Project-, problem-, and inquiry-based learning

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Introduction

Inquiry-based learning and related approaches such as project- and problem-based learning respond to the increased availability of information in a networked world by emphasizing the location and application of information by the learner rather than its transmission from teacher to learner. The role of teacher necessarily shifts toward being a designer and facilitator of projects through which students learn rather than the primary source of knowledge in the classroom. That shift is facilitated by the application of digital technologies to initiate learning activities, access and process information, and present results. It confronts teachers with challenges in relation to the relative emphases on content and process in learning and assessment, and the role of learners in deciding what is learned and how.

Critical questions

- What are some potential benefits and disbenefits of inquiry-based approaches to education?
- What similarities and differences are there among various inquiry-based learning pedagogies?
- What are the theoretical foundations of inquiry-based learning?
- How can digital technologies be used to facilitate inquiry-based learning?

Learners and learning at the centre

Traditional understandings of education centre on teaching. A typical image is of a teacher delivering content to a class. Over the past 50 years that image may have evolved from a man at a blackboard to a woman with a tablet and smartboard but, despite changes in technology, the essential paradigm remains. Teaching is telling.

Historically, human knowledge was limited in scope and changed slowly. Access was limited to those who had memorized it or could read scarce written records. It made sense for education to dispense scarce knowledge from teacher to learner using efficient processes such as lectures. We had *pedagogies of scarcity* (Weller, 2011).

Now, information is not scarce but is expanding exponentially. The Internet makes it much more accessible and networked mobile devices allow us access to much of human knowledge anywhere at any time. Twenty or thirty years ago the information challenge for educators was one of access to scarce information but now it is one of critical selection from abundance. We need *pedagogies of abundance* (Weller, 2011).

A family of pedagogies

Problem-based learning, identified by Weller (2011) as a possible *pedagogy of abundance*, is one of a growing family of pedagogies based on students learning through finding and applying information rather than memorizing information transmitted by teachers. Larmer (2013) lists thirteen pedagogical variants that are described as "*something*-based learning" but discussion here will be confined to four of them:

inquiry-based learning, project-based learning, problem-based learning, and challenge-based learning.

Larmer suggests that all thirteen variants share essential features but with distinct flavours based on the particular contexts for learning. Many, but not all, include some form of project work. They fall under a broad category of inquiry-based learning.

Inquiry-based learning as parent

The origins of education through inquiry go back to Socrates and his questioning of learners to develop their knowledge. Credit for the development of inquiry in the twentieth century is usually given to John Dewey, who responded to a prevailing emphasis on facts, rather than thinking, in education by arguing that learning begins with the curiosity of the learner and is rooted in experience and reflection.

Dewey's inquiry model was based on the scientific method and "has five specific and cyclical stages: asking questions, investigating solutions, creating new knowledge as information is gathered, discussing discoveries and experiences, and reflecting on new found knowledge" (Crippen & Archambault, 2012, p. 159). Science Education uses inquiry methods such as the 5E model of Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 2009) and Crippen and Archambault (2012) present scaffolded inquiry using a Vee diagram as a signature pedagogy for STEM (Science, Technology, Engineering and Mathematics) education.

Fundamental to all inquiry-based pedagogies is a *big question* that is variously described as a problem, project, or challenge. This provides a focus and starting point from which learners refine their questions and seek information toward an answer. In this process students become active learners and teachers function as facilitators or guides rather than primarily as sources of information to be transmitted.

Distinguishing sibling pedagogies

The other members of the family of pedagogies are like siblings with family resemblances and individual characteristics. Resemblances include:

- beginning with a focus on a question related to a real world issue,
- open-ended investigation of the topic or issue over an extended time,
- interpretation of collected information to answer the initial question, and
- reporting the findings, often through creation of an artefact or event.

In all cases, the project, problem or inquiry is central to learning and teaching, not just an adjunct to more conventional instruction in which the teacher delivers the content. Teacher presentation of information may play a role but it should not be the major component of the learning sequence.

Project-based learning

Dewey's focus on experience and reflection as a source of learning has been encapsulated in the phrase, *learning by doing*. That idea leads naturally to project-based learning and its focus on developing a meaningful product.

Larmer and Mergendoller (2012) argue that projects must be more than busy work. Meaningful projects must matter sufficiently to learners that they want to do them well. They must also have an educational purpose that enables the teacher to meet curriculum requirements. They suggest eight essentials for meaningful projects:

1. Significant content: Projects should link to curriculum and reflect essential content, which should also be significant to students' interests.
2. Need to know: Teachers can initiate a project with an event – video, guest, field trip – that engages student interest and makes its relevance clear.
3. Driving question: The question should challenge students and give a sense of purpose beyond class requirements. It should not invite a simple answer.
4. Student voice and choice: At a minimum, students might select a topic or choose how to present a product. As their capacity develops they might decide on other aspects, including the topic or driving question.
5. 21st Century competencies: Projects should develop general capabilities such as critical thinking, collaboration, communication, and creativity.
6. In-depth inquiry: Projects should go beyond finding information and copying it for presentation. Students should learn to generate new questions that eventually lead to answers to the driving question.
7. Critique and revision: Students should learn that revision based on evaluation by self and others is a common feature of real work. They should be coached to critique each other's work and outside experts may be involved.
8. Public audience: Regular classroom work is often judged against artificial criteria. Projects created in response to a real-world issue and presented to a real audience will be judged against authentic criteria.

Miller (2014) distinguishes between high-quality, *main course*, project-based learning where students learn the material through completing the project, and *dessert projects*, in which students generate a presentation based on information provided by the teacher. He addresses four common misconceptions about project-based learning. Fully-fledged project-based learning is an extended process and NOT a short-term 'lesson', though it may incorporate lessons on the way to meeting multiple objectives. It goes beyond students finding information on a topic to cycles of inquiry in which students develop and answer new questions. Student voice and choice goes beyond the products they create to participating in decisions about every phase appropriate to their age and experience with project-based learning. The public audience needs to make sense in terms of the project so simple publication on a website is not as effective as having relevant professionals respond.

Although the value of projects that entail only presentation of information will be less than that of more complete projects, the significance of making learning public should not be disregarded. Engaging learners in presentation activities may form part of a strategy for developing essential skills for more extensive projects.

Success with project-based learning depends upon multiple factors. The skills for working collaboratively need to be developed, perhaps through a graded series of projects. Projects need to be planned to be developmentally appropriate, engaging for students, and relevant to curriculum. Buck Institute for Education, NewTech Network, and Edutopia have resources to assist with planning projects, including rubrics for assessing how well projects match requirements (see website URLs at end of chapter).

Problem-based learning

Problem-based learning developed in North American medical education more than 40 years ago and is now used around the world in medicine, nursing, engineering, architecture and other professions (Savery, 2006). It was introduced in response to the crowding of medical education by rapidly expanding scientific knowledge and to address important objectives not well addressed by more traditional education. Those included structuring knowledge for clinical application, developing clinical reasoning, building capability for self-directed learning, and increasing motivation (Barrows, 1986).

Larmer (2013) categorises problem-based learning as a subset of project-based learning that is more often used in post-secondary than in K-12 education and is more structured. A typical process for problem-based learning follows these steps:

1. Presenting an ill-structured problem as the starting point,
2. Clarifying the problem in a problem statement,
3. Determining what is known and what needs to be known for a solution,
4. Formulating learning issues to guide individual and group research,
5. Sharing collected information in the group to generate possible solutions, and
6. Presenting proposed solutions and checking against the initial problem.

A tutor facilitates the process and prompts investigation but does not provide information or suggest solutions. Key characteristics include arranging curriculum around problems rather than disciplines, students taking responsibility for their learning, starting a learning sequence with an authentic ill-structured problem likely to be faced by professionals, and collaboration among learners in small groups. The length of time devoted to problems varies. In some cases a single problem might be the focus for several weeks but some institutions have adopted a 'problem a day' cycle.

Challenge-based learning

Apple (2011) promotes challenge-based learning in conjunction with their renewed Apple Classrooms of Tomorrow project. It begins from a big idea or question and engages students in a collaborative search for information to answer the question and construct solutions. Its goal is to encourage learners to "leverage the technology they use in their daily lives to solve real-world problems" (challengebasedlearning.org). The solution should be "actionable in the local community" and tested in practice.

In practice it is likely to be very similar to project-based learning. The distinction is that it has a "focus on global challenges with local solutions" (Apple Inc., 2011, p. 1). Examples of challenges described in project reports include sustainability issues with water, food, energy and air quality. Students have engaged in broad investigation of these issues with global implications and then planned and implemented projects to make a difference in their local communities.

Foundations in learning theories

Inquiry-based pedagogies place the learner at the centre with key responsibility for the learning, which is to derive from personal experience. In doing so they separate from behaviourist and cognitivist theories of learning and align with constructivist theory in which knowledge is built upon personal experience.

Constructivism

Constructivism is characterized by three propositions (Savery & Duffy, 1995, p. 31):

1. Understanding is in our interactions with the environment. That is, what is learned is inseparable from how it is learned.

2. Cognitive conflict or puzzlement is the stimulus for learning and determines the organization and nature of what is learned. Consequently the learner's goals are central to what is learned.
3. Knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings. We test the viability of our constructed understandings in negotiation with others.

Those propositions are embodied in each of the pedagogies described above. Savery and Duffy (1995, pp. 32-34) derive eight instructional principles from constructivism:

1. Anchor all learning activities to a larger task or problem. There should be meaning and purpose for the learner beyond meeting teacher requirements.
2. Support the learner to develop ownership of the problem or task.
3. Design an authentic task. The cognitive demands should match the real world at a level appropriate to the learner.
4. Design the task and learning environment to reflect the complexity of the target environment at the end of learning.
5. Give the learner ownership of the process used to develop a solution.
6. Design the learning environment to support and challenge the learner's thinking.
7. Encourage testing ideas against alternative views and contexts.
8. Provide opportunity for, and support, reflection on both the content learned and the learning process.

According to Savery and Duffy (1995) problem-based learning captures constructivist principles almost ideally. Given the similarities among the pedagogies discussed above, the same is largely true for other members of the family. In other words, implementing inquiry-based learning, or one of the closely related approaches, is a sound strategy for supporting learning according to constructivist theory.

Constructionism

Constructionism is a term coined by Seymour Papert, who is best remembered for the Logo computer language. It pushes constructivist theory further by arguing that learning occurs best when the learner engages in personally meaningful activity that makes the learning that occurs in the learner's head visible to others (Martinez & Stager, 2013). That may involve constructing and sharing a physical or intellectual artefact of some kind.

Martinez and Stager suggest that, while constructivism is a theory of learning that does not mandate a method of teaching, constructionism is a theory of teaching and the best way to implement constructivist learning. It is clearly a good match for project-based learning, with which it shares an emphasis on learner directed projects that result in sharing a product with a public audience. Although the emerging maker movement may not name constructionism as the theory behind its approach to learning through making, there is a natural link.

Effects of inquiry-based learning

Because problem-based learning is widely adopted in medical education, there has been extensive research into its effects on learning. Research on the other inquiry pedagogies is not so extensive but, with appropriate adjustments, the research on problem-based learning should be a fair guide to the effects of related pedagogies.

The original rationale for problem-based learning was to address discipline content overload, promote interdisciplinary integration, encourage orientation toward continuing professional education, and enhance capacity for clinical reasoning. Early research found that problem-based learning was more enjoyable for students., Compared to conventionally prepared students, they performed at least as well on clinical tests but perhaps less well on basic sciences. Other research found that there might not be the expected improvement in general problem solving skills but there was enhanced transfer of concepts to new problems and integration of basic concepts in complex problem solving along with better long term retention of knowledge, improved motivation, and skills for self-directed learning. Overall the evidence suggests that there are improvements in the intended directions that may be offset by a slight decrease in discipline knowledge, which, in our networked age, is changing rapidly and readily accessible when needed.

Other researchers have challenged the effectiveness of inquiry-based pedagogies. Kirschner, Sweller, and Clark (2006) mounted arguments based on knowledge of human cognitive architecture, expert-novice differences, and cognitive load to explain why minimally guided instruction does not work. The essence of their argument is that inquiry and discovery are inefficient at transferring newly acquired knowledge from working memory to long-term memory. In their view, the learner's need for guidance is reduced only when they have sufficient prior knowledge to provide internal guidance. In effect, they argue that inquiry is always less efficient and effective than guided instruction but has fewer disadvantages for learners beyond the novice stage.

In response, Hmelo-Silver, Duncan, and Chinn (2007) argue that Kirschner and colleagues mistakenly grouped inquiry-learning together with unguided discovery. They demonstrate that inquiry pedagogies are highly structured and use scaffolding to reduce cognitive demand and support learning in complex domains. They note that, in addition to content knowledge, the constructivist pedagogies address other important educational goals such as dispositions for lifelong learning and soft skills such as collaboration and self-directed learning.

On balance, it seems that inquiry-based pedagogies provide an appropriate response to our 21st century need for *pedagogies of abundance* to replace traditional *pedagogies of scarcity*. Moderate proponents of inquiry have no objection to including direct instruction where appropriate to particular needs. They favour structured approaches to inquiry with appropriate scaffolding for students to work on age-appropriate and curriculum-relevant issues. Under those circumstances it is possible to develop both essential knowledge of content and the attitudes and skills needed to apply it.

When information was scarce teachers and learners faced challenges with locating and accessing the information they required. Abundance of easily accessible information brings its own challenges. The first of these is to assist learners with developing the information literacy skills necessary to select reliable and appropriate information sources from among the many on offer. Learners need to develop the capabilities to identify authoritative sources and to use multiple sources to verify information. A second challenge is to develop the skills and ethical attitudes to appropriately attribute sources. Copy and paste from the web is a tempting solution when pressed for time but careful design of classroom processes can insert checkpoints that scaffold work on projects and assist learners to develop responsible approaches to using information.

Digital Technologies and inquiry-based learning

Reigeluth (2014) notes that in teacher-centred education digital technologies are peripheral and primarily serve the teacher for delivering content and managing records. In learner-centred education they have a more central role, serving the student and enabling the change in paradigm. He suggests four roles for digital technologies: keeping records of student learning, planning for learning, delivering instruction, and assessing learning.

In recordkeeping, Reigeluth identifies three parts of a system that could replace traditional reporting. The first records curriculum or other standards broken down to individual attainments or mini-standards. The second maps a learner's personal attainments against those standards with links to evidence. The third records personal characteristics that can be used to customize the learning experience.

Planning covers setting long- and short-term goals, selecting projects and roles, assembling student teams for projects, assigning support for the learner, and developing learning contracts. The records of standards, prior attainment and student characteristics provide background for planning.

In learner-centred environments student teams work independently with guidance. Reigeluth (2014) suggests that digital technologies can assist in at least two ways. They can introduce projects or provide project opportunities through simulations, virtual worlds and other environments that enhance learners' motivation. They can also offer instructional support for learning *just in time* during a project as part of the scaffolding that increases the effectiveness of the learning experience.

Because students in learner-centred environments work on different tasks at different times, assessment against standards becomes complex. Digital technologies can collect data and manage records against standards. Where project activity occurs in, or is managed by, a suitable system, "there is no separate test; the practice is the test" (Reigeluth, 2014, p. 20) and performance records can be transferred directly to the record of student attainment. Digital technologies can be used to develop assessments and to collect and manage relevant data.

In relation to the problems, projects, challenges or big questions with which learners engage in various forms of inquiry-based learning, digital technologies can play an important role at each stage, from initiation, through research and development, to construction or presentation of a final product.

Initiating inquiry

Any form of inquiry-based learning requires initiation that engages learners and sets direction. Occasionally, as with inquiry into a local issue, the stimulus may be present in the local environment but digital technologies may enhance its presentation.

Depending on the inquiry the digital technology stimulus may take a variety of forms. Video, from a news service, documentary, Youtube or TED recording, can provide a powerful motivation. Photographs may be used to present an issue or a remote guest may present using Skype or other audio and video connections. Simulations or multimedia presentations are other options.

Support the inquiry process

Inquiry-based learning entails learners gathering information to assist in their investigation toward answering a question, proposing a solution to a problem, or developing some product in response to a need. A common approach will be to use Google or another search engine on the World Wide Web. That will be appropriate for some needs and can be supported by developing capabilities for effective search. However, there are other possible applications of digital technologies in support of inquiry.

Depending on the needs, students may be better served by searching the deep or hidden web. That is, they may access and search databases and documents provided through libraries, museums and other agencies. These often hold specialized material that may not be visible to standard search engines.

Digital technologies will also be useful for processing information and other materials in various ways. Spreadsheets and databases may support certain forms of analysis. For some projects it may be necessary to develop detailed plans of structures or apparatus or to engage in visual or other forms of analysis using specialized digital technology tools. Developing project plans, maintaining records, and communicating with team members and external experts using email and other modes are also potential applications for digital technologies.

Presenting inquiry outcomes

The abovementioned *dessert projects* criticized by Miller (2014) typically consist of a presentation using PowerPoint or equivalent, a poster created with a word processor or desktop publishing application, or a webpage. These are all examples of the use of digital technologies for presenting the outcomes of an inquiry process. If the learning activity has met the other expectations of a *main course* project with relevant learning, these may be part of an appropriate final product to be shared with an authentic public audience or, as noted above, may be part of a strategy for developing skills for more extensive projects. Nevertheless, digital technologies can offer greater scope for presenting the outcomes of inquiry in creative formats appropriate to particular content or audiences and it is appropriate to explore a range of these.

Using digital technologies to develop products with richer media is one way to extend projects. Photographic exhibitions, short movies, audio recordings of music or podcasts, and other media productions are possible expressions of outcomes. Games, simulations, and computer programs to perform various functions are other possibilities, as are objects created using 3-D printers.

WebQuest as inquiry pedagogy

One widely recognized application of digital technologies for inquiry-based learning is the WebQuest (Dodge, 1997). Templates have been developed to facilitate the construction of WebQuests according to some patterns that are known to work and many WebQuests have been developed and made freely available.

The WebQuest site (webquest.org) provides a searchable collection of WebQuests categorized by learning area and grade level. Most will require some adaptation to local curriculum but they provide useful starting points or ideas for reworking. That site also has templates for WebQuests and links to relevant research and other resources.

Assessment

Chapter 17 addresses some general principles of assessment and possible roles for digital technologies. As noted in that chapter, alignment of assessment to match learning objectives and the anticipated outcomes of learning activities is an important consideration for *construct validity*. As for any classroom, inquiry-based classrooms will need to address relevant curriculum and assessment should reflect that.

In well-designed inquiry the learning occurs in the process of engaging in the inquiry or project work. Learning will include content relevant to the curriculum and processes of inquiry. In the Australian Curriculum, collaboration, critical and creative thinking, and other aspects of the process are represented in the General Capabilities. The final product of inquiry should incorporate evidence of both content and processes but it may be important to observe some aspects of process directly during the inquiry and there may be cases in which separate assessment of content is justified. In this respect the comments about analytical and holistic approaches found in Chapter 17 will be helpful.

As for any approach to learning, well-planned assessment strategies and techniques are essential to ensuring that the learning objectives are achieved. The Buck Institute for Education (BIE) (bie.org) offers a variety of resources to assist with planning and implementing assessment of project-based learning. They include tools for mapping assessment in a project to ensure appropriate formative assessment of content and skills leading to summative assessment in the final product. BIE notes the importance of assisting learners to self-assess, that is, to identify what they know and can do and to set goals for growth. Rubrics are commonly used to provide guidance for students in the process of inquiry and project development. Examples of rubrics for checking the design of projects and for assessing the projects are available from the websites listed below. BIE offers access to a variety of sample rubrics, including a "rubric for rubrics" to assist educators with developing clear and useful rubrics.

As mentioned previously, where digital technologies are used to host projects and inquiries through simulations or are used extensively in the process, it may be possible to collect performance data as learners engage in the inquiry. In such cases the assessment takes on the characteristics of assessment *for*, rather than *of*, learning as it assists with formative guidance of the learners.

Conclusion

Inquiry-, project-, and problem-based learning represent one educational response to the change from a world in which information was scarce and difficult to access to one in which information is abundant and readily accessible. That raises questions about the relative importance of learning content and the process skills necessary to locate, assess and apply information. Inquiry-based pedagogy is not monolithic. There is a spectrum of possibilities and each of those will offer flexibility around the balance between content and process appropriate to the curriculum and learners. Digital technologies can be used to support all phases of inquiry-based pedagogies from initiation through investigation to presentation. Teachers will need to exercise their professional knowledge and capabilities to make and implement decisions about the pedagogy appropriate to particular circumstances and the ways in which digital technologies can enhance the learning experience. The key issues are:

- Establishing the appropriate balance between content and process in learning when information is both abundant and easily accessible,
- Designing projects that engage learners while ensuring comprehensive inclusion of required curriculum,
- Balancing student voice and choice with the requirements of curriculum, and
- Ensuring valid assessment of individual learners working on collaborative projects with variable outcomes.

Exploring

- How can teachers ensure an appropriate balance between content and process in the curriculum for school education?
- How is the work of teachers likely to be changed through using inquiry pedagogies rather than more didactic approaches?
- Select a topic within a curriculum learning area and develop an idea for a project including a suitable prompt to engage the learners and an appropriate audience for the product.
- From the WebQuest.Org site or elsewhere identify a WebQuest for an age level and topic within a learning area that you teach. Review it and plan how you might adapt it to local curriculum requirements.

Websites

Buck Institute for Education Project Based Learning http://bie.org

This site has a focus on assisting teachers to use project-based learning across all learning areas with multiple age groups. It offers a variety of quality explanations in different media and teacher resources.

Challenge Based Learning https://www.challengebasedlearning.org/

Apple Inc. has promoted challenge-based learning as part of its renewed Classrooms of Tomorrow project. The focus is on taking local action to tackle global challenges.

Edutopia Project-Based Learning http://www.edutopia.org/project-based-learning

The George Lucas Educational Foundation supports the Edutopia site which offers a variety of resources for teachers. This section has a variety of short videos about different aspects of project-based learning.

Invent to Learn http://www.inventtolearn.com

The authors are well known in educational technology. This website and book make links between project-based learning and the emerging maker movement.

NewTech Network http://www.newtechnetwork.org/about/project-based-learning

This site is supported by a non-profit foundation that promotes project-based learning using technologies as a means of transforming schools. The site offers a variety of ideas and resources for teachers.

WebQuest.Org http://webquest.org

WebQuest is an approach to inquiry-based learning using the World Wide Web. This site has a searchable collection of WebQuests for adoption or adaptation and templates for building your own.

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