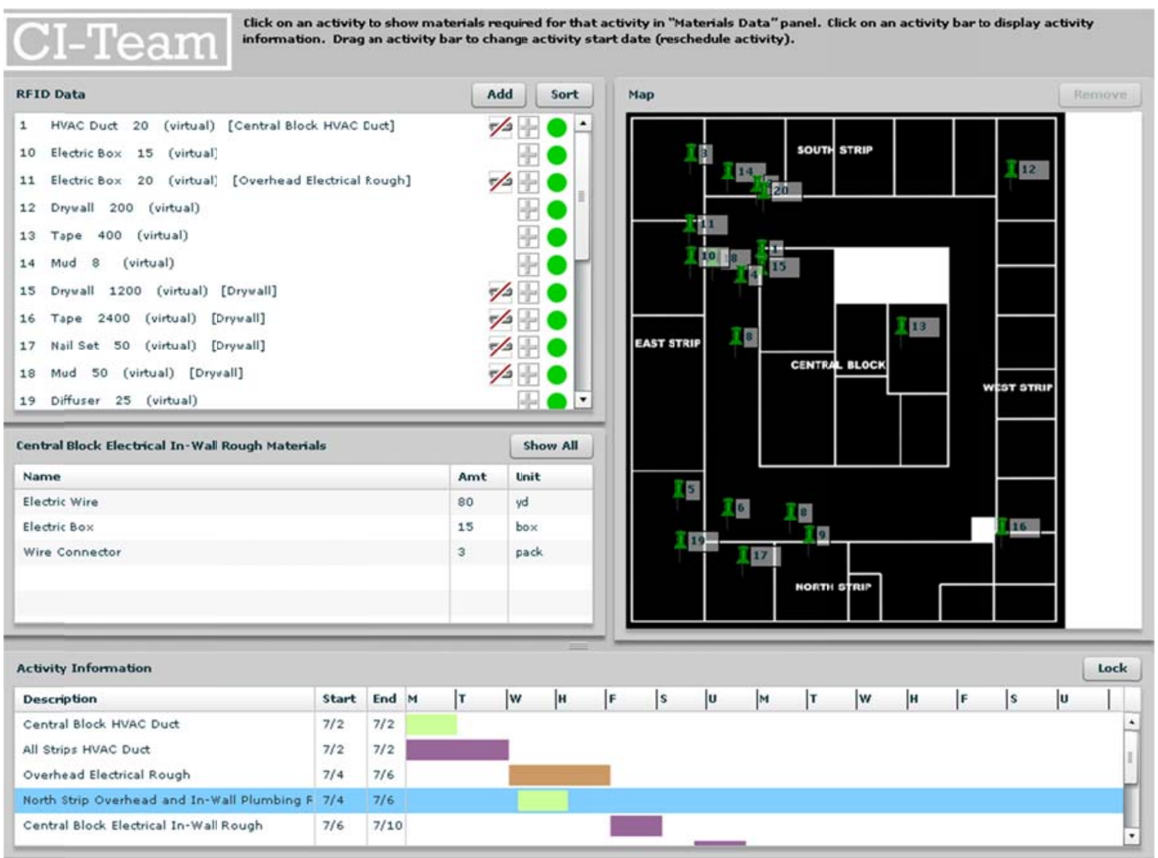

Figure 2: Sample material locations and schedule status

7. For the map and schedule shown in figure 2, what are the potential problems? (shown a map with lots of pins in one area, a schedule with many activities lacking materials)

8. Refer to figure 3 (show a figure with required materials for an activity). What are the materials required for activity Overhead Electrical Rough?

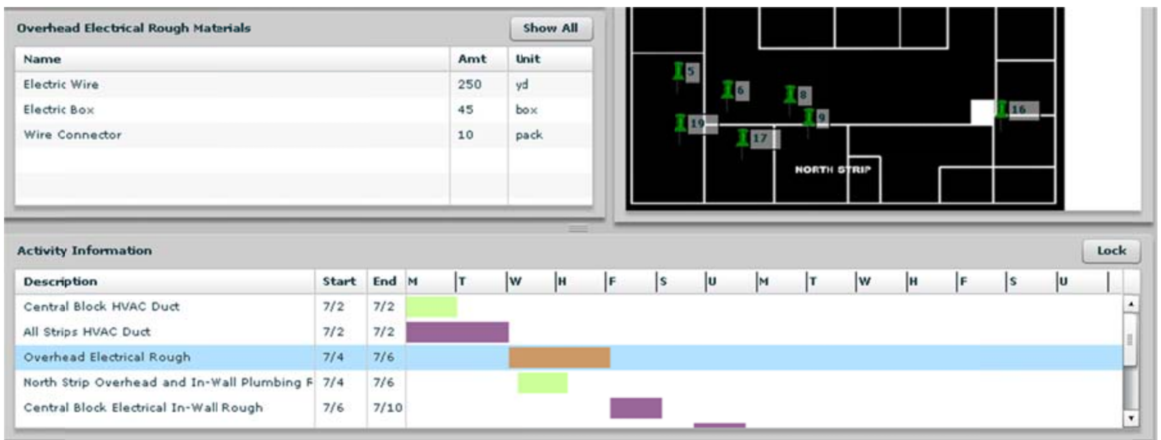

Figure 3: Required materials for Overhead Electrical Rough

For each of the statements below (9 to 16), please indicate whether it is true or false or you don't know based on your learning from the exercise.

#	Statement	True	False	Don't know
9	An RFID tag is a little pre-coded piece of hardware attached to an item to be located.	☐	☐	☐
10	An RFID tag communicates with a central device (a receiver) via radio waves.	☐	☐	☐
11	An RFID tag has a unique ID that can contain or can be mapped to information on the item it is attached to.	☐	☐	☐
12	An RFID tag has to be wired to a central device for communication.	☐	☐	☐
13	In this learning module, real RFID tags were used.	☐	☐	☐
14	In this learning module, sensors were used to generate RFID-like data.	☐	☐	☐
15	Data broadcasted by sensors or RFIDs can be detected equally easily by a receiver in any environment, rain or shine.	☐	☐	☐

16	Data broadcasted by sensors or RFIDs are not affected by obstructions such as walls, furniture and other devices. They are detectable in the same range whether or not obstructions are present.	☐	☐	☐

General

17. The task descriptions were clear.
    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neutral
    - ☐ Agree
    - ☐ Strongly agree

18. The flow of task was logical and easy to follow.
    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neutral
    - ☐ Agree
    - ☐ Strongly agree

19. The expectations were communicated clearly and you understood what you were supposed to do.
    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neutral
    - ☐ Agree
    - ☐ Strongly agree

20. How was the amount of instruction given to you before the task?
    - ☐ Too little
    - ☐ Just enough
    - ☐ Somewhat redundant
    - ☐ Overwhelming

21. How often did you need extra instruction from the instructor when you carried out the task?
    - ☐ Never
    - ☐ Rarely
    - ☐ Occasionally
    - ☐ Often
    - ☐ Very often

22. Was the task easy or challenging? Rate your experience.
    - ☐ Very easy
    - ☐ Easy
    - ☐ Normal
    - ☐ Challenging
    - ☐ Very challenging

23. Was the length of the exercise appropriate?
    - ☐ Too long
    - ☐ Long
    - ☐ Just right
    - ☐ Short
    - ☐ Too short

24. Did you enjoy the experience? Rate your experience.
    - ☐ Did not enjoy at all
    - ☐ Did not enjoy it
    - ☐ Neutral
    - ☐ Enjoyed it somewhat
    - ☐ Enjoyed it very much

25. Do you think this technology shows promise for future application to live

construction sites?
☐ Yes. (Please explain why)
☐ No. (Please explain why)

Technology usability

#	Statement/Question	1 (not at all)	2	3 (neutral)	4	5 (very)
26	Was the interface visually appealing?	☐	☐	☐	☐	☐
27	How comfortable were you working with this device in general?	☐	☐	☐	☐	☐
28	How comfortable were you working with using the stylus?	☐	☐	☐	☐	☐
29	How comfortable were you with the lighting of the screen?	☐	☐	☐	☐	☐

30. According to you, the size of the screen was
☐ Too small
☐ Rather small
☐ Just right
☐ Rather big
☐ Too big

31. How often did you find what you wanted to find?
☐ Never
☐ Rarely
☐ Occasionally
☐ Often
☐ Very often

32. Did the technology make the exercise more interesting or less interesting?
☐ A lot less interesting
☐ Somewhat less interesting
☐ No impact
☐ Somewhat more interesting
☐ A lot more interesting

33. What technical problems did you encounter when using the devices? Please check all that apply.
☐ Unable to read data from a sensor
☐ Touch screen not sensitive
☐ Unable to see screen clearly
☐ Difficult to use stylus
☐ Unable to find wanted functions
☐ Difficult to navigate the site
☐ Battery failure
☐ Unable to load plan, schedule or material list
☐ Difficult to switch views
☐ Other problems (please specify)

34. Do you have any other comments? What would you suggest that we do to improve the users' experience?

Learning Experience

For each of the following statements (35 to 50), please indicate whether or not you agree.
1 – Strongly disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly agree

#	Statement	1	2	3	4	5
35	The interactive features of the exercise made me feel engaged throughout the whole exercise.	☐	☐	☐	☐	☐
36	As the design of the exercise was flexible and interactive enough for me freely explore different ways to do things.	☐	☐	☐	☐	☐
37	The range of things I could do at a time was too broad, and I got lost during the exercise.	☐	☐	☐	☐	☐
38	The flexibility of the program and the repetitiveness of some tasks helped me correct the mistakes I had made and reinforce my previous learning.	☐	☐	☐	☐	☐
39	The exercise motivated me to learn more about the topic of RFID/wireless technology and its application in construction.	☐	☐	☐	☐	☐
40	I believe the exercise promoted active interactions and thinking that facilitated long-term retention of the material.	☐	☐	☐	☐	☐
41	The number of repetitive tasks was just enough for me to understand how the exercise works and perform the action smoothly without getting bored.	☐	☐	☐	☐	☐
42	There was not enough structure to the learning module. I want a specific procedure to follow so that I don't have to think about what to do next.	☐	☐	☐	☐	☐
43	The learning module was flexible enough for me to be actively using my own judgment and intuition to make decisions.	☐	☐	☐	☐	☐
44	The design of the learning module represented well the physical and conceptual relationships in the real world. I can relate the virtual representations in the module with the physical relationships in the real world.	☐	☐	☐	☐	☐

45	The learning module had too many graphics without enough text of audio instructions to help me understand.	☐	☐	☐	☐	☐
46	The graphical representations (such as push pins, color codes, chain links) were helpful in improving my understanding about the consequences of the activities I was performing.	☐	☐	☐	☐	☐
47	The design of the learning module was comprehensive and fluid enough to give me the big picture of the ultimate task at every stage.	☐	☐	☐	☐	☐
48	I need more sequential instructions to avoid getting lost and not knowing what to do next.	☐	☐	☐	☐	☐
49	The instructional presentation was helpful in introducing the concept that I would learn more about in the actual exercise.	☐	☐	☐	☐	☐
50	The flowcharts and list of learning objectives helped me see the big picture and made learning more effective.	☐	☐	☐	☐	☐

Thank you for your participation!

Appendix C: Technology and Construction Baseline Survey

Technology and Construction Baseline Survey

<u>Informed Consent</u>

Title: CI-TEAM: Educating a Competitive, Cyberinfrastructure Savvy Engineering and Construction Workforce. IRB Protocol #2006-07-0091

You are being asked to complete this survey as part of a research study. Your participation is entirely voluntary. You can refuse to participate without penalty. You can stop your participation at any time and your refusal will not impact current or future relationships with your institution or participating sites.

The purpose of this questionnaire is to assess the level of technology skills and construction knowledge and experience of students in construction-related programs. No sensitive or private information will be collected or recorded as part of the study.

The questionnaire is a survey of three parts: Demographic and Background Knowledge, Technology Attitude and Exposure, and Construction-Related Knowledge. The estimated burden is 20 minutes.

Risks: There is no physical risk associated with this study.

Compensation: There is no compensation for this study.

Benefits: You will have an opportunity to assess your basic technology and construction knowledge.

Privacy and Confidentiality Protections: Your participation in this study will be kept confidential to the extent allowed by law. The records of this study will be stored securely and kept confidential. All publications will exclude any information that will make it possible to identify you as a subject.

Contacts and Questions: If you have any questions about the study please ask now. If you have questions later, want additional information, or wish to withdraw your participation, please contact co-investigator Dr. Kathy Schmidt at (512)-232-1536 or k.schmidt@mail.utexas.edu.

Instructions:
Please record how much time it took you to complete the whole survey. We would like to know if the length of the survey is appropriate.

1. Name of your institution

____

Demographic and Background Information

1. Age group:
   - ☐ Under 18
   - ☐ 18-25
   - ☐ 26-35
   - ☐ Over 35

2. Gender:
   - ☐ Male
   - ☐ Female

3. Current academic standing:
   - ☐ 1st year
   - ☐ 2nd year
   - ☐ 3rd year
   - ☐ 4th year
   - ☐ 5th year
   - ☐ Graduate school

     What was your undergraduate major?
     - ☐ Engineering
     - ☐ Architecture
     - ☐ Building Construction
     - ☐ Other: ____________________________

4. Current academic major area (be specific; if you don't have a major yet please specify intended major):
   - ☐ Civil Engineering
   - ☐ Architectural Engineering
   - ☐ Construction Engineering
   - ☐ Building Construction/ Building Science/ Construction Management
   - ☐ General Engineering/Engineering Technology

     With construction major?
     - ☐ Yes
     - ☐ No

5. What is your Grade Point Average, across all your subjects, up to date?
   - ☐ +4.0 – 3.5
   - ☐ 3.4 - 3.0
   - ☐ 2.9 – 2.5
   - ☐ 2.4 – 2.0

6. Describe your institution/academic program:
   - ☐ 4-year college
   - ☐ 2-year program
   - ☐ Graduate school
   - ☐ Other: ______________________________

8. What kind of construction work experience do you have? Give answers as number of months of experience.
   - ☐ None
   - ☐ Engineering/Design: _____ months
   - ☐ Facilities Management/Operations: _____ months
   - ☐ Project Management: _____months
   - ☐ Site Supervision: ______months
   - ☐ Project Controls: ______months
   - ☐ Labor: ______months
   - ☐ Other: ______months

9. Intended work area after graduation:
   - ☐ Engineering/Design
   - ☐ Facilities Management/Operations
   - ☐ Project Management
   - ☐ Site Supervision
   - ☐ Project Controls
   - ☐ Labor
   - ☐ Other:__________________________

Technology Attitude and Exposure

10. How do you find a PowerPoint presentation as a lecture format? (choose one answer)
    - o Usually sufficient as a learning aid as it helps me follow what the professor says
    - o Necessary, but not sufficient. I want more videos, animations, and class activities
    - o Not really necessary. I prefer other ways to learn

11. Which background activities do you do with your computer during a lecture? (please check all that apply)
    - □ Emailing
    - □ Instant messaging
    - □ Internet surfing
    - □ Playing games
    - □ Looking up information relevant to the lecture
    - □ Other:__________________
    - □ I stay focused in lectures and do not perform any background tasks

12. Do you find these background activities disruptive to your learning? (choose one answer)
    - o Yes, I have to divide my attention between the lecture and these activities
    - o Sometimes, I might miss a few points but can still grasp the basic content of the lecture
    - o No, these tasks do not impede my learning in any way

13. Which of the following interactive learning activities do you like to be incorporated in your classes? (please check all that apply)
    - □ In-class group discussions
    - □ Group projects
    - □ Role playing
    - □ Simulations
    - □ Individual assignments
    - □ Other: _________________

14. How often are videos/animations used in your class? (choose one answer)
    - o Never
    - o Rarely
    - o Occasionally
    - o Often
    - o Very often

15. You find that videos and animations when used in class (please check all that apply)
    - □ Are engaging
    - □ Help you remember materials better
    - □ Help you understand the materials better
    - □ Are engaging but does not make a difference to my understanding or retention of materials
    - □ Are distracting
16. When working with a team on a group project, which collaborative tools do you use? (please check all that apply)
    - □ Face-to-face meeting
    - □ Email
    - □ Telephone
    - □ Instant messaging
    - □ Web document sharing (such as SharePoint, GoogleDocs, etc.)
    - □ Online discussion forums
    - □ Other: _________________
    - □ I don't have group projects

17. How do you use social networks (Facebook, Twitter, MySpace, etc.) to support your school work? (please check all that apply)
    - □ To post questions to a group
    - □ To send messages to my class mates
    - □ To send messages to my professors
    - □ To join study groups
    - □ Other: ___________________
    - □ I don't use social network for my school work

18. Which of the following ways do you use to communicate with your professors outside of class? (please check all that apply)
    - □ I come to see my professors during office hours
    - □ I email professors with questions
    - □ I post questions to class discussion forums (such as BlackBoard)
    - □ I send professors instant messages
    - □ I send professors messages on Facebook (or something equivalent)
    - □ Other: ___________________
    - □ I don't communicate with professors outside of class

19. If given a choice to do homework, assignments or class projects anyway you like, what would you choose? (choose one answer)
    - o I prefer to use computer applications (word processing, spreadsheets, presentations, web tools, etc.)

- I prefer to use manual methods (pen, paper and calculators) to do the task and avoid using computers when possible.
- I use a balance of both computer tools and manual methods.

20. When using a computer program or tool, you (choose one answer)
    - tend use just the basic and commonly used features or functions
    - make an effort to explore some more sophisticated features to get a feel for the potential of the software
    - perform in-depth exploration to become an expert user.

21. Which of the following devices are you comfortable using? (please check all that apply)
    - ☐ Touch screen phones
    - ☐ PDAs (Personal Digital Assisstants)
    - ☐ GPS's (Global Positioning Systems/Navigation)
    - ☐ TabletPCs
    - ☐ Entertainment devices (such as NintendoDS)
    - ☐ Other: _________________

22. How comfortable are you with using touch screens and stylus? (choose one answer)
    - Very uncomfortable
    - Uncomfortable
    - Neutral
    - Comfortable
    - Very comfortable

23. Regarding your technology skills and attitude towards technology, you consider yourself (choose one answer)
    - A very low-tech person
    - A low-tech person
    - An average person, technology-wise
    - Technology-savvy
    - Very technology-savvy

Please indicate your skill level for each of the following technology groups (i.e. how well do you use them?). You are to rate your skill level for the whole group in general, not for each of the individual technology listed in that group.

1 – No skill **2** – Beginner **3** – Low intermediate **4** – High intermediate **5** – Expert

Group	**Technology Examples**	**Expertise Level**				
		1	2	3	4	5
HARDWARE						
Basic hardware	Computers, printers, fax machines, scanners, digital cameras, projectors, etc.	☐	☐	☐	☐	☐
Touch screen devices	TabletPCs, PDAs, iPhones, iPods, GPS, etc.	☐	☐	☐	☐	☐
Sensing technologies	RFID, sensors, etc.	☐	☐	☐	☐	☐
TASK SPECIFIC APPLICATIONS						
Office document tools	Word processors, spreadsheets, presentations, etc.	☐	☐	☐	☐	☐
Graphic and web design tools	Photoshop, Paintbrush, Fireworks, CorelDraw, FrontPage, Dreamweaver, etc.	☐	☐	☐	☐	☐
Time/Task management tools	MS Outlook, Mail, desktop organizers, iCalendar, Google Calendar, etc.	☐	☐	☐	☐	☐
Group	**Technology Examples**	**Expertise Level**				
		1	2	3	4	5
Knowledge and Data management tools	MS Access, EndNote, Time Machine, etc.	☐	☐	☐	☐	☐
Structural/Architectural design tools	SAP2000, ADINA, STAAD-Pro, ArchiCAD, etc.	☐	☐	☐	☐	☐
2D- & 3D-CAD	AutoCAD, Unigraphics, Solid Works, Inventor, MicroStation, Revit, etc.	☐	☐	☐	☐	☐
Computational	MathLab, LabView, etc.	☐	☐	☐	☐	☐
Computer games	Strategy games, simulation games, eductional games, etc.	☐	☐	☐	☐	☐
PROJECT MANAGEMENT APPLICATIONS						
Scheduling	Navisworks, Microsoft Project, Primavera, etc.	☐	☐	☐	☐	☐
4D tools	4D/nD-CAD	☐	☐	☐	☐	☐
Estimating	PROEST, Bid4Build, etc.	☐	☐	☐	☐	☐
Contracts	Primavera CONTRACT MANAGEMENT, Meridian Prolog, Autodesk Constructware	☐	☐	☐	☐	☐

GENERAL WEB APPLICATIONS						
Email & Instant messaging	Yahoo Messenger, AOL, MSN, Google Talk, etc.	☐	☐	☐	☐	☐
Search engines	Google, Yahoo, etc.	☐	☐	☐	☐	☐
Social networks	Facebook, MySpace, LinkedIN, Twitter, etc.	☐	☐	☐	☐	☐
Web/Video conferences	Webex, GoToMeeting, Adobe Connect, etc.	☐	☐	☐	☐	☐
Electronic Resources	Online publications, online libraries, YouTube, wikis, blogs, etc.	☐	☐	☐	☐	☐

Construction-Related Knowledge

Level of acquaintance

Select the number that best describes your familiarity with each topic:

Level of acquaintance	**Example – Safety Management**
0 – I never heard of this concept.	
1 – (Remembering) I recall/recognize this concept.	Know the safety rules.
2 – (Understanding) I can explain the basics of this concept and give some examples.	Explain the procedure of evacuating when an emergency occurs.
3 - (Applying) I can implement this concept in a problem with minimum instructions.	Recreate a similar set of previously learned safety rules for a similar facility.
4 – (Analyzing) I can look at a problem and break it down into conceptual components, such as assumptions, context, hypothesis, evidence, structure.	Recognize all the important components interacting in an emergency situation, such as weather, equipment, human psychology, physical layout, emergency response capacity, and how each component can influence the emergency procedure.
5 - (Evaluating/Creating) I can make a judgment or take a stand about a problem related to this concept. I can challenge the learned concept based on my prior knowledge and experience, and create a new viewpoint or practice.	Realize the inappropriate or dangerous safety practices in a setting different from conventional. Develop new rules to address the uniqueness of the situation.

1 – Remembering **2** – Understanding **3** – Applying **4** – Analyzing **5** – Evaluating/Creating

Topic	**Level of acquaintance**					
	0	1	2	3	4	5
Cost and Schedule Controls	☐	☐	☐	☐	☐	☐
Field Management	☐	☐	☐	☐	☐	☐
Contracts and Delivery Methods	☐	☐	☐	☐	☐	☐
Project Economics	☐	☐	☐	☐	☐	☐
Materials and Methods	☐	☐	☐	☐	☐	☐
Safety	☐	☐	☐	☐	☐	☐
Green Construction	☐	☐	☐	☐	☐	☐

Time taken to complete survey: ________

Thank you for your participation!

Appendix D: Felder's Index of Learning Style Questionnaire

ID ____________________

Directions

This questionnaire is designed to identify your preferred style (styles) of learning. For each of the 44 questions below select either "a" or "b" to indicate your answer. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

1 I understand something better after I
- ☐ **(a)** try it out.
- ☐ **(b)** think it through.

2 I would rather be considered
- ☐ **(a)** realistic.
- ☐ **(b)** innovative.

3 When I think about what I did yesterday, I am most likely to get
- ☐ **(a)** a picture.
- ☐ **(b)** words.

4 I tend to
- ☐ **(a)** understand details of a subject but may be fuzzy about its overall structure.
- ☐ **(b)** understand the overall structure but may be fuzzy about details.

5 When I am learning something new, it helps me to
- ☐ **(a)** talk about it.
- ☐ **(b)** think about it.

6 I were a teacher, I would rather teach a course
- ☐ **(a)** that deals with facts and real life situations.
- ☐ **(b)** that deals with ideas and theories.

7 I prefer to get new information in
- ☐ **(a)** pictures, diagrams, graphs, or maps.
- ☐ **(b)** written directions or verbal information.

8 Once I understand
- ☐ **(a)** all the parts, I understand the whole thing.
- ☐ **(b)** the whole thing, I see how the parts fit.

9 In a study group working on difficult material, I am more likely to
- ☐ **(a)** jump in and contribute ideas.
- ☐ **(b)** sit back and listen.

10 I find it easier
- ☐ **(a)** to learn facts.
- ☐ **(b)** to learn concepts.

11 In a book with lots of pictures and charts, I am likely to
- ☐ **(a)** look over the pictures and charts carefully.
- ☐ **(b)** focus on the written text.

12 When I solve math problems
- ☐ **(a)** I usually work my way to the solutions one step at a time.
- ☐ **(b)** I often just see the solutions but then have to struggle to figure out the steps to get to them.

13 In classes I have taken
- ☐ **(a)** I have usually gotten to know many of the students.
- ☐ **(b)** I have rarely gotten to know many of the students.

14 In reading nonfiction, I prefer
- ☐ **(a)** something that teaches me new facts or tells me how to do something.
- ☐ **(b)** something that gives me new ideas to think about.

15 I like teachers
- ☐ **(a)** who put a lot of diagrams on the board.
- ☐ **(b)** who spend a lot of time explaining.

16 When I'm analyzing a story or a novel
- ☐ **(a)** I think of the incidents and try to put them together to figure out the themes.
- ☐ **(b)** I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17 When I start a homework problem, I am more likely to
- ☐ **(a)** start working on the solution immediately.
- ☐ **(b)** try to fully understand the problem first.

18 I prefer the idea of
- ☐ **(a)** certainty.
- ☐ **(b)** theory.

19 I remember best

- ☐ **(a)** what I see.
- ☐ **(b)** what I hear.

20 It is more important to me that an instructor

- ☐ **(a)** lay out the material in clear sequential steps.
- ☐ **(b)** give me an overall picture and relate the material to other subjects.

21 I prefer to study

- ☐ **(a)** in a study group.
- ☐ **(b)** alone.

22 I am more likely to be considered

- ☐ **(a)** careful about the details of my work.
- ☐ **(b)** creative about how to do my work.

23 When I get directions to a new place, I prefer

- ☐ **(a)** a map.
- ☐ **(b)** written instructions.

24 I learn

- ☐ **(a)** at a fairly regular pace. If I study hard, I'll "get it."
- ☐ **(b)** in fits and starts. I'll be totally confused and then suddenly it all "clicks."

25 I would rather first

- ☐ **(a)** try things out.
- ☐ **(b)** think about how I'm going to do it.

26 When I am reading for enjoyment, I like writers to

- ☐ **(a)** clearly say what they mean.
- ☐ **(b)** say things in creative, interesting ways.

27 When I see a diagram or sketch in class, I am most likely to remember

- ☐ **(a)** the picture.
- ☐ **(b)** what the instructor said about it.

28 When considering a body of information, I am more likely to

- ☐ **(a)** focus on details and miss the big picture.
- ☐ **(b)** try to understand the big picture before getting into the details.

29 I more easily remember

- ☐ **(a)** something I have done.
- ☐ **(b)** something I have thought a lot about.

30 When I have to perform a task, I prefer to
- ☐ **(a)** master one way of doing it.
- ☐ **(b)** come up with new ways of doing it.

31 When someone is showing me data, I prefer
- ☐ **(a)** charts or graphs.
- ☐ **(b)** text summarizing the results.

32 When writing a paper, I am more likely to
- ☐ **(a)** work on (think about or write) the beginning of the paper and progress forward.
- ☐ **(b)** work on (think about or write) different parts of the paper and then order them.

33 When I have to work on a group project, I first want to
- ☐ **(a)** have "group brainstorming" where everyone contributes ideas.
- ☐ **(b)** brainstorm individually and then come together as a group to compare ideas.

34 I consider it higher praise to call someone
- ☐ **(a)** sensible.
- ☐ **(b)** imaginative.

35 When I meet people at a party, I am more likely to remember
- ☐ **(a)** what they looked like.
- ☐ **(b)** what they said about themselves.

36 When I am learning a new subject, I prefer to
- ☐ **(a)** stay focused on that subject, learning as much about it as I can.
- ☐ **(b)** try to make connections between that subject and related subjects.

37 I am more likely to be considered
- ☐ **(a)** outgoing.
- ☐ **(b)** reserved.

38 I prefer courses that emphasize
- ☐ **(a)** concrete material (facts, data).
- ☐ **(b)** abstract material (concepts, theories).

39 For entertainment, I would rather
- ☐ **(a)** watch television.
- ☐ **(b)** read a book.

40 Some teachers start their lectures with an outline of what they will cover. Such outlines are

☐ **(a)** somewhat helpful to me.
☐ **(b)** very helpful to me.

41 The idea of doing homework in groups, with one grade for the entire group,

☐ **(a)** appeals to me.
☐ **(b)** does not appeal to me.

42 When I am doing long calculations,

☐ **(a)** I tend to repeat all my steps and check my work carefully.
☐ **(b)** I find checking my work tiresome and have to force myself to do it.

43 I tend to picture places I have been

☐ **(a)** easily and fairly accurately.
☐ **(b)** with difficulty and without much detail.

44 When solving problems in a group, I would be more likely to

☐ **(a)** think of the steps in the solution process.
☐ **(b)** think of possible consequences or applications of the solution in a wide range of areas.

Appendix E: Common Active Learning Strategies: Descriptions

Strategy	Definition	References
Think-Pair-Share	Students reflect on class material individually, then share with another student.	McKinney, 2009
Games	Games such as jeopardy and crossword puzzles used for review, assignments, or exams. They can be used at the individual, small group or full class levels.	McKinney, 2009 Thiagi.com
Analysis or reactions to videos	Have students work alone or in pairs to answer critical questions, write a "review" or reaction, or apply a theory.	McKinney, 2009
Student debates	A formal discussion in which an issue or topic is approached from two, completely opposite points of view.	McKinney, 2009 ICC, 2009
Student generated exam questions	This helps students actively process material, review material, and practice for the exam.	McKinney, 2009. Thiagi.com
Case study analysis	A narrative of an actual event to examine, discuss, and advance solutions to a realistic problem situation. Consider combining this with a brief in-class writing assignment.	McKinney, 2009 Meyers and Jones Hansen, 1987
Journal/log keeping	Have students make journal or log entries periodically (on paper or computer, in or outside of class). Require a brief critical reflection or analysis of each entry as well.	McKinney 2009
Concept mapping/idea map	**A** technique for representing knowledge in graphs, used to generate ideas, design a complex structure, to assess understanding or diagnose misunderstanding.	ICC, 2009 McKinney 2009 Thiagi.com
Superlatives: reflection on most extreme experiences	Ask students to identify the most important, most disturbing, most surprising, or most complex idea presented.	Thiagi.com
Mistake documentation	Give students access to previous learners mistakes. Great source for insights.	Expert Opinion
Mistake documentation	Give students access to previous learners mistakes. Great source for insights.	Expert Opinion
Role playing	Usually involves a small number of students, puts students into someone else's shoes by giving them a character to play, a scene to act, or a situation to imagine.	Meyers and Jones, 1993 Shannon, 1986
Simulations exercises/simulation games	Refer to situations in which several students are involved, assuming different roles as they act out a prescribed scenario. These scenarios incorporate specific rules and activities designed to teach a concept or to have students put a theory into practice.	Meyers and Jones, 1993
Computer models	Simulation exercises and games designed as software packages for computers, allowing students to deal with practical, problem-solving experiences, or to practice skills "that are either too dangerous, too expensive, or too remote and inaccessible for humans to encounter directly"	Meyers and Jones, 1993
Mind mapping	Involves writing down a central idea and thinking up new and related ideas which radiate out from the centre.	ICC, 2009

Strategy	Definition	References
Feedback loop	Students use handheld or web-based tools to answer assessment questions as the lecture is presented.	CULC, 2009
Leading question	Ask students an interesting/controversial question related to the subject matter at the beginning of a lecture to stimulate thinking and engagement.	ICC 2009
Clarification pauses	Mini breaks within a lecture/lesson for reflection and quick quizzes.	CULC, 2009
Concept clouds	On a prepared handout of key concepts to be learned, students visually highlight best understood concepts, then compare with instructor's expectations.	ICC, 2009

Appendix F: Taxonomy of Game-Based Instructional Strategies – Details

Interactive Case Studies

Descriptions. Case studies provide relevant, meaningful experiences in which learners can discover and abstract useful concepts and principles. In a case study, learners are given a comprehensive example to study. The case can be a real-world event, process, or system. Learners are also given materials that describe or perhaps even simulate the case. After working with these materials, learners attempt to answer questions about the case or to generalize the principles revealed by the case.

In general, there are the activities involved in a case study, in the order of complexity and level of cognitive processing: receiving information, self-study and analysis, participating in group discussions, further analysis and reflection, and potentially further research. All of these activities can be done without even using technology, however, technology have the potential to help implement each of these activities more efficiently. It is up to the teacher/designer to decide which part of a case study to be implemented with the help of technology, and to what extent.

In e-learning, case studies differ from classroom case studies in the variety of material available through the Internet, in the use of interactive multimedia presentations, and in the multiple perspectives possible through e-collaboration. E-learning case studies can include a richer mix of materials for learners to examine and can more realistically mimic real-world cases.

Uses. Case studies can be used for a variety of purposes, usually to provide comprehensive information and/or facilitate discussions/analyses to understand a complex issue with interdependent events, conditions and relationships. Case studies help comprehend the big picture with the right amount of relevant details. The level of complexity and amount of information conveyed by each interactive case study varies, consisting one or more of the following components:

- Informational: a platform to introduce the case, provide background information (such as reading material, related literature), reading activity, if we just wanted learners to absorb information from the study. This kind of case studies is all about content organization and presentation.
- Discussion-facilitated: a platform to enhance interactions and discussions among students. This is an effective way to record, generate and share ideas.
- Guided-analysis: case studies make fine discovery activities when learners must actively apply analytical and problem-solving skills to the events cited in the case study. Such a platform can be considered as a simple case study combined with a

platform for practice and experimentation, such as a guided analysis, an interactive spreadsheet, or a math simulation.

Suitable instructional objectives. Judgment, facts, theories, systems, observations.

Most important aspect of design. Logical content organization, thought provoking presentation, and lively discussions/idea exchange. If practice or implementation is offered: Consider guided analysis/math simulation for further guidance.

Examples.
The case of the Vengeful customer:
http://www.horton.com/portfolio/casestudy/index.htm
Promoting excellence in palliative and end-of-life care.
http://demos.enspire.com/demo/AACN-Palliative/movie.html?one=1266540160630
Medical simulations: http://www.medicalsimulations.com/

Device Simulation/Virtual Products

Descriptions and Uses. Device simulations and virtual products refer to simulated model of a product or device (or a part of it). Virtual products and devices are widely used for testing a product design for form, fit, performance, and manufacturability (Wang, 2002). These can also serve very well as a study or training tool for perspective users of the actual devices/products. Virtual products have an important advantage over real products in the way they "allow students to interact with visual, selectively accurate representations of actual products without the physical restrictions of the reality." They are useful in teaching advanced skills that would otherwise unsafe to acquire using the actual products. (Aldrich 2005 p.5, William Horton 2006, Wang 2002)

Device simulation and virtual prototyping include both geometrical and functional simulations, and might or might not involve humans. Since they generally require high fidelity to the real products, both physically and functionally, they consume more resources to be developed and are often quite technologically elaborate. For this reason, newly developed device simulations or virtual products are only appropriate when they are to be used by a large number of users/students.

Device simulations focus more on teaching about a piece of equipment/technology works, and how to operate such equipment. The device is the center of such an application. It might involve some procedures involving the device, but usually limited. For methods/strategies that focus more on skill building and procedures, please refer to Skill Building Simulations where the device might be a part of a simulated environment, but the focus is the interactions of students with the system and the skills they learn from such interactions.

Suitable instructional objectives. physical systems, theories, technical skills.

***Most important aspect of design*.** Moderate visual fidelity to reality, high fidelity in terms of functionality.

***Example*.**NEC DSX Telephone demo.
http://www.necdsx.com/interactive/dsx_interactive.html

Math-based Simulations

(Include Interactive Spreadsheet/ Guided Analysis/Virtual Lab)
Descriptions and Uses. Math simulations refer to all interactive analyses that involve complex behind-the-scene mathematical calculations and an interactive interface for results with tools to aid analyses and decision-making. Typical elements of such an interface include charts, graphs, tables, models/prototypes, comparison tools, adjustable variables, etc. The users input data through relevant variables, the program calculates the desired functions, and results are displayed mostly visually. Input values for variables can be adjusted and the result of this adjustment is reflected in the output. Additional information, such as background readings or case studies, can be supplied to help students learn more about the topic. (William Horton 2006, Aldrich 2005 p.5, ICC 2009, McKinney 2009, thiagi.com). Topics suitable for math simulations: accounting, economic problems, structural stability, process systems, physics, etc.

Suitable instructional objectives. Calculations, calculation-based analyses.

Most important aspect of design. Focus on aids for analyses such as interactive graphs, charts, summaries, and comparisons.

Example. Heat flow laboratory
http://www.horton.com/portfolio/heat_transfer/index.htm

Skill building simulations

Descriptions and Uses. Skill building simulations involve a simulated environment in which students operate virtual equipment and carry out procedures in order to learn some desirable skills, mostly technical (as opposed to soft skills, which can be learned through role playing and other management/strategy games and simulations). Skill building simulations are a method-centered role-playing and used primarily to develop skills in specific procedures, methods and techniques. They tend to deal with frequently reoccurring situations or problems of relatively short durations. A skill building simulation can be considered as an extended device simulation in which virtual devices/systems are present, but are not the center of the application. The focus of the learning experience is the students' doing things with those devices, possibly with the support of some predefined procedures in order to learn hard skills. The simulation is not as sophisticated and cognitively challenging as a management/strategy game since it focuses on some certain specific technical skills that can be measured and assessed more easily.

Suitable instructional objectives. Physical systems, procedures, technical skills

Most important aspect of design. Moderate visual fidelity with reality, high functional fidelity, clearly defined levels of skills to be learned.

Examples**.** Virtual Knee Surgeryhttp://www.agame.com/game/Virtual-Knee-Surgery.html

Design/ Invention games

Descriptions and Uses. Design/invention games are games that provide the basic building blocks for creating an object or a system that serves a predefined function. For example: design a steel bridge that sustains a certain load, or invent a car that uses alternative energy (and estimate its life cycle cost). The interface provides a wide range of options for basic elements from which users can choose, enforces the most important design principles (such as science), and visualizes as well as evaluate the creation. Such an interface is usually highly visual and emphasizes impact each component/element has on the whole system.

This kind of games is useful in learning about the anatomy of a structure or system, how the components interact, and how the final product is affected by the choice of each basic element. It is a great tool for developing creativity and problem solving skills for engineering and science problems.

Suitable instructional objectives. Creativity, physical systems

Most important aspect of design. Workspace and object organizations, visual resemblance of objects, providing lots of options, total user control

Examples**.** http://www.bridgebuilder-game.com/

Role-playing

Descriptions and Uses. Role-playing is an unrehearsed dramatization in which individuals improvise behaviors that illustrate acts expected of persons involved in defined situations. Participants are presented with a realistic or hypothetical situation, in which each of them assumes a role and puts himself/herself in the shoes of that character. They will then have to act and interact with the assumed perspectives and views of the character they are playing. Role-playing helps students understand the perspectives and feelings of different stakeholders in a complex situation of conflicts of dilemmas.

Within the scope of our research, we refer to role-playing as developmental role-playing, the form of role-playing that deals with complex situations for which it is not normally possible to develop a step-by-step procedure. The other form is method-centered role-playing, which we cover in the name of skill building simulations (Wohlking and Gill, 1980). Role-playing has two major uses: 1) training people in attitudinal areas, and 2) integrating and applying learning from a variety of sources to deal with problem situations.

Role-playing is a valuable way to teach subtle, interpersonal skills and to reveal the hidden complexity of many human endeavors. **Common uses of role-playing activities include**:

- Force someone to view events from a different perspective. Give an environmental activist the role of a real-estate developer. And vice versa.
- Allow someone to experience events online that they would not experience in real life. For example, let a man experience sexual harassment as a woman.
- Demonstrate the many perspectives necessary for a complex undertaking. Have a management team guide a project from initial idea to successful product.
- Teach interpersonal skills. Hold a committee meeting to find an effective compromise among competing ideas, groups, and individuals.

Role-playing is simply a less technologically elaborate form of simulations (Blatner, 2009). Within role-playing, there are different levels of technological sophistication, depending on the need of interaction simulation. In general, the more in person interaction that is present, the less simulation required.

- Simple role-playing: when all role players are in one physical setting, when the lesson is more instructor-led than self-studied. In this case the technology platform serves the purpose of a centralized medium for resources, history of interactions, and outcomes.
- Technology-enhanced role-playing: when role players lack face-to-face interaction (such as online classroom, distant learning), when the instructor is less available to provide guidance, or when the lesson is purposely designed to

simulate interaction through the interface.

Suitable instructional objectives. Judgment, language, technical skills, behavior/soft skills, observation, communication.

Most important aspect of design. Focus is on mechanism for interaction, not on a rich media interface. It is much less technologically heavy than a strategy game/simulation.

Examples**.** Mekong eSim:
http://services.eng.uts.edu.au/~robertm/mekong/default.htm

Strategy Games/ Management Simulations/ God games

Descriptions and Uses. Strategy/management games refer to the most complex and technologically elaborate simulation platform of all. The extreme end of this category is games that are highly sophisticated in the visual interface, highly interactive and engaging, and cognitively comprehensive. A strategy game usually include more than one of the other game types, such as role-playing, device simulations, math simulations, interactive case studies, timed games, puzzles, and design/invention games. It is up to the designer to choose between a strategy game and simpler, more linear and less technologically sophisticated option.

In a strategy/management game, "players' decision-making skills have a high significance in determining the outcome. Learners manage the concepts of exploration, building, defending, logistics and conquering. They have to juggle a lot of things at the same time, and coordinate several tasks. Prioritizing is critical. They need long-term philosophies, not just minute-to-minute reactions. They balance short-term vs. long-term goals. They learn the use of time. They have to move between the small and big picture, juggling a bigger task of distraction or destruction of a key facility." (Aldrich 2005)

Suitable instructional objectives. Judgment, theories, reasoning/decision making, process, systems

Most important aspect of design**.** A highly interactive, media savvy and technologically elaborate interface; storyline is complex, actions comprehensive.

Examples. Construction Destruction.

Concept/Mind Mapping

Descriptions and Uses. Concept mapping is a method to create, explore, present, and structure knowledge graphically. In many cases, concept/mind mapping is considered a better alternative to outlines and purely textual hierarchy of ideas. It helps the visual brain process the information and grasp both the meaning of details and the big picture of relevant concepts in a context.

A concept map usually consists of concepts as nodes (boxes, circles), and relationships among them as links. These links are represented by arrows with words or phrases that describe the relationships. In a concept map, the most general concept is often placed at the top, with the less general concepts arranged below hierarchically. There might be several cross-links between the concepts of different segments or domains. A concept map is more free form than a mind map, and often involves more than one single central concept.
Mind mapping is a less fluid version of concept mapping in the sense that it is more like a tree-branching map. Mind mapping are better suited for topics that are more descriptive, while concept mapping works well for more abstract topics. A mind map often evolves around a central concept, which is then broken down into sub concepts or relevant aspects. This is a very useful tool for brainstorming and generating ideas.(Novak &Canas, 2006)

Concept and mind mapping is a simple and useful tool in a wide range of learning activities, such as note taking, brainstorming, idea generation, documenting and tracking team input. The method is also believed to aid memory, communicate complex arguments and ideas, and improve language and writing abilities. The use of concept mapping to capture and archive expert knowledge in several fields is gaining increased popularity in recent years thanks to its simplicity and effectiveness in documenting thoughts and ideas. (Horton, 2006, pp136-137)

Suitable instructional objectives. Creativity, facts, language, observation, communication

Most important aspect of design. Simplicity, visibility of information, easy editing

Examples. The IHMC Cmap Tools: http://cmap.ihmc.us/conceptmap.html

Quiz-show Games

Descriptions and Uses. Quiz-show games, such as those TV game shows, can be used in place of tests official quizzes and exams to test students' knowledge. This will make the task of taking tests less intimidating, more engaging, and more motivating if games are played prior to teaching the subject. Quiz-show games are good for testing factual knowledge, and if done right, will encourage and motivate to learn and improve.

Quiz-show games usually have multiple questions with clearly right or wrong answers, or well-identified outcomes to be achieved. The gamers (or students, in this case) gain scores or make progress toward desired outcomes for getting the right answers. Questions might go from easy to hard, or any other order, with or without other mechanisms or rules to make the games more unpredictable, engaging, and interesting.

Suitable instructional objectives. Facts, language.

Most important aspect of design. Visual simplicity.

***Examples*.** http://www.horton.com/portfolio/quizshow_files/frame.htm

Appendix G: High-level user interface design guidelines – Detailed version

1) Consistency

- Visual consistency: for the overall "look" of a single application or service--splash screens, design elements. Icons, size boxes, scroll arrows, etc. need to appear the same throughout the application, ideally at the same location.
- Inconsistency: It is just as important to be visually inconsistent when things must act differently as it is to be visually consistent when things act the same. Avoid uniformity. Make objects consistent with their behavior. Make objects that act differently look different.
- Anticipation: interpretation of user behavior (anticipation) to offer consistent information/tools.

2) Provide psychological/ emotional comfort

- Put a “human touch” to the human-interface interaction by appealing to all senses with sounds, visuals, texts, dialogues, feedback.
- Use voice/narration where appropriate to create a sense of dialogue. Use audio/video conferencing to add sounds, emotions. Provide encouraging messages when something goes wrong, explanations where necessary, or providing options at decision-making points.
- Allow enough time for users to response.

3) Support cognitive processing of information

- Base the system on a small number of rules that apply throughout. Use generic commands wherever possible.
- Reduce memory load: whenever possible, create "see and point" user entry rather than "remember and type". Only display active components/windows, close unnecessary windows. Front load menu entries.
- Use visuals effectively: color codes, design theme graphics, logical maps/geographic maps/timeline
- Speak the language of learners (e.g. terminologies/jargons, or the lack thereof)

4) Simplicity

- Prioritize: most important components should not have to compete with details for the user's attention – make these prominent. Supplement basic task components by easily accessible menu items and controls that perform additional tasks.
- Modularity of topics: break complex tasks into simpler ones.
- Simplicity means visibility. Avoid hiding components too deeply in submenus or making them accessible only from a contextual menu.
- Focus attention on content delivery, not on fancy media: avoid using background music or graphic that is distracting to users.

5) Efficiency of users

- Prioritize: give easy access to the features that most users will need most of the time; features used less often or by only a subset of users can be less accessible. Optimize for most important tasks. Use large objects for important functions.
- Typical use cases: provide some special browse trails based on anticipated typical workflow of users.
- Stand-alone: provide reference materials or additional information/tools users might need within the application. Have built-in tools, such as browsing or searching, note taking, online discussions, electronic polling, etc., if these are what a typical use case might call for.

6) Aesthetic integrity

- Graphics: keep simple; use them only when they truly enhance usability. Don't overload windows and dialogs with dozens of icons or buttons. Choose right background/foreground contrast. Interface should look pleasant on the screen, even when viewed for a long time.
- Conventionality: don't change the meaning or behavior of standard items(always use checkboxes for multiple choices, not for mutually exclusive choices). Don't use arbitrary symbols to represent concepts; they may confuse or distract users. Try to use metaphors.
- Legible text. Avoid the "Picasso effect" when colorful highlighted text make user view it as pictures and miss the semantics.

7) Accommodate individual differences

- Vision: avoid confusing colors to the color blinds; flexible font size
- Sound: provide audio narrative in addition to/in place of text chunks for the visually challenged.
- Tactic control: level of precision for touch pads, cursors, mouses should be sensitive to individual differences
- Content: adapt to different expertise levels of users.

8) Feedback and communication

- Confirmations: confirm upon receiving input from users.
- Informing of progress: inform users of validity of their actions. Use a progress indicator for potentially long operations.
- Warnings, suggestions, reminders: use a mix of verbal (textual or audio) and visual feedback for warning and suggestive messages (pop-ups, voice messages, animations such as bouncing icons, running hour glass, ticking clock, etc.)

9) User control

- User control: Allow the user, not the computer, to initiate and control actions. Provide the level of user control that is appropriate for your audience. Novice users might need less than total control, while advanced users enjoy a complete control of their tasks.
- Help users avoid dangerous, irreversible actions. For example, if an action might lead to accidental destroy of data, warn users before they proceed.
- Direct manipulation: when the user is acting on an object represented by the computer, the object and the consequences of actions should be immediately visible. For example, with a drag-and-drop operation users can move a file by dragging its icon from one location to another, or drag selected text directly into another document.

10) Forgiveness

- Make most actions reversible. Create safety nets, such as the Undo and Revert to Saved commands.
- Warn users when they initiate a task that will cause irreversible loss of data.
- Anticipate common problems and alert users to potential side effects. Provide extensive feedback and communication at every stage so users feel that they have enough information to make the right choices.

11) Explorable interfaces

- Stable visual and structural elements to give users the overall picture of application and a sense of "home"
- Offer users a default sequence and alternatives, then let them choose whether or not to follow. This lets both the new and goal-oriented users to quickly get their job done and the more curious users to explore the application.
- Level of flexibility: depends on frequency of use for the task. A single-use application for accomplishing an unknown task requires a far more directive interface than a habitual-use interface for experts.

- Menu: should be broad, not deep with many layers of options. Balance constantly displayed menus vs. menu-on-demand

12) Use of metaphors

- Appeal to people's perceptions–sight, sound, touch, and kinesthesia–as well as triggering their memories. Take advantage of people's knowledge of the world by using metaphors to convey concepts and features of your application.
- Use metaphors that represent concrete, familiar ideas, and make the metaphors obvious, so that users can apply a set of expectations to the computer environment, e.g. the metaphor of file folders for storing documents.
- Metaphors should suggest a use for a particular element, but that use doesn't have to limit the implementation of the metaphor. For example, the number of items a user puts in the Trash is not limited to the number of items a physical wastebasket could hold.

Appendix H

Mapping Instructional Strategies to User Interface Design Principles

Interactive Case Studies

Feedback and communication	• Informational: Pop-up questions to trigger thinking where appropriate while the learner is reading (probing, challenging, connecting, predictive, analytical, or evaluative questions). Immediate response can be optional. • Discussion-facilitated: Include note taking tools for real time reflection • Discussion-facilitated: Include discussion tools, such as a discussion forum, with other active users of the application during class session, or outside class time.
Accommodate individual differences/Provide emotional comfort	• Informational: Provide a rich mixture of case materials, including text, sound, animations, etc. Instructions, if present, should be in form of voice narration, with text as an option, and the ability to turn either voice or text on or off. • Informational: Provide various background knowledge materials to accommodate students of different baseline competence in the subject matter. • Discussion-facilitated: Technology can make shy students more willing to participate in discussions. Make students give comments on others ideas and have a system to collect responses/comments in one place (real time or not real time). Allow students to send responses anonymously where appropriate.
Explorable interfaces	• Navigation should be simple but clear and visible, with options to pause, go back to a certain point, or replay a certain section.
Support for cognitive processing of info/efficiency of users	• Informational: Provide a clear story line or structure to present the case. • Informational: Provide occasional summaries as the story goes to help remember the content. • Informational: Avoid providing too much information or details. Make extra materials optional references. • Discussion-facilitated: Provide a resource sharing tool for students to add relevant literature/materials to the platform, e.g. allow to post pictures, upload videos, post a link to the discussion forum.
Simplicity	• Informational: Break content into sub topics if case is too complicated. • Informational: The structure of all content has to be clear, with shortcuts to each section visible at all times (e.g: a permanent table of content, or permanent tabs representing chunks of information) • Discussion-facilitated: simplify for fast actions, for example: a blank text box and a “Submit idea” button to collect real time reactions from classmates to an argument being raised by a fellow student.

Concept/Mind-Mapping

Simplicity	• Use the most neutral background possible, with no visual distraction and a sense of a large empty canvas to work on. • Use just one or two layers of information, i.e. all relevant information is either permanently on the screen, or can be accessed with one mouse click. • Most important features/functions should be always there on the toolbar, and can be used by dragging and dropping (no going to the dropdown menu and select commands)
Support cognitive processing of information/User efficiency	• Provide note taking tool to capture thoughts and ideas that are not ready to go onto the map • Help users keep track of different versions of their work (occasionally ask users to save, and keep that version separately in the archive for short-term future retrieval, e.g. always keep 2-3 latest versions) • Provide different options for visual layout formats of maps (e.g. central concept on top, in the middle, on the right) • Make zooming effortless so that users can always go into a small area for focused attention or back out to see the big picture • Make it easy to edit: move things around, change the layout, edit text and pictures
Aesthetic integrity	• Use simple graphics, very minimal text • Encourage users to think of and use strong and short texts (words are preferred, short phrases only). This can be somehow enforced by constraining the text box sizes. • Options to hide and show details to avoid clustering, such as providing links to additional text or pictures. However use no more than one layer of hidden information.

Design/Invention Games

Simplicity	• Have most of real estate dedicated as a workspace (a board, a canvas, a work area) where objects can be placed and ideas tested out. • Set simple rules, focus on providing several ideas and objects. • Focus on functional fidelity of objects, visual fidelity of each object can compromise.
User control	• Users have total control for exploration: no rigid built-in path • Provide several options for editing and reviewing • Enforce reality: If two physical parts do not fit in reality, users should not be allowed to be able to attach them.
Feedback and communication	• Give prompt feedback when something goes wrong: a component is upside down, in a wrong position, etc.
User efficiency	• Support imagination by providing lots of options, prototypes, suggestions • Like the real world, most design actions are heavily visual: drag/drop command, editing commands • Organize objects (or building blocks) in logical groups

Device Simulation

Consistency	Also Aesthetic Integrity Require significant fidelity with real world • While the virtual product is not full scale, the relative physical proportions of components have to be accurate. • Whatever the scale, the model should not distort users' perception of real product size, especially in features that require manual operations. Occasionally put users in visual contexts that provide perspectives with the real world. • Colors and sounds have to be consistent with the real world, as it has impact on users' cognitive and emotional reactions. • Although absolute visual and system fidelity is not required, make sure simplifications do not make the model unrealistic (e.g. making the operations too much easier than they actually are).
Feedback	• Feedback must be very timely, accurate, and educational preferably narrated if physical activities are being performed, or the tasks at hand already require heavy visual processing. • Detailed feedback should be given at the end of the exercise/simulation/experience for more in-depth reflection.
Efficiency of Users	• Provide both opportunities to explore different features of the products, as well as concrete assignments with specific learning goals that facilitate explorations along predefined paths. • Accommodate individual differences in visual/hearing capabilities by allowing users to adjust volume, zoom, and/or providing options of text/narration • If time is not a critical factor affecting performance, allow users to pause and resume at their convenience.

Math Simulation

Support cognitive processing	• Make list of variables/values/assumptions accessible anytime so that users know what the input is at any moment. • Highlight the change in results caused by change in input • Provide worked examples as a demo. • Provide background knowledge as reference materials (theories, formulae, principles)
Forgiveness	• Allow users to make and correct errors in every step of the analysis: make these options explicit and visible.
Simplicity	• Use the simplest background to highlight analysis/calculation tasks. • Focus on content and effective analysis presentation, not fancy graphics and multimedia.
Explorable interfaces	Also Efficiency • Allow users to see what they did in the previous steps while still showing what the results to date are. • Keep a history of analyses for retrieval without reentering data • Make supporting tools (calculations, charts, graphs) accessible at all times.

Quiz Show Game

Accommodate individual differences	• Questions of different levels of difficulty. • Flexibility in achieving required score.
Forgiveness	• Do not punish too hard for early mistakes. Allow multiple attempts
Simplicity	• Simple, short, clear answers. • Intuitive command buttons for answers to avoid confusion that affects results. • Focus on learning, not entertainment or media of game show. • Background should not be distractive. Background music, if any, should be kept to a minimum. • When a question is presented in textual format, make sure it's clear, both linguistically and visually. Don't use colored or highlighted text, unless absolutely necessary.
Feedback and communication	• Always ask users to confirm an answer. • Provide users with opportunities to change answers before proceeding to the next step. • Quiz-show games are usually timed. Display the clock to guide users. • Sound and graphic alerts (such as timeout, wrong/right answers) should not be too loud or too bold. • Provide educational feedback after an answer is locked in, whether it is correct or incorrect. If the game is introduced before the subject is supposed to be taught, refer to relevant materials to encourage students to get the facts.

Role Playing

Simplicity	• Simplify the interface: give priority to rich interactivity, not a rich media show case. (Horton, 2006) • Do not show what users can easily imagine. (Horton, 2006) • Balance the level of real-life interaction (with instructor, other role players) with the level of built-in interaction - If there is a lot of face-to-face interaction (in a classroom setting): the interface can be minimized to serve as a centralized medium for resources, records of interactions, and analyses. - If there is a lack of in-person interaction (e.g. role players interact online): more sophisticated features to create a sense of interaction (judgment, emotion, a sense of community)
User control/Direct manipulation/Forgiveness	Be very accurate about what a character can and cannot manipulate or control. • Some of his/her actions can be reversed; some cannot, especially those involving other players. • What a player can see and influence needs to reflect the real world power/authority structure. • Combine fluidly browsing and action modes
Feedback and communication	• Provide ongoing status of interaction and state of affairs. Dedicate a considerable amount of permanent real estate for providing context and record interactions. • Give in-depth feedback of actions and consequences. Provide opportunities to take corrective actions. • Corrective actions should not be suggested explicitly. In role-playing, learning occurs in context and feedback. Always help users be aware of how their action relates to others, and let them make the judgment. • For online role-playing: a built-in live forum is essential to create lively interactions among parties.
Provide psychological/emotional comfort	• Roles much be specific, and paired with clear duties • Match roles with personality and skills • Use role names in messages and interaction (as opposed to real names) • Modality principle: where possible, use audio speech instead of text to add the human impact and a sense of conversation.

Skill Building Simulation

Efficiency of user	• Gradually reduce scaffolding: increase the challenge at every step: show me, teach me, coach me, let me. • Offer lots of practice • Divide big task into smaller tasks and graduate challenges gradually • For easy tasks, let users use their intuition. For more complex tasks, demos and guidance are necessary.
Use of metaphors	• Have a "virtual" coach who trains and supports the user. Give a name, a face, and pop him up when feedback is given. But don't be annoying. • Interface should have moderate fidelity with the real world, but does not have to be total fidelity (simplifications are desirable to avoid distractions and focus on the skill being learned). • Use visual metaphors for command/action buttons (that mimic/represent the physical action, such as drag and drop for locating, associating, attaching)
Feedback and communication	• Teach in feedback: give intrinsic and educational feedback. • For invalid actions: give explanation • Indicate progress of tasks by elapsing clock, color coding, etc.

Strategy/Management Games

Use of Metaphors	• Rich and realistic simulated social and physical environment. • Scenario-specific reference materials (e.g. file cabinets, to-do lists as agenda) • Interruptions and crises just like the real world (phone, fax)
Simplicity/ Efficiency of users	• Introduce the context clearly, including the scenario and the learner's role in it. • Deep, unifying assignment: a single task/goal, don't try to cover everything. • Don't show what learners can easily imagine. • Deeply articulated world to give rich context: materials created in simple media
Feedback and communication	• Primary feedback through reactions to learner's actions. Major errors produce attention-getting results. • Most strategy/management games involve multiple players: design built-in communication tools within the interface
Explorable Interfaces/ Forgiveness	• Opportunities to fail and to correct minor problems. • Divide complex games into simpler tasks to give landmarks and help exploration

Appendix I

Specific Instructional Events for Specific Instructional Strategies

Interactive case studies

Instructional event	Events
Gain attention	• Present the situation briefly as a conflict, a crisis, a controversy, a dilemma • Use a current event, an interesting video demo. • Ask a critical leading question, use a speech, set up for a debate
Inform learners of objectives	A case study is usually an open-ended problem that does not have a unique solution. • Break down objectives into small and tangible goals, rather than a few abstract overarching goals (e.g. "understand potential conflicts between land owners and state agencies for Right Of Way, and solutions to resolve them", instead of "understand the difficulty of ROW acquisition") • Establish objectives for both process and results – the course of interactions is usually an important learning objective in itself.
Stimulate recall of prior learning	• Provide optional materials for students to gain background. Make sure students have enough background knowledge – individual differences, because "a successful case study experience grows out of a solid, fundamental understanding of a subject"(Meyers and Jones, 1993) • Use a popular current event to trigger association to prior knowledge (again, make sure to give a summary to those who might not know the event
Present the content	• <u>Informational</u>: Break content into sub topics if case is too complicated. • <u>Informational</u>: The structure of all content has to be clear, with shortcuts to each section visible at all times (e.g: a permanent table of content, or permanent tabs representing chunks of information) • <u>Informational</u>: case can be presented as a "virtual field trip" that takes students to a virtual site where the story takes place. Students can • Coherence principle: adding interesting material can hurt (Clark, Mayer)
Provide "learning guidance"	• <u>Discussion-facilitated</u>: most real estate dedicated to supporting discussions, such as displaying feedback, comments, ideas, and to providing supporting documents (text, videos, etc.) • <u>Discussion-facilitated</u>: use online community as support, via forums or discussion boards • Apply the personalization principle: have a virtual coach to guide through the case to create a sense of conversation • <u>Informational</u>: Provide rich resources for reference • <u>Informational</u>: Ask questions as learner go through the case to trigger thinking.
Elicit performance (practice)	• <u>Informational</u>: leading questions encourage students to dig deep into a certain aspect, and can help achieve previously defined learning goals or sub-goals. • <u>Discussion-facilitated</u>: Reward challengers, and ideas. • <u>Discussion-facilitated</u>: When learners interact through an interface instead of in

	person, use emotionally charged "icons" or features for emotional responses, such as a flag for disagreements, a thumb-up for agreement. • Informational: Ask questions as learner go through the case to trigger thinking.
Provide feedback	• Discussion-facilitated: most real estate dedicated to supporting discussions, such as displaying feedback, comments, ideas, and to providing supporting documents (text, videos, etc.)
Assess performance	For case studies, it's the process, not the result that is the most importance assessment. • Consider win/lose state as a metric (such as a debate winner), but should not be the only one assessment criteria • Align metrics with stated objectives • Have peer assessment in place (and have them define it too). They might learn more from each other than from their own activities. • Self assessment: reflection should be a key assessment metric, as most of learning in case studies occurs in reflection
Enhance retention	• Suggest new situations where knowledge can be applied, or can be challenged • When possible, have students participate in a real world situation (students of a legal subject participating in a trial or a negotiation with a role similar to what they are playing)

Device simulations

Instructional event	Events
Gain attention	• Use an interesting video demo. • Although it's not a game, have a challenge/competition to set up a goal to motivate students and solicit performance.
Inform learners of objectives	• Express goals as specific tasks • Create specific assignments to target specific goals
Stimulate recall of prior learning	• Have pop-up probe questions to check/confirm mastery of background knowledge
Present the content	• Have a somewhat linear structure to content presentation to provide information gradually. This is especially true in teaching procedures. • For highly visual applications that focus on operations: only display the most relevant information on the current task to be carried out. • For more informational models: provide access additional information as an option.
Provide "learning guidance"	• Apply the personalization principle in providing guidance (Clark, Mayer): conversational style and virtual coaches, rather than text-based information • In providing feedback and guidance, make explicit references to prior knowledge as well as potential future consequences
Elicit performance (practice)	• Break down learning goals into small assignments • Trigger thoughts: ask questions, or prompt users to self ask questions. • Have different levels of difficulties of tasks
Provide feedback	• With device simulation, feedback has to be prompt and accurate right after action is taken • Provide comfort: the modality principle – add sound, narration are generally

	better than text. This creates a sense of conversation • Use short quizzes, multi-choice questions as educational feedback and learning guidance.
Assess performance	• Performance can be assessed for every action, or every set of actions serving a particular assignment. Students know how they are doing as they are doing it. • Provide comprehensive assessment at the end for reflection.
Enhance retention	• Educational feedback that make references to future applications or challenges.

Math-based simulations

Instructional event	**Events**
Gain attention	• Emphasize the new and exciting aspects of the tool: show the most unconventional feature(s) of the simulation as striking differences compared to traditional labor-intensive mathematical analyses.
Inform learners of objectives	• Introductory demo of simulation can create appropriate expectations for learning. • Create specific assignment to be completed.
Stimulate recall of prior learning	• Have pop-up probe questions to check/confirm mastery of background knowledge
Present the content	• Have a somewhat linear structure to content presentation to provide information gradually. This is especially true in teaching procedures. • The interface should have an experimental and explorative nature, but concrete assignments with specific goals help emphasize important points (e.g. find the largest load a beam can take)
Provide "learning guidance"	• Apply the personalization principle in providing guidance (Clark, Mayer): conversational style and virtual coaches, rather than text-based information • In providing feedback and guidance, make explicit references to prior knowledge as well as potential future consequences
Elicit performance (practice)	• Establish specific goals to pursue • Offer much practice • Trigger thoughts: ask questions, or prompt users to self ask questions. • Have different levels of difficulties of tasks
Provide feedback	• Provide prompt and accurate feedback. Refer to additional theory/background materials when needed. • Provide comfort: the modality principle – add sound; narrationis generally better than text. This creates a sense of conversation • Use short quizzes, multi-choice questions are educational feedback and learning guidance.
Assess performance	• Record interaction history as an assessment criterion. This might give insight into the students' thought process • In addition to official assessment (how well students accomplish predefined goals), provide a means for students to self-assess (such as a summary of actions, and their results)
Enhance retention	• Use media to introduce potential application of the knowledge being learned • Relate/compare students performance to expert performance

Skill building simulations

Instructional event	Events
Gain attention	• Set up a challenge, and/or a prize
Inform learners of objectives	• Create specific assignments to target specific goals
Stimulate recall of prior learning	• Have pop-up probe questions to check/confirm mastery of background knowledge during the process, especially after an important decision
Present the content	• Have a somewhat linear structure to content presentation to provide information gradually. • For highly visual applications that focus on operations: only display the most relevant information on the current task to be carried out. • For complex tasks: provide tools for further research (browsing, searching), or background information
Provide "learning guidance"	• Apply the personalization principle in providing guidance (Clark, Mayer): conversational style and virtual coaches, rather than text-based information • In providing feedback and guidance, make explicit references to prior knowledge as well as potential future consequences
Elicit performance (practice)	• Break down learning goals into small assignments • Trigger thoughts: ask questions, or prompt users to self ask questions. • Have different levels of difficulties of tasks • Offer much practice, but make it optional so that students can choose how much practice they do (to accommodate students with different learning curves)
Provide feedback	• With device simulation, feedback has to be prompt and accurate right after action is taken • Provide comfort: the modality principle – add sound, narration are generally better than text. This creates a sense of conversation • Use short quizzes, multi-choice questions as educational feedback and learning guidance.
Assess performance	• Emphasize learning, not acting: the goal is to learn the skills to be learned, not to go through the exercise in the shortest amount of time or the fewest mouse clicks. • Procedural actions can be recorded and use as one assessment criterion • Provide comprehensive assessment at the end for reflection.
Enhance retention	• Have a report of student performance, what they did well and what they did not do well. • Relate/compare students performance to expert performance

Design/Invention games

Instructional event	Events
Gain attention	• Show the best demo products to inspire • Although it's not a game, have a challenge/competition to set up a goal to motivate students and solicit performance.
Inform learners of objectives	• Have criteria for end products, but leave the problem open-ended to encourage creativity • Reward creativity and originality • To help constrain the scope: give examples of what not to do • Give students a chance to challenge the rules
Stimulate recall of prior learning	• Base problem on an existing issue to be resolved • Provide or link to background information where appropriate
Present the content	• Always have the three most important components visible: workspace, objects, editing options • Let users know how additional information about an object, a design rule, or a suggestion can be assessed • Have a benchmark system to measure creativity or unconventionality (e.g. indicate typical options, extreme options, popular options) – this would motivate and challenge students to go far from conventional design.
Provide "learning guidance"	• Apply the personalization principle in providing guidance (Clark, Mayer): conversational style and virtual coaches, rather than text-based information • In providing feedback and guidance, make explicit references to prior knowledge as well as potential future consequences
Elicit performance (practice)	• Make suggestions, offer ideas to help trigger thinking, especially when students seem to get stuck • Have a list of popular/possible design errors as a reference, and provide reasoning. Do not provide this to students up front. Wait for them to make mistakes and then offer.
Provide feedback	• Give feedback on practicability of a design (whether or not it's functionally or physically possible), not on merit of design. • Emotions can help boost creativity: be enthusiastic in positive feedback, and supportive and encouraging in negative feedback
Assess performance	• In addition to teacher's assessment, have students evaluate their own design, for example: originality vs. practicability (what are the things you want to implement, which theoretically would improve the design significantly, but cannot because of time/cost/physical constraints?) • Have peer assessment (e.g. vote for the best design)
Enhance retention	• Where practical have students create physical prototypes of their virtual creations

Role-playing

Instructional event	Events
Gain attention	The “attract mode”: • Present the situation as a conflict, a crisis, a controversy, a dilemma, a comedy • Use a current event, an interesting video demo. • Ask a critical leading question, use a speech, set up for a debate • Present a prize for an outstanding outcome (e.g. a pair of football tickets to the highest scoring person)
Inform learners of objectives	• Introduce the context fully and clearly, including the scenario and the learner's role in it. • Match role to personality and skills. • Pay attention to your student diversity: who should be assigned which role? Are their social skills adequate? Is their background knowledge of the subject sufficient? • Objectives might be the same, but how to assess the achievements might be different for different students in different roles. Are there any major differences in the roles that require “customized” assessment? • Promise support and opportunities to learn
Stimulate recall of prior learning	• Make sure your students have the background (bare competence) before assuming a role. • Show a short video that complements the topic being investigated, but with familiar content to students. • Have students predict the outcome of a situation using their current judgment of the issue.
Present the content	Content presentation has to be stimulating and engaging in order to keep learners in the game/task. So the key is to maintain attention. • Complex content should be modularized into meaningful chunks: to reveal the situation layer by layer. This will help stimulate thinking as students explore the complexity in a comprehensible manner. • Coherence principle: adding interesting material can hurt (Clark, Mayer) • Align each major stimulus or content chunk with learning goals, or clearly indicate why it’s relevant to achieving the goals
Provide "learning guidance"	• Pay attention to the “stage” where the status of interactions is presented/displayed: use this as implicit guidance for the learners. • Offer challenges for learners to expand the reasoning of current situation to another context • When in person interaction is limited: use online community as support, via forums or discussion boards • Single player role play: apply the personalization principle (Clark, Mayer): conversational style and virtual coaches • Provide rich resources for reference (both browsing and searching)
Elicit performance (practice)	• Establish sub-goals to elicit performance • Set up more milestones for critical tasks to prompt practice • Trigger thoughts: ask questions, or prompt users to self ask questions. This is best done through interactions among participants of role-playing. A challenge from a party of conflicting interest usually results in well

	thought through responses. • Dramatize on the method of delivery of these challenges: a high-importance email, an alert, a press conference, a newspaper headline.
Provide feedback	• In role-playing, the best feedback should be given as a feedback from the community, not from the interface or program. It should create a sense of interacting with other role players, instead of with a computer manipulating everything behind the scenes. • Update on progress, how the situation is unfolding • Provide comfort: the modality principle – add sound, narration, instead of all text. This creates a sense of conversation
Assess performance	For role-playing, it's the process, not the result that is the most importance assessment. • Consider win/lose state as a metric, but should not be the only one assessment criteria • Align metrics with stated objectives • Assessment might change during the course of role-playing. It might be necessary to revisit criteria for assessment, as well as rules for playing. • Have peer assessment in place (and have them define it too). They might learn more from each other than from their own activities. • Self assessment: reflection should be a key assessment metric, as most of learning in role playing occurs in reflection and might not represented in final state results
Enhance retention	• Suggest new situations where knowledge can be applied, or can be challenged • Having a strong theme to the situation helps long-term encoding, and hence retention • Graduate challenge: consider a certificate if appropriate. This should be a very good reminder of what key lessons they take away from the learning experience. • When possible, have students participate in a real world situation (students of a legal subject participating in a trial or a negotiation with a role similar to what they are playing)

Strategy games/Management simulations/God games

Instructional event	**Events**
Gain attention	The "attract mode": • Present the situation as a conflict, a crisis, a controversy, a dilemma, a comedy • Have a competition
Inform learners of objectives	• Introduce the context fully and clearly, including the scenario and the learner's role in it. • Define clear, colorful characters • Define rules, winning status

	• Allow users to choose roles that match their personality and skills.
Stimulate recall of prior learning	• Provide the storyline • During the game, refer to actions or results from previous stages of game
Present the content	• Complex content should be modularized into meaningful chunks: to reveal the situation layer by layer. This will help stimulate thinking as students explore the complexity in a comprehensible manner. • Provide multiple ways to achieve a goal • Introduce variety: use different variables, involve more factors so that multiple plays are interesting • In complex games, integrate a research tool for students to search for further information, possibly another stand-alone tool that helps understand the problem at hand better.
Provide "learning guidance"	• When in person interaction is limited: use online community as support, via forums or discussion boards • Single player role play: apply the personalization principle (Clark, Mayer): conversational style and virtual coaches • Provide rich resources for reference (both browsing and searching)
Elicit performance (practice)	• Set up more milestones for critical tasks to prompt practice • Trigger thoughts: ask questions, or prompt users to self ask questions. This is best done through interactions among participants of role-playing. A challenge from a party of conflicting interest usually results in well thought through responses. • Dramatize on the method of delivery of these challenges: a high-importance email, an alert, a press conference, a newspaper headline. • Emphasize learning, not mere acting. Leave time for reflection. • Challenge learners
Provide feedback	• Provide feedback from co-players for a more immersive feel • Provide feedback from the simulated environment (other characters and objects), not from the non-playing character. • Update on progress, how the situation is unfolding • Provide comfort: the modality principle – add sound, narration, instead of all text. This creates a sense of conversation • Don’t give too much explanation for actions’ consequences. Let the game playout and reveal the cause of failure (or success)
Assess performance	• Consider win/lose state as a metric, but should not be the only one assessment criteria • Have lessons learned as an assessment criterion. Students might learn more from each other than from their own activities. • Self assessment: reflection should be a key assessment metric, as most of learning in role playing occurs in reflection and might not represented in final state results
Enhance retention	• Having a strong theme to the situation helps long-term encoding, and hence retention

Concept/Ming mapping

Instructional event	Events
Gain attention	• Set up a goal, a competition, an award (for maps with best ideas, most diverse ideas, most irregular shapes). • Show a demo of how a map is created (have a feature that record the formation/growth of an idea map)
Inform learners of objectives	• Have criteria for end products, but leave the problem open-ended to encourage creativity • Reward creativity and originality
Stimulate recall of prior learning	• Trigger students to recall past experiences related to the subject by presenting a whole range of graphics, stories that might make them start thinking about issues around the topic under consideration.
Present the content	• Encourage the use of succinct language to express ideas by limiting the space available for an entry (but not too limited) • Have a built-in clip art for users to use icons to present ideas in place of or in addition to text when possible
Provide "learning guidance"	• Use a built-in glossary, thesaurus, encyclopedia to help trigger ideas
Elicit performance (practice)	• Have a built-in glossary, thesaurus, encyclopedia to help trigger ideas
Provide feedback	• Concept/mind mapping is all about creating ideas. Dedicate an area for summary of statistics, such as number of branches, sub-branches, ideas, "depth" of map, etc.
Assess performance	• In addition to teacher's assessment, have students evaluate their own design • Have peer assessment (e.g. vote for the best design)
Enhance retention and transfer to the job	• Ask for a summary of 3-5 best ideas from their map, as highlights in their opinion. • Ask students about the light-bulb moments, or most rewarding/satisfying/creative moment in the learning experience (this is a positive reinforcement)

Quiz-show games

Instructional event	Events
Gain attention	• Set up a goal, a competition, an award
Inform learners of objectives	• Explain rules • Define win/lose states
Stimulate recall of prior learning	• This kind of games is more like tests and quizzes. Provide hints, background reading to help students answer a question, upon request.
Present the content	• Short, accurate, succinct questions to avoid confusion. • Organize questions in various ways so that students have options of what kind of questions or topics they want to answer next.
Provide "learning guidance"	• Through feedback.
Elicit performance (practice)	• Enforce a time limit.
Provide feedback	• Feedback should be educational with explanations, whether answer is wrong or right. • Always inform learners of their performance (e.g. how many questions they got right, what level they are at)
Assess performance	• Criteria should be very clear and assessment always reflects the rules established.
Enhance retention and transfer to the job	• Ask students about the most interesting things they learned from the game, questions that confirm or challenge their prior knowledge of the subject.

Appendix J: Student Background Checks Programmed in EDDEaid

For instructional goals and strategies

Student background	Goal	Strategy	Message
- Domain KL: None or Limited	Judgment Or Reasoning/DM Or Creativity Or Leadership		Your students might not yet have enough background in domain knowledge to do well with this learning objective. Choose a learning strategy that provides substantial amount of basic knowledge.
- Domain KL: Substantial	Facts Or Physical systems		Your students' domain knowledge indicates that they might have met this learning objective. You might want to consider a more challenging objective.
- Savvy + very savvy > 2 (Very low + low)		Quiz-show games	Your audience seems to be too technology-savvy for these simple games.
- savvy + very savvy < low + very low		Device simulations Or Strategy games	Your audience seems to have low technology background and might need training and/or orientation to be ready for this.
- Domain KL: None or Limited		Math simulations	Your students have none or limited knowledge in the domain. Adequate background knowledge might be needed as a prerequisite as the interface for this is largely visual.
- Learning style: sensing > 50%		Role-playing	Your students have a strong preference for facts, while role-playing requires significant intuition. Make sure you provide enough background information in the learning module.
- Learning style: sequential > 50%		Role-playing	Your students have a strong preference for sequential learning, while role-playing is more open-ended. Make sure enough structured is built-in or provided where needed.
- Learning style: sensing > 50%		Strategy games	Your students have a strong preference for facts, while strategy games rely on intuition and making decisions with imperfect information. Make sure you provide enough background information and reference materials in the learning module.
- Learning style: sequential > 50%		Strategy games	Your students have a strong preference for sequential learning, while strategy games more open-ended. Make sure enough structured is built-in or provided where needed.

For interface design

Strategy	Student background	Warning message
Case studies	Domain KL = substantial	Your students already have substantial knowledge in the domain. You might want to focus on an interface that is more discussion-facilitated rather than purely informational.
	Domain KL = None or Limited	Your students have either none of limited background knowledge in the domain. Make sure your learning module is strong at providing information. Pay significant attention to breaking content into sub topics if the case is complicated.
	Sequential > 50%	Make sure the story line is clear and well structured.
	Sum of lowest 2 GPAs > 40%	You have a significant number of low scorers in your student audience. Pay attention to providing multimedia where possible, as low scoring students benefit considerably from multimedia.
Design/Invention games	Sequential > 50%	Your students have a strong preference for sequential learning. Make sure to complement user control/explorability with some suggestive procedure. One way to do this is to break the design exercise into smaller tasks so that students can work on one task at a time and have a sense of progress when a task is completed.
	Sum of lower 2 GPA's > 30%	Give feedback to invalid actions by directing to reference materials that provide examples or background theories.
Device simulations	Reflective > 50%	Your students are reflective learners, who will benefit from occasional pauses. Make sure that option is available by dividing task into sections.
	Visual > 50%	Most students have a preference for visual learning. Command buttons and other action icons should be highly visual, intuitive, and metaphorical.
	Tech savvy + very savvy > low tech + very low tech AND tech savvy + very savvy > 30%	Your students are quite technology savvy. You might want to enable multitasking where appropriate.
	Tech savvy + very savvy <	You have some low tech students in the audience. Do not make

	low tech + very low tech AND low tech + very low tech > 30%	multitasking compulsory. Have options for more guided tasks.
Math-based simulations	Visual > 50%	Your students are visual learners. Make the interface as visual and light in text as possible.
	Domain KL = None or Limited	Your students have no to little knowledge in the domain. As the interface is highly visual, make sure reference materials on background theories are provided at users' convenience.
	Sum of 2 lower GPAs > 40%	You have a significant number of low scorers in the audience. Examples and demonstrations are important to them.
Role-playing	Domain knowledge = None or Limited	Although you should not show what users can easily imagine, students with no or little knowledge in the field might need more explicit guidance and explanations of the cause and consequences of their actions.
	Sequential > 50%	Many of your students are sequential learners and hence might not be comfortable with role-playing that is too open-ended. Have some structure built-in, such as a global navigation systems with areas dedicated to tasks students can intuitively understand.
	Tech savvy + very savvy > low tech + very low tech AND tech savvy + very savvy > 30%	Your students are technology savvy and can handle multitasking.
	Tech savvy + very savvy < low tech + very low tech AND low tech + very low tech > 30%	Your students are not technology savvy enough to be comfortable with required multitasking. Have options for one or few tasks at a time.
Skill building	Tech savvy + very savvy > low tech + very low tech AND tech savvy + very savvy > 30%	Your students are technology savvy and can handle multitasking.

	Tech savvy + very savvy < low tech + very low tech AND low tech + very low tech > 30%	Your students are not technology savvy enough to be comfortable with required multitasking. Have options for one or few tasks at a time.
	Visual > 50%	Your students are visual. Limit text-based content and feedback. Use voice narration instead of text on screen when possible.
Strategy games	Tech savvy + very savvy > low tech + very low tech AND tech savvy + very savvy > 30%	Your students are technology savvy and can handle multitasking. This will make it more challenging, and hence more exciting to them.
	Tech savvy + very savvy < low tech + very low tech AND low tech + very low tech > 30%	Your students are not technology savvy enough to be comfortable with required multitasking. Have options for one or few tasks at a time.

For instructional design

Student background	Event	Warning message
(Age < 25) > 70%	Gain attention	Majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.
(Age >= 26) > 30% or Domain KL = substantial	Present content Elicit performance	There is a big group in your audience that is matured students or your students already have substantial knowledge in the subject. For this group, it's best to present content and elicit performance by relating to real world examples. Have them participate by sharing their knowledge with the class in person or through collaborative tools.
Domain KL = none, limited	Stimulate recall of prior knowledge	Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.
(Age > =26) > 30	Inform learners of objectives	You have a significant group of matured students in your audience who tend to be goal-oriented in learning. Make sure your learning objectives meet their practical need so that they stay motivated.
Tech savvy + very savvy < low tech + very low tech AND low tech + very low tech > 30%	Elicit performance	Your students are not very technology savvy. Make sure options for learning activities are clear. Do not enforce too much multitasking.
Visual > 50%	Present content	Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
Sequential> 50%	Present content	Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.
Sum of 2 lowest GPAs > 40%	Elicit performance	A significant number of your students are low scorers. These students will benefit from multimedia supported learning, and teamwork. Provide materials in various forms, and have team projects to encourage these students to participate and perform.

Appendix K: Post-test Questionnaire for Pilot Design Re-evaluation

For the re-evaluation of the refined materials management learning module that implemented EDDEaid recommendations in October 2010, a few new questions were introduced to assess the usefulness of the newly added features. The post-test questionnaire for this testing is the same as the one used for the November 2007 testing (Appendix B), except that the Learning Experience table at the end was replace by the following four questions.

30. For each of the following features, please rate the usefulness/effectiveness the feature from your experience on the scale from 0 to 10, with “0” being “not useful/effective at all”, “5” being “neutral”, and “10” being “very useful/effective”

#	**Feature descriptions**	**Rating**
1	Color coding for pins (red for “unfound”, green for “found”)	
2	Color coding for activity status (yellow, light green, dark green with check mark)	
3	User performance statistics	
4	“Instructions” button	
5	Ability to “lock/unlock” schedule	
6	Visual feedback (schedule panel changes color when locked, unlocked; activity status changes when pins removed or disassociated)	
7	Ability to move and remove pins on map	
8	Hoover tooltips (information boxes appear upon mouse-overs)	
9	Ability to sort materials	

31. From the list of nine features above, please rank the best three features. Please explain why.

32. What were the problems you ran into?

33. Do you have any other comments? What would you suggest that we do to improve the users’ experience?

Appendix L: Summary of EDDEaid Test User Interviews

PARTICIPANT #1

BACKGROUND

- *Position/title*: Assistant professor, CEM
- *Teaching experience*:1 year as university faculty, 6 years teaching English as a foreign language, 2 years as teaching assistant
- *# of courses designed*: 1.5
- *Formal instructional design training/education*: 2-year teaching certification program, 12 2-day workshops, one 6-months teacher education program
- *Approach to instructional design*: Context-driven, use a formal instructional design method
- *Challenges/most important aspects in instruction design*: 1) addressing learners' differences as different people learn in different ways, 2) building the right mental models for students is more important than pushing content, 3) use the classroom as a portal to get students interested and engaged; they can get extra information from multiple information sources outside of classroom
- *Student background data collected*: major, year, learning, origin
- *Experience in teaching with technology/simulated learning*: variability game to teach productivity, VICO (Virtual Construction) applications, Naviswork/Autodesk
- *Pro/con of technology-supported learning in general*: Makes teaching more effective but difficult to design well. There might be a learning curve just to know the mechanics of using the application.

EDDEaid DESIGN 1

- *Purpose of using EDDEaid*: Evaluate an existing technology-supported teaching tool.
- *Instructional topic*: 4D unit for BIM: examine the capabilities and limitations for 4D in supporting the decision making process of project managers.
- *Instructional Goal/Type of knowledge being taught*: Technical skills
- *Instructional objective(s)*:Examine the capabilities and limitations of 4D in supporting the decision making process of project managers.
- *Technology-supported instructional strategy*: Skill building simulations

EDDEaid DESIGN 2

- *Purpose of using EDDEaid*: Create a new technology-supported learning tool
- *Instructional topic*: Interactive BIM case studies.
- *Instructional Goal/Type of knowledge being taught*: Technical skills
- *Instructional objective(s)*:Examine the capabilities and limitations of 4D in supporting the decision making process of project managers.
- *Technology-supported instructional strategy*: Skill building simulations

EVALUATION OF EDDEaid

- *New concepts/insights*: Gagne's Nine Events of Instruction
- *Perceived value of EDDEaid*: 1) Informative, information buttons are useful. 2) Very flexible: I can relate to examples, but can also add my own ideas. 3) Multiple uses: good as a starting point, but can be used again to evaluate teaching/learning as classes evolve and students maturing. 4) Helps you formalize and verbalize your thinking in planning and creating instruction, starting with learning objectives then content building then syllabus development, not the other way round. 5) Comprehensive and diverse: choosing a different strategy or goal takes you down a very different path.
- *Ease of use*: Very easy to use
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable
- *Comments/recommendations*: 1) Add a diagram visualizing relationships among the terms/concepts in EDDEaid, 2) After users minimize an event box on screen #3, there should be some visual feedback in the way it looks to tell users "I got what you wrote".
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 4.6/5.0

PARTICIPANT #2

BACKGROUND

- *Position/title*: Assistant professor (starting Fall 2010), CEM
- *Teaching experience*: 1 year as teaching assistant
- *# of courses designed*: 0
- *Formal instructional design training/education*: Basic TA orientation
- *Approach to instructional design*: Experience-based, adopting existing materials
- *Challenges/most important aspects in instruction design*: Content development in areas with limited background
- *Student background data collected*: Plan to collect student background information.
- *Experience in teaching with technology/simulated learning*: Monte Carlo simulations
- *Pro/con of technology-supported learning in general*:

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Create a new technology-supported teaching tool.
- *Instructional topic*: Computer information system: teaching human resource management with a simulated database
- *Instructional Goal/Type of knowledge being taught*: Reasoning/Decision-making
- *Instructional objective(s)*:1) Introduction to human resource management in construction; 2) Understand characteristics and skills; 3) Show issues and challenges; 4) How to make decisions
- *Technology-supported instructional strategy*: Role-playing

EVALUATION OF EDDEaid

- *New concepts/insights*: Gagne's Nine Events of Instruction, Bloom's taxonomy of educational objectives, Felder's index of learning styles, strategies for engaging students
- *Perceived value of EDDEaid*: 1) Diverse: there are several instructional goals to choose from and a wide variety of instructional strategies. 2) Generic: applicable to different domains, not only construction, and not limited to just calculations and technical areas. There are also options for you if you want to teach soft skills. 3) Multiple uses: based on my preference, or my students' preference, and see the difference. 4) Provides lots of ideas about how to teach better.
- *Ease of use*: Easy to use
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and a little bit overwhelming
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable
- *Comments/recommendations*: 1) More examples, more information buttons; 2) Screen #3 is a little bit overwhelming, should be broken into two screens
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 4.8/5.0

PARTICIPANT #3

BACKGROUND

- *Position/title*: Assistant professor, Building Construction
- *Teaching experience*: 1 year as faculty
- *# of courses designed*: 3
- *Formal instructional design training/education*: None. Self taught through books.
- *Approach to instructional design*: Experience-based, content-driven. Method: based on standards for accreditation
- *Challenges/most important aspects in instruction design*: Time constraints leading to the content-focused attitude.
- *Student background data collected*: Not for every class. For one class, used a survey to assess student's existing knowledge in that area.
- *Experience in teaching with technology/simulated learning*: Lego games, VICO (Virtual Construction). Using Excel as a calculation-based simulation for the Estimating class
- *Pro/con of technology-supported learning in general*:

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Create a new technology-supported teaching tool.
- *Instructional topic*: Construction estimating
- *Instructional Goal/Type of knowledge being taught*: Calculations/Mathematical analyses
- *Instructional objective(s)*:Analyze the impact of productivity data on the total cost of a building system.
- *Technology-supported instructional strategy*: Math-based simulations

EVALUATION OF EDDEaid

- *New concepts/insights*: Gagne's Nine Events of Instruction, Bloom's taxonomy of educational objectives, Felder's index of learning styles, linkages between instructional strategies and user interface design principles
- *Perceived value of EDDEaid*: 1) Thought provoking and systematic: makes you think about the whole process at different levels from broad to specific, about both what you want to teach and how you teach it, things you might not be thinking about otherwise. 2) Rich: provides a lot of great information and knowledge. Flexible. 3) Student-centered: I get to put myself in the shoes of students and think along the line of how they learn.
- *Ease of use*: Average
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable (I like it very much)
- *Comments/recommendations*:1) Provide guidelines on how to communicate these features with the design team (software designers). 2) Add direct link to survey on Home screen.
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 4.2/5.0

PARTICIPANT #4

BACKGROUND

- *Position/title*: Assistant professor, Building Construction
- *Teaching experience*: 7 months as faculty
- *# of courses designed*: 1
- *Formal instructional design training/education*: None.
- *Approach to instructional design*: Experience-based, content-driven. For both content development and teaching method: based on my background in the topic, how I learned as a learner, and what other professors have been doing.
- *Challenges/most important aspects in instruction design*:
- *Student background data collected*: Informally ask students about their background in the subject. Based on the curriculum and prerequisites. Also get pushed from the industry to address their needs in the course content.
- *Experience in teaching with technology/simulated learning*: Simple games on PowerPoint using existing templates, mostly quizzes.
- *Pro/con of technology-supported learning in general*: Depends on the technology skills of the instructor. The more savvy he is, the more comfortable and effective to use technology. Students always love it.

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Create a new technology-supported teaching tool.
- *Instructional topic*: Construction soils. Earthwork and infrastructure construction: simulate soil conditions, project partners. Students have to gather information, lots of room for mistakes. Choices have consequences. Have criteria for successful projects. Students manage the resources and make decisions.
- *Instructional Goal/Type of knowledge being taught*: Reasoning/Decision making
- *Instructional objective(s)*:

- *Technology-supported instructional strategy*: Role-playing

EVALUATION OF EDDEaid

- *New concepts/insights*: Gagne's Nine Events of Instruction, Bloom's taxonomy of educational objectives, Felder's index of learning styles
- *Perceived value of EDDEaid*: 1) Provides a more complete and structured view of the instructional strategies in the form of simulation/game-based applications. 2) Helps to design learning modules in a more logical and structured manner. 3) Informs users of potential problems/traps/issues that might lie ahead. 4) Provides guidelines for user interface design
- *Ease of use*: Very easy to use
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable
- *Amount of user effort required*: Reasonable
- *Flexibility*: A little bit structured in the way instructional goals are mutually exclusive. I'd like to choose more than one goal at a time.
- *Comments/recommendations*: Build this into an Instructional Information Management System. 1) EDDEaid as a centralized place for collecting and synthesizing ideas. 2) Might organize designs by topic, keywords and make them searchable. 3) As a new user works with a design, they can see what others have done before.
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 4.1/5.0

PARTICIPANT #5

BACKGROUND

- *Position/title*: Assistant professor, Construction
- *Teaching experience*: 2 years as faculty, 4 years as teaching assistant
- *# of courses designed*: 3
- *Formal instructional design training/education*: Basics through TA and faculty orientation.
- *Approach to instructional design*: Depending on the class. Adopt some curriculum standards to meet requirements.
- *Challenges/most important aspects in instruction design*: 1) Most construction students are visual, how to teach them best. 2) The flow of instructional sequence is very important.
- *Student background data collected*: Experience in construction, special learning needs, baseline knowledge.
- *Experience in teaching with technology/simulated learning*: As a TA: simulations. As a faculty: developed a construction safety game to recognize hazards on job sites.
- *Pro/con or challenges of technology-supported learning in general*: How to make it a learning instead of playing tool. The ultimate goal is learning, not winning.

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Evaluate an existing technology-supported teaching tool.
- *Instructional topic*: Simulation of construction equipment site operations
- *Instructional Goal/Type of knowledge being taught*: Procedures

- *Instructional objective(s)*: 1) Recognize different tools for creating models of construction equipment operations. 2) Recognize when each tool can be used depending on the specific job site
- *Technology-supported instructional strategy*: Skill building simulations

EVALUATION OF EDDEaid

- *New concepts/insights*: A lot of instructional design knowledge and insights that I might not have thought of before.
- *Perceived value of EDDEaid*: 1) Provides an efficient checklist of things I might not have thought of, but when I see them, I know I need them. 2) Helps review and enhance my design. 3) Helps me address some of the challenges in instructional and game design that I ran into before. 4) I can compare EDDEaid insights with my own observations and student feedback. 5) If I had not previously designed the game, I would probably have taken every thing from EDDEaid.
- *Ease of use*: Very easy to use
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable
- *Comments/recommendations*:1) 1st time users might be unclear about what instructional goal to choose in step 1. 2) List of 7 or more items are hard to remember and compare.
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 4.3/5.0

PARTICIPANT #6

BACKGROUND

- *Position/title*: Assistant professor, Construction
- *Teaching experience*: 3 years as faculty, 1.5 years as teaching assistant
- *# of courses designed*: 3
- *Formal instructional design training/education*: A communication course that covered some teaching methodology. A few informal training workshops at school's Office of Effective Teaching where experienced faculty come and talk about their experience.
- *Approach to instructional design*: Vary content and teaching format based on student audience as I have very different groups of students, some typical college students, and many non-traditional students (adults within wide age range)
- *Challenges/most important aspects in instruction design*: Again, addressing diverse students needs and background. I have to form teams of students with mixed background across different groups.
- *Student background data collected*: Informal student introductions posted to Blackboard.
- *Experience in teaching with technology/simulated learning*: Use Stroboscope in Construction Equipment and Method class to develop simulation. It's mostly a programming application with limited user interface. Issue: complex, simulation runs on three different platforms.
- *Pro/con or challenges of technology-supported learning in general*: Some tools are researcher-oriented, not student or practitioner-oriented, hence difficult to use for teaching.

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Evaluate an existing technology-supported teaching tool.

- *Instructional topic*: Simulation of construction equipment site operations
- *Instructional Goal/Type of knowledge being taught*: Procedures
- *Instructional objective(s)*:1) Recognize different tools for creating models of construction equipment operations. 2) Recognize when each tool can be used depending on the specific job site
- *Technology-supported instructional strategy*: Skill building simulations

EVALUATION OF EDDEaid

- *New concepts/insights*: Pretty much everything.
- *Perceived value of EDDEaid*: Astructured process that blends in the knowledge in different areas. (However, I am not clear how the linkages and recommendations are made, and whether or not they are 100% reliable)
- *Ease of use*: Average
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive but a little overwhelming.
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable
- *Comments/recommendations*: 1) For student data, use headcounts instead of percentage. 2) For first time users, should have local access to instructions and reference materials so that they don't have to go back and forth. Or add a button on every screen for reference materials. 3) Installation procedure: package Adobe AIR with EDDEaid into one file for easier installation.
- *Would use EDDEaid again or recommend to other colleagues*? Yes. But I need to see verifications or confirmations of the value of EDDEaid: add case studies, success stories. As of now I do not trust that 100% information in EDDEaid is valid.
- *Average overall assessment*: 4.2/5.0

PARTICIPANT #7

BACKGROUND

- *Position/title*: Assistant professor, Construction
- *Teaching experience*: 3.5 years as faculty, 3-4 years as teaching assistant
- *# of courses designed*: 6 courses
- *Formal instructional design training/education*: no formal background.
- *Approach to instructional design*: depends on classes – have accreditations, school provide some guidelines
- *Challenges/most important aspects in instruction design*: for a topical area, how much depth can you reach in one class, where students are in terms of intellectually development
- *Student background data collected*: their interest in the subject and where they are in terms of domain knowledge.
- *Experience in teaching with technology/simulated learning*:4D commercially developed
- *Pro/con or challenges of technology-supported learning in general*: technology is there, but not adapted to the domain.

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Design a new technology-supported learning tool.
- *Instructional topic*: RFI (Request for Information) cycle

- *Instructional Goal/Type of knowledge being taught*: Procedures
- *Instructional objective(s)*: Explain the RFI cycle
- *Technology-supported instructional strategy*: Skill building simulations

EVALUATION OF EDDEaid

- *New concepts/insights*: Gagne's events of instruction.
- *Perceived value of EDDEaid*: Conceptual design of the course.
- *Ease of use*: Easy
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable.
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable
- *Comments/recommendations*: 1) Should be able to compare two strategies (designs) to teach one given topic. 2) A visualization of idea progressions to show how lesson plan develops along Bloom's scale. 3) The ability to start the design with specific educational objectives (in addition to the starting point of broad instructional goal like it is now)
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 3.8/5.0

PARTICIPANT #8

BACKGROUND

- *Position/title*: Assistant professor, Construction
- *Teaching experience*: 4 years as faculty, 1 years as teaching assistant
- *# of courses designed*: 10-12
- *Formal instructional design training/education*: a few workshops, NSF Delta program for developing graduate diploma
- *Approach to instructional design*: Content-driven.
- *Challenges/most important aspects in instruction design*: it could be content or context, the approach evolves with the course. Most students are mature with1-25 years of experience, therefore adjustment is always needed. Don't start with students in mind because don't know who they are beforehand.
- *Student background data collected*: experiences with content, previous learning/formal education in the area, research interests. The purpose is to informally determine the level at which content has to be taught.
- *Experience in teaching with technology/simulated learning*: Blackboard management of class
- *Pro/con or challenges of technology-supported learning in general*:

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Design a new technology-supported teaching tool.
- *Instructional topic*: Decision and risk analysis
- *Instructional Goal/Type of knowledge being taught*: Reasoning/decision making
- *Instructional objective(s)*: Compare various alternatives and choose the one with the best payoff
- *Technology-supported instructional strategy*: Interactive case studies

EVALUATION OF EDDEaid

- *New concepts/insights*: All is new.
- *Perceived value of EDDEaid*: Ease of use, the way concepts are connected, feedback on decisions.
- *Ease of use*: easy.
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable.
- *Amount of user effort required*: Reasonable
- *Flexibility*: A little structured.
- *Comments/recommendations*: 1) Make clear how much of the recommendations is based on the hard numbers of the index of learning styles. 2) Relate choice of strategy to class size.
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 4.7/5.0

PARTICIPANT #9

BACKGROUND

- *Position/title*: Professor, Construction
- *Teaching experience*: 19 years as faculty
- *# of courses designed*:7
- *Formal instructional design training/education*: a few formal courses for new member of staff on teaching and learning strategies.
- *Approach to instructional design*: Both content and context-driven, depending the student cohort.
- *Challenges/most important aspects in instruction design*: generating content is not challenging, but accommodating different student abilities is. Example class profile: 120 students from eight different countries, speak 12 different languages. Based on an outline, delivery method changes quite often.
- *Student background data collected*: No formal collection. Students provide assessment at the end of class.
- *Experience in teaching with technology/simulated learning*: simulation models for students to work in groups, construction productivity, interactive animation.
- *Pro/con or challenges of technology-supported learning in general*: a blend of delivery is important, can do a good job to get students interested. Might be challenging to incorporate in courses that are accredited with specific requirements.

EDDEaid DESIGN

- *Purpose of using EDDEaid*: Design a new technology-supported teaching tool.
- *Instructional topic*: Risk management
- *Instructional Goal/Type of knowledge being taught*: Theories
- *Instructional objective(s)*: Understanding, knowing
- *Technology-supported instructional strategy*: Interactive case studies

EVALUATION OF EDDEaid

- *New concepts/insights*: Ways to provide feedback using technology.
- *Perceived value of EDDEaid*: Open up options when you start designing the course.

- *Ease of use*: Very easy
- *Amount of information/knowledge built-in in EDDEaid*: Comprehensive and reasonable.
- *Amount of user effort required*: Reasonable
- *Flexibility*: Reasonable
- *Comments/recommendations*: Incorporate experience feedback from users, such as what to do to meet specific accreditation requirements.
- *Would use EDDEaid again or recommend to other colleagues*? Yes.
- *Average overall assessment*: 3.9/5.0

Appendix M: EDDEaid Designs Produced by Test Users

P#1 (1): 4D Unit for BIM class

Topic of Teaching: 4D Unit for BIM class

Instructional Goal: Technical skills

Instructional objectives: Examine the capabilities and limitations of 4D in supporting the decision making process of project managers.

Instructional Strategy: Skill building simulations

User Interface Features:

Feedback and communication

- Teach in feedback: give intrinsic and educational feedback

Efficiency of users

- Gradually reduce learning support: increase the challenge at every step - show me, teach me, coach me, let me.
- Offer lots of practice
- Graduate challenge

Other User Interface comments:

- Your students are visual. Limit text-based content and feedback. Use voice narration instead of text on screen when possible.
- Your students are technology savvy and can handle multitasking.

Instructional Events:

1) Gain attention:

- Comments: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

- Create specific assignments to target specific objectives.

3) Stimulate recall of prior learning:

- Comments: Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- For complex tasks: provide tools for further research (browsing, searching), or background information.
- For highly visual applications that focus on operations: only display the most relevant information on the current task to be carried out.
- Have a hands-on lab-based class to get students up and running with Vico and Navisworks.

- Comments: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Personalization principle in providing guidance: conversational style and virtual coaches, rather than text-based information.

6) Elicit performance (practice):

- Students will gain practice both during in class hands-on session with a simple wall example, but mainly while carrying out their homework assignment.

7) Provide feedback:

- Provide feedback when students present their reflection in class.

8) Assess performance:

- Emphasize learning, not acting: the goal is to learn the skills to be learned, not to go through the exercise in the shortest amount of time or the fewest mouse clicks.
- Provide comprehensive assessment at the end for reflection.
- Performance is assessed both in the presentation the students will give with a reflection of what they learned as well as through a written report. Students are assessed on fluency with tool as well as critical thinking.

9) Enhance retention:

- Have students present and discuss reflection on what the benefits and limitations of 4D are and when to use such technology

P#1 (2) BIM case studies

Instructional topic: BIM case studies

Instructional goal: Facts

Instructional objectives: 1) Describe a case in which BIM was applied to capital projects. 2) Discuss benefits, challenges and shortcomings of the case.

Instructional Strategy: Case Studies

User Interface Features:

Support cognitive processing of information

- Provide a clear story line or structure to present the case.
- Provide occasional summaries as the story goes to help remember the content.
- Avoid providing too much information or details. Make extra materials optional references.
- Discussion-facilitated: Provide a resource sharing tool for students to add relevant literature/materials to the platform, e.g. allow to post pictures, upload videos, post a link to the discussion forum

Explorable interfaces

- Navigation should be simple but clear and visible, with options to pause, go back to a certain point, or replay a certain section

Other User Interface comments:

- Your students have either none of limited background knowledge in the domain. Make sure your learning module is strong at providing information. Pay significant attention to breaking content into sub topics if the case is complicated.
- Make sure the story line is clear and well structured.

Instructional events

1) Gain attention:

- Use a current event, an interesting video demo.
- Comments: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

- Create objectives for both process and results: the course of interactions is usually an important learning objective in itself.

3) Stimulate recall of prior learning:

- Use a popular current event to trigger association to prior knowledge (make sure to give a summary to those who might not know the event).
- Comments: Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- Case can be presented as a "virtual field trip" that takes students to a virtual site where the story takes place.

- Comments: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Case can be presented as a "virtual field trip" that takes students to a virtual site where the story takes place.

6) Elicit performance (practice):

- Ask questions as learner go through the case to trigger thinking.
- To facilitate discussions: reward challengers, and ideas.
- Leading questions encourage students to dig deep into a certain aspect, and can help achieve previously defined learning objectives.

7) Provide feedback:

- If facilitated discussion is the central aspect of the tool: dedicate significant space for feedback, comments, ideas, and to provide supporting documents (text, videos, etc.)

8) Assess performance:

- Make sure to also reward the process, not only the results. Consider win/lose state as a metric (such as a debate winner), but should not be the only one assessment criterion.

9) Enhance retention:

- When possible, have students participate in a real world situation (students of a legal subject participating in a trial or a negotiation with a role similar to what they are playing).

P#2 Human Resource Management

Instructional topic: HRM with Computer Information System

Instructional goal: Reasoning/Decision Making

Instructional objectives: Introduction to human resource in construction; understanding characteristics and skills; Showing issues and challenges; how to make decisions

Instructional Strategy: Role-playing

User Interface Features:

Provide psychological/ emotional comfort

- Match roles with personality and skills
- Roles much be specific, and paired with clear duties
- Use role names in messages and interaction (as opposed to real names)
- Modality principle: where possible, use audio speech instead of text to add the human impact and a sense of conversation

User control/Direct manipulation

- Be very accurate about what a character can and cannot manipulate or control.
- What a player can see and influence needs to reflect the real world power/authority structure.

Feedback and communication

- Give in-depth feedback of actions and consequences. Provide opportunities take corrective actions.
    - if there is a lot of face-to-face interaction (in a classroom setting): the interface can be minimized to serve as a centralized medium for resources, records of interactions, and analyses.

Simplicity

- Simplify the interface: give priority to rich interactivity, not a rich media show case.

Other User Interface comments:

- Although you should not show what users can easily imagine, students with no or little knowledge in the field might need more explicit guidance and explanations of the cause and consequences of their actions.
- Many of your students are sequential learners and hence might not be comfortable with role-playing that is too open-ended. Have some structure built-in, such as a global navigation systems with areas dedicated to tasks students can intuitively understand.
- Your students are technology savvy and can handle multitasking.

Instructional events

1) Gain Attention:

- Set up a goal, a competition, an award (for maps with best ideas, most diverse ideas, most irregular shapes).
- Notes: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

- Have criteria for end products, but leave the problem open-ended to encourage creativity

3) Stimulate recall of prior learning:

- Trigger students to recall past experiences related to the subject by presenting a whole range of graphics, stories that might make them start thinking about issues around the topic under consideration.
- Notes: Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- Encourage the use of succinct language to express ideas by limiting the space available for an entry (but not too limited)
- Notes: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Use a built-in glossary, thesaurus, encyclopedia to help trigger ideas

6) Elicit performance (practice):

- Have a built-in glossary, thesaurus, encyclopedia to help trigger ideas

7) Provide feedback:

- Concept/mind mapping is all about creating ideas. Dedicate an area for summary of statistics, such as number of branches, sub-branches, ideas, depth of map, etc.

8) Assess Performance:

- In addition to teacher's assessment, have students evaluate their own design
- Have peer assessment (e.g. vote for the best design)

9) Enhance retention:

- Ask students about the light-bulb moments, or most rewarding/satisfying/creative moment in the learning experience (this is a positive reinforcement)
- Ask for a summary of 3-5 best ideas from their map, as highlights in their opinion.

P#3 Estimating

Instructional topic: Estimating

Instructional goal: Calculations/Mathematical Analyses

Instructional objectives: Analyze the impact of productivity data on the total cost of a building system

Instructional Strategy: Math-based Simulations

User Interface Features:

Simplicity

- Use the simplest background to highlight analysis/calculation tasks.
- Focus on content and effective analysis presentation, not fancy graphics and multimedia

Explorable interfaces

- Allow user to see what they did in the previous steps while still showing what the results to date are.
- Make supporting tools (calculations, charts, graphs) accessible at all times

Other User Interface comments:

- Your students have no to little knowledge in the domain. As the interface is highly visual, make sure reference materials on background theories are provided at users' convenience.
- Your students are visual learners. Make the interface as visual and light in text as possible.

Instructional events:

1) Gain attention:

- Emphasize the new and exciting aspects of the tool: show the most unconventional feature(s) of the simulation as striking differences compared to traditional labor-intensive mathematical analyses.
- Comments: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

3) Stimulate recall of prior learning:

- Have pop-up probe questions to check/confirm mastery of background knowledge.
- Comments: Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- Comments: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

6) Elicit performance (practice):

7) Provide feedback:

- Use short quizzes, multi-choice questions are educational feedback and learning guidance.

8) Assess performance:

9) Enhance retention:

P#4 Earthwork

Instructional topic: Soils

Instructional goal: Reasoning/Decision Making

Instructional objectives: Enable students to make decisions in complicated situations that simulate the real life scenarios

Instructional strategy: Role-playing

User Interface Features:

Provide psychological/emotional comfort:

- Match roles with personality and skills
- Modality principle: where possible, use audio speech instead of text to add the human impact and a sense of conversation

Simplicity:

- Balance the level of real-life interaction (with instructor, other role players) with the level of built-in interaction
- If there is a lack of in-person interaction (e.g. role players interact online): more sophisticated features to create a sense of interaction (judgment, emotion, a sense of community

Feedback and communication:

- Corrective actions should not be suggested explicitly. In role-playing, learning occurs in context and feedback. Always help users be aware of how their action relates to others, and let them make the judgment.
- Provide ongoing status of interaction and state of affairs. Dedicate a considerable amount of permanent real estate for providing context and record interactions.

User control/direct manipulation:

- Be very accurate about what a character can and cannot manipulate or control.
- What a player can see and influence needs to reflect the real world power/authority structure.

Other User Interface comments:

- Although you should not show what users can easily imagine, students with no or little knowledge in the field might need more explicit guidance and explanations of the cause and consequences of their actions.
- Many of your students are sequential learners and hence might not be comfortable with role-playing that is too open-ended. Have some structure built-in, such as a global navigation systems with areas dedicated to tasks students can intuitively understand.
- Your students are technology savvy and can handle multitasking.

Instructional events:

1) Gain Attention:

- Use a current event, an interesting video demo.
- Real scenarios can attract the student's attention
- Comments: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

- Introduce the context fully and clearly, including the scenario and the learner's role in it.
- Pay attention to your student diversity: who should be assigned which role? Are their social skills adequate? Is their background knowledge of the subject sufficient?

3) Stimulate recall of prior learning:

- Have students predict the outcome of a situation using their current judgment of the issue.
- Show a short video that complements the topic being investigated, but with familiar content to students.
- Comments: Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- Complex content should be modularized into meaningful chunks: to reveal the situation layer by layer. This will help stimulate thinking as students explore the complexity in a comprehensible manner.
- Comments: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.

- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Pay attention to the "stage" where the status of interactions is presented/displayed: use this as implicit guidance for the learners.
- Offer challenges for learners to expand the reasoning of current situation to another context.

6) Elicit performance (practice):

- Dramatize on the method of delivery of these challenges: a high-importance email, an alert, a press conference, a newspaper headline.
- Set up more milestones for critical tasks to prompt practice.

7) Provide feedback:

- In role-playing, the best feedback should be given as a feedback from the community, not from the interface or program. It should create a sense of interacting with other role players, instead of with a computer manipulating everything behind the scenes.
- Update on progress, how the situation is unfolding.

8) Assess performance:

- Define performance indicators in alignment with the instructional objectives you defined on the left.
- Consider win/lose state as a metric, but should not be the only one assessment criterion.

9) Enhance retention:

- When possible, have students participate in a real world situation (students of a legal subject participating in a trial or a negotiation with a role similar to what they are playing)

P#5 Safety - Ladder

Instructional topic: Construction safety

Instructional goal: Judgement

Instructional objectives:

Instructional Strategy: Role-playing

User Interface Features:

Simplicity:

- Simplify the interface: give priority to rich interactivity, not a rich media show case.
- Do not show what users can easily imagine.
    - If there is a lack of in-person interaction (e.g. role players interact online): more sophisticated features to create a sense of interaction (judgment, emotion, a sense of community

User control/direct manipulation:

- Be very accurate about what a character can and cannot manipulate or control.
- Combine fluidly browsing and action mode

Feedback and communication:

- Give in-depth feedback of actions and consequences. Provide opportunities to take corrective actions.

Provide psychological/emotional comfort:

- Roles much be specific, and paired with clear duties
- Match roles with personality and skills
- Modality principle: where possible, use audio speech instead of text to add the human impact and a sense of conversation

Other User Interface comments:

- Although you should not show what users can easily imagine, students with no or little knowledge in the field might need more explicit guidance and explanations of the cause and consequences of their actions.
- Many of your students are sequential learners and hence might not be comfortable with role-playing that is too open-ended. Have some structure built-in, such as a global navigation systems with areas dedicated to tasks students can intuitively understand.

Instructional events

1) Gain Attention:

- Present the situation as a conflict, a crisis, a controversy, a dilemma, a comedy.
- Notes: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

- Introduce the context fully and clearly, including the scenario and the learner's role in it.

3) Stimulate recall of prior learning:

- Show a short video that complements the topic being investigated, but with familiar content to students.
- Make sure your students have the background (sufficient competence) before assuming a role.
- Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- Align each major stimulus or content chunk with learning goals, or clearly indicate why it is relevant to achieving the goals.
- Content presentation has to be stimulating and engaging in order to keep learners in the game/task. So the key is to maintain attention.
- Notes: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content. (more so with construction students)
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Provide rich resources for reference (both browsing and searching).
- Single player role play: personalization principle - conversational style and virtual coaches: more of a challenge rather than controversy.
- Pay attention to the "stage" where the status of interactions is presented/displayed: use this as implicit guidance for the learners.

6) Elicit performance (practice):

- Establish small objectives to elicit performance.

7) Provide feedback:

- Update on progress, how the situation is unfolding.

8) Assess Performance:

- Self assessment: reflection should be a key assessment metric, as most of learning in role playing occurs in reflection and might not represented in final state results.
- Consider win/lose state as a metric, but should not be the only one assessment criteria.
- Define performance indicators in alignment with the instructional objectives you defined on the left.

9) Enhance retention and transfer to job:

P#6 Equipment Modeling and Simulation

Instructional topic: Simulation of Construction Equipment Site Operations

Instructional goal: Procedures

Instructional objectives: 1) Recognize different tools for creating models of construction equipment operations2) Recognize when each tool can be used depending on the specific job site

Instructional strategy: Skill building simulations

User Interface Features:

Efficiency of users

- Gradually reduce scaffolding: increase the challenge at every step: show me, teach me, coach me, let me.
- Offer lots of practice
- Divide big task into smaller tasks and graduate challenges gradually
- For easy tasks, let users use their intuition. For more complex tasks, demos and guidance are necessary

Feedback and communication

- For invalid actions: give explanation

Use of metaphors

- Interface should have moderate fidelity with the real world, but does not have to be total fidelity (simplifications are desirable to avoid distractions and focus on the skill being learned).
- Use visual metaphors for command/action buttons (that mimic/represent the physical action, such as drag and drop for locating, associating, attaching

Other User Interface comments:

- Your students are visual. Limit text-based content and feedback. Use voice narration instead of text on screen when possible.

Instructional events

1) Gain Attention:

- Set up a challenge, and/or a prize.

2) Inform learners of objectives:

- Create specific assignments to target specific objectives.

3) Stimulate recall of prior learning:

- Ask questions to class during model development/software demonstration

4) Present the content:

- For highly visual applications that focus on operations: only display the most relevant information on the current task to be carried out.
- Have a somewhat linear structure to content presentation to provide information gradually.

Comments:

- Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Provide step-by-step case study development to use as guidance for model development

6) Elicit performance (practice):

- Offer much practice, but make it optional so that students can choose how much practice they do (to accommodate students with different learning curves).
- Trigger thoughts: ask questions, or prompt users to reflect.

Comments:

- A significant number of your students are low scorers. These students will benefit from multimedia supported learning, and teamwork. Provide materials in various forms, and have team projects to encourage these students to participate and perform.

7) Provide feedback:

- Show screen of student computers to discuss errors and successes with the rest of the class

8) Assess Performance:

- Define performance indicators in alignment with the instructional objectives you defined on the left.

9) Enhance retention and transfer to job:

- Assign homework to in-class modeling exercise
- Develop follow-up assignment to continue on the following learning path:
  - Learn software procedures
  - Observe actual work processes
  - Analyze actual work processes and model them
  - Analyze results of simulation and make decisions

P#7 Request for Information

Instructional topic: RFI – request for information

Instructional goal: Procedures

Instructional objectives: Explain the RFI cycle

Instructional Strategy: Skill building simulations

User Interface Features:

Efficiency of users

- Gradually reduce learning support: increase the challenge at every step: show me, teach me, coach me, let me.
- Offer lots of practice
- Divide big task into smaller tasks and graduate challenges gradually
- For easy tasks, let users use their intuition. For more complex tasks, demos and guidance are necessary

Feedback and communication

- Teach in feedback: give intrinsic and educational feedback.
- For invalid actions: give explanation
- Indicate progress of tasks by elapsing clock, color coding, etc

Use of metaphors

- Have a "virtual" coach who trains and supports the user. Give a name, a face, and pop him up when feedback is given. But don't be annoying.
- Interface should have moderate fidelity with the real world, but does not have to be total fidelity (simplifications are desirable to avoid distractions and focus on the skill being learned).
- Use visual metaphors for command/action buttons (that mimic/represent the physical action, such as drag and drop for locating, associating, attaching

Other User Interface comments:

- Your students are visual. Limit text-based content and feedback. Use voice narration instead of text on screen when possible.
- Your students are technology savvy and can handle multitasking.

Instructional Events:

1) Gain Attention:

- Comments: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

3) Stimulate recall of prior learning:

- Comments: Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- Have a somewhat linear structure to content presentation to provide information gradually.
- Comments: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

6) Elicit performance (practice):

7) Provide feedback:

8) Assess performance:

9) Enhance retention:

- Relate/compare students performance to expert performance.
- Have a report of student performance, what they did well and what they did not do well.

P#8 Decision analysis

Instructional topic: Decision and risk analysis

Instructional goal: Reasoning/Decision making

Instructional objectives: Compare various alternatives and choose the one with the best payoff

Instructional Strategy: Interactive case studies

User Interface Features:

Support cognitive processing of information:

- Provide a clear story line or structure to present the case.
- Provide occasional summaries as the story goes to help remember the content.

Simplicity:

- Break content into sub topics if case is too complicated.
- The structure of all content has to be clear, with shortcuts to each section visible at all times (e.g: a permanent table of content, or permanent tabs representing chunks of information)

Accommodate individual differences:

- Provide a rich mixture of case materials, including text, sound, animations, etc. Instructions, if present, should be in form of voice narration, with text as an option, and the ability to turn either voice or text on or off.
- Provide various background knowledge materials to accommodate students of different baseline competence in the subject matter.

Explorable interfaces:

- Navigation should be simple but clear and visible, with options to pause, go back to a certain point, or replay a certain section

Instructional Events:

1) Gain Attention:

- Ask a critical leading question.
- Present the situation briefly as a conflict, a crisis, a controversy, a dilemma.
- Use a current event, an interesting video demo.

2) Inform learners of objectives:

- Break down objectives into small and tangible statements, rather than a few abstract overarching objectives (e.g. "understand potential conflicts between land owners and state agencies for Right Of Way, and solutions to resolve them" instead of "understand the difficulty of ROW acquisition").

- Comments: You have a significant group of matured students in your audience who tend to be goal-oriented in learning. Make sure your learning objectives meet their practical need so that they stay motivated.

3) Stimulate recall of prior learning:

- Use a popular current event to trigger association to prior knowledge (make sure to give a summary to those who might not know the event).
- Make sure students have enough background knowledge through a pre-test or in-class discussion, etc.

4) Present the content:

- Coherence principle: adding interesting material can hurt.
- Case can be presented as a "virtual field trip" that takes students to a virtual site where the story takes place.
- Break content into subtopics if case is too complicated.

Comments (if any):

- There is a big group in your audience that is matured students or your students already have substantial knowledge in the subject. For this group, it is best to present content and elicit performance by relating to real world examples. Have them participate by sharing their knowledge with the class in person or through collaborative tools.
- Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Break content into subtopics if case is too complicated.

6) Elicit performance (practice):

- Leading questions encourage students to dig deep into a certain aspect, and can help achieve previously defined learning objectives.
- Ask questions as learner go through the case to trigger thinking.
- To facilitate discussions: reward challengers, and ideas.

- Comments: There is a big group in your audience that is matured students or your students already have substantial knowledge in the subject. For this group, it is best to present content and elicit performance by relating to real world examples. Have them participate by sharing their knowledge with the class in person or through collaborative tools.
- A significant number of your students are low scorers. These students will benefit from multimedia supported learning, and teamwork. Provide materials in various forms, and have team projects to encourage these students to participate and perform.

7) Provide feedback:

- If facilitated discussion is the central aspect of the tool: dedicate significant space for feedback, comments, ideas, and to provide supporting documents (text, videos, etc.)

8) Assess Performance:

- Self assessment: reflection should be a key assessment metric, as most of learning in case studies occurs in reflection.
- Make sure to also reward the process, not only the results. Consider win/lose state as a metric (such as a debate winner), but should not be the only one assessment criterion.
- Define performance indicators in alignment with the instructional objectives you defined on the left.

9) Enhance retention:

- When possible, have students participate in a real world situation (students of a legal subject participating in a trial or a negotiation with a role similar to what they are playing).
- Suggest new situations where knowledge can be applied, or can be challenged.

P#9 Risk management

Instructional topic: Decision and risk analysis

Instructional goal: Theories

Instructional objectives: Understanding, knowing

Instructional Strategy: Interactive case studies

User Interface Features:

Simplicity

- Break content into sub topics if case is too complicated.
- The structure of all content has to be clear, with shortcuts to each section visible at all times (e.g: a permanent table of content, or permanent tabs representing chunks of information)

- To encourage discussions, simplify for fast actions, for example: a blank text box and a “Submit idea” button to collect real time reactions from classmates to an argument being raised by a fellow student

Feedback and communication

- Pop-up questions to trigger thinking where appropriate while the learner is reading (probing, challenging, connecting, predictive, analytical, or evaluative questions). Immediate response can be optional.
- Include note taking tools for real time reflection
- To facilitate discussions, include discussion tools, such as a discussion forum, with other active users of the application during class session, or outside class time

Instructional Events:

1) Gain Attention:

- Present the situation briefly as a conflict, a crisis, a controversy, a dilemma.
- Comments: The majority of your students are young, they might expect a high level of engagement in learning activities. They get bored easily. Make sure you have milestones and excitement built-in throughout the exercise to keep their attention.

2) Inform learners of objectives:

3) Stimulate recall of prior learning:

- Make sure students have enough background knowledge through a pre-test, an in-class discussion, etc.
- Comments: Your students have no to little existing knowledge in the field. Instead of helping them recall prior knowledge, try to make them curious about what they are about to learn.

4) Present the content:

- The structure of all content has to be clear, with shortcuts to each section visible at all times (e.g: a permanent table of content, or permanent tabs representing chunks of information).
- Break content into subtopics if case is too complicated.
- Comments: Your students are visual learners. Avoid using too much text, or using graphics, diagrams, figures to summarize text content.
- Your students are more comfortable with content that is structured than too open-ended. Break content into sub topics, have summaries, review, process charts to help them understand the material better.

5) Provide learning guidance:

- Break content into subtopics if case is too complicated.

6) Elicit performance (practice):

- Leading questions encourage students to dig deep into a certain aspect, and can help achieve previously defined learning objectives.

7) Provide feedback:

- Provide comfort: the modality principle - add sound; narration is generally better than text. This creates a sense of conversation.

8) Assess performance:

- Align metrics with stated objectives.

9) Enhance retention:

- Suggest new situations where knowledge can be applied, or can be challenged.

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