Constructivism and the Roles of Technology, Cognitive Function, and Learning Styles

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Abstract

Recent developments in K-12 education have focused upon constructivist learning theories and adaptation of instruction that considers learning styles and cognitive load. Integration of technology in the classroom provides tools and information, in a sensory-rich environment, with which students may construct knowledge. An overview of constructivism, comparing key theorists and viewpoints, research on cognitive function and learning style preferences, and the essential role of technology are explored and implications for constructivist learning environments are documented.

Keywords: constructivism, cognitive function, Cognitive Load Theory, guided learning, learning styles, technology
Introduction

Constructivism has long been a part of educational thought yet is plagued by confusion, lack of standardization, and ineffective application by many in the field. Constructivist theories are well supported by recent studies of cognitive function, but there are few models upon which to build, or guidelines for the evaluation of classroom application. Research related to cognitive function, particularly the impact of novel information and problem solving tasks on working memory, will provide much-needed support for the development of constructivist learning tasks grounded in research. The role of technology is well recognized and the effectiveness of technology-enhanced constructivist learning can be further improved by consideration of students’ prior experience and learning style preferences. “If teaching is conceived as constructing a bridge between the subject matter and the student, learner-centered teachers keep a constant eye on both ends of the bridge” (Bransford, Brown & Cocking, 2000, p. 136).

Components of Effective Constructivist Learning

The Constructivist Perspective

A learning theory based the work of Dewey, Piaget and Vygotsky, constructivism has been part of education for over 30 years, with roots dating back to Italian philosopher Giambattista Vico (1668 – 1744). Growing in popularity since the 1990s, differing schools of thought have developed which have taken constructivism down divergent paths but the common thread is belief that learners construct meaning in an active way, with new knowledge being built upon existing knowledge. A brief overview of constructivist points of view (Oxford, 1997) will demonstrate the differences:

- Piaget – Individual child develops mental frameworks. Viewed as the original constructivist, “Piaget’s version of individual/psychological constructivism remains
largely accepted throughout the world and has provided a useful, heuristic set of broad stages of cognitive development (Oxford, 1997, p. 39).

- von Glasersfeld – Radical constructivism; reality does not exist outside the mind.
- Iran-Nejad – Wholethemes constructivism; knowledge is simplified through integration and reorganization.
- Kelly – Personal construct theory; a "construct" is a distinction between opposites. Unique interpretations help the individual predict future events.
- Crockett – Cognitive complexity; when the learner has many experiences, and learns from them, cognitive differentiation and complexity result.
- Dewey – Knowing is “constructed by a participant, with society providing a reference point or theory for making sense of experience” (Oxford, 1997, p. 42).
- Vygotsky – Social context, zone of proximal development; emphasized the individual learner, knowledge is constructed through interaction with others; scaffolds support, as needed, as learners become more self-directed.
- Lave, Rogoff – Learning communities; learning is situated in the setting and activity and cannot be separated.

A simplified view of central themes highlights fundamental differences:

<table>
<thead>
<tr>
<th>Knowledge Constructor</th>
<th>Individual/Psychological Constructivists</th>
<th>Social/Cultural Constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Individual within a group or whole society</td>
<td></td>
</tr>
<tr>
<td>Formal Knowledge</td>
<td>Seldom addressed</td>
<td>Central theme</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Stressed by some, not by others</td>
<td></td>
</tr>
<tr>
<td>Increased Knowledge</td>
<td>Complex vs. simplified knowledge structures</td>
<td></td>
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<tr>
<td>Role of Consciousness</td>
<td>Ignored by many, others contradict</td>
<td></td>
</tr>
<tr>
<td>Transmission-Based Learning</td>
<td>None vs. Some</td>
<td></td>
</tr>
</tbody>
</table>
Despite, or perhaps because of, differing points of view, guidelines and expectations for constructivist learning tasks are often unclear.

Because there are so many versions of constructivism, with important overlaps but also with major differences, it is difficult to see the forest for the trees – it is a matter of pressing concern to find some way of categorizing them so that they overall picture does not get lost. (Phillips, 1995, p. 7)

Phillips (1995) proposes that spreading various forms of constructivism along three dimensions will clarify similarities and differences among them:

First Dimension: Individual Psychology ------- Public Discipline
Second Dimension: Human the Creator --------- Nature the Instructor
Third Dimension: Individual Cognition ------- Both ---------- Social Processes

To add to the difficulties, “A common misconception regarding ‘constructivist’ theories … is that teachers should never tell students anything directly but, instead, should always allow them to construct knowledge for themselves. This perspective confuses a theory of pedagogy (teaching) with a theory of knowing” (Bransford et al., 2000, p. 11).

The broadness of the theory of constructivism, coupled with conflicting practices, has resulted in a lack of standardization within the field. Despite difficulties, there are clear ramifications for education: 1) focus on the learner, not the subject matter being taught, 2) provide opportunities for learners to become actively engaged, individually and socially, and 3) the learner must have a knowledge base upon which to build.

Cognitive Load and Memory

Understandings of working memory and long-term memory support the cognitivist belief that knowledge is constructed by the function of, and interaction between, working memory,
long-term memory, schemas, and automation, and is built upon prior knowledge. Recent research into brain function has provided researchers evidence to support theories of learning and effective teaching practices. Working memory, formerly known as short-term memory, is limited in capacity and duration. It can hold seven (plus or minus two) chunks of information, can hold two or three items simultaneously when processing, and information is lost in 15-30 seconds if not rehearsed. Long-term memory, on the other hand, is essentially limitless.

Our understanding of the role of long-term memory in human cognition has altered dramatically over the last few decades. It is no longer seen as a passive repository of discrete, isolated fragments of information that permit us to repeat what we have learned … Long-term memory is now viewed as the central, dominant structure of human cognition. Everything we see, hear, and think about is critically dependent on and influenced by our long-term memory. (Kirschner, Sweller & Clark, 2006, p. 76)

In long-term memory, information is stored in schemas, domain-specific knowledge structures, which categorize information for greater accessibility, and augment working memory capacity. “These schemata organize and store knowledge, but also heavily reduce working memory load because even a highly complex schema can be dealt with as one element in working memory (van Merriënboer & Sweller, 2005, p. 149). With repeated practice, some processes become automated, which bypass working memory.

Cognitive Load Theory is an instructional theory in which cognitive function, particularly the role of working memory, is optimized. Learning tasks are evaluated based on various components of cognitive load: intrinsic - working memory needed to process content, germane – that which helps build schema, and extraneous – that which does not contribute to learning.
Whether extraneous cognitive load presents students with a problem depends, in part, on the intrinsic load: If intrinsic load is high, extraneous cognitive load must be lowered; if intrinsic load is low, a high extraneous cognitive load due to an inadequate instructional design may not be harmful because the total cognitive load is within working memory limits. (Merriënboer & Sweller, 2005, p. 150)

It is important to note that processing limitations of working memory apply only to novel information. “In the sense that information can be brought back from long-term memory to working memory over indefinite periods of time, the temporal limits of working memory become irrelevant” (Kirschner et al., 2006, p. 76).

A number of effects have been researched and studied (Chandler & Sweller, 1991; Darabi, Nelson, & Paas, 2007; Sweller, 2002; Sweller, Merriënboer & Paas, 1998) and related instructional procedures have proven to reduce extraneous cognitive load:

- **Worked Example Effect**: “Instruction should be explicit and complete, Withholding information from students based on a constructivist teaching regime is likely to be ineffective” (Sweller, 2009).

- **Split Attention**: Integrated information is more efficiently processed by working memory than information from multiple sources.

- **Modality**: When presenting diagrams and text, spoken text will make use of both auditory and visual channels expanding capacity of working memory.

- **Redundancy**: Elimination of redundant information improves performance. “If, for example, textual information merely repeats diagrammatic information, it is redundant and should be eliminated rather than integrated with the diagram or present in auditory form” (Sweller, 2009, p. 22).
Expertise Reversal: Effects apply to complex information, novel information, and/or novice learners.

As noted by Merriënboer and Sweller (2005), “because modern instructional theories often incorporate real-life learning tasks as a driving force, cognitive load considerations are becoming increasingly important” (p. 171).

**Guided Discovery Learning**

Though constructivism may take many forms, guided discovery is well supported by research and an understanding of cognitive function. “The debate about discovery has been replayed many times in education but each time, the evidence has favored a guided approach to learning” (Mayer, 2004, p. 18). Further, Kirschner et al. (2006) note that “the past half-century of empirical research on this issue has provided overwhelming and unambiguous evidence that minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning” (p. 76).

A carry-over of Bruner’s recommendations, some proponents of constructivist learning environments advocate minimally guided discovery in which learners engage in active tasks with little or no guidance from the teacher. It is believed that independent knowledge construction provides a deeper, more personal understanding. Mayer (2004) refers “to this interpretation as the constructivist teaching fallacy because it equates active learning with active teaching” (p. 15). A common criticism of minimally guided instruction is that there is every chance that the learner will not come into contact with desired content or that students will acquire misconceptions, incomplete or incorrect information. “Recommending minimal guidance was understandable when Bruner proposed discovery learning as an instructional tool because the
structures and relations that constitute human cognitive architecture had not yet been mapped” (Kirschner et al., 2006, p. 76).

Kirschner, et al. (2006) present research findings in mathematics, science, medical and law school students and “it almost uniformly supports direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners” (p. 83). These findings are in agreement with studies related to cognitive function. For example, in guided discovery scaffolds provide support necessary to free working memory for learning, as opposed to using working memory to processing large amounts of novel information.

Learning Styles

Cognitive function and instructional design are just two of the forces that influence knowledge acquisition. In the field of educational technology, research (Felder & Spurlin, 2005) has focused on the effects of learning styles on student learning, instruction and course design. Learning styles influence students' comfort level with the presentation of educational activities as well as ease completing tasks. Researchers and practitioners alike conclude that students experience greater difficulty when there is a mismatch between teaching styles preferred learning styles. Felder and Solomon’s (1991) Index of Learning Styles (ILS) Questionnaire is based on the Felder-Silverman model and is comprised of 44 questions which assess preferences in four dimensions: 1) Processing: active or reflective, 2) Learning: sensing or intuitive, 3) Remembering: visual or verbal, and 4) Understanding: sequential or global. ILS data will enable the design of more effective instruction and modification of learning experiences to suit the needs of all (Sutliff & Baldwin, 2001).
Though other models may be used, there are advantages to the Felder-Silverman Learning Styles Model. Most other learning style models classify learners into a few groups, whereas Felder and Silverman describe the learning style of a learner is more detail, distinguishing between preferences on four dimensions. Another main difference is that FSLSM is based on tendencies, indicating that learners with a high preference for certain behaviour can also act sometimes differently. (Graf, Viola, Leo & Kinshuk, 2007, p. 81)

Further, Graf et al.’s (2007) analysis of 207 student ILS questionnaires identified the five most representative questions for each dimension; information which will “lead to a more accurate representation of students’ learning styles and therefore enhance the potentials of adaptive learning environments” (p. 90).

While some advocate adaption of instruction to allow each learner to work in his/her preferred dimension, others recommend a balanced approach. When instruction is geared only toward the preferred modality, students will experience greater comfort and confidence that result in more “effort-free” learning. However, students will benefit from the opportunity to build areas of relative weakness. Designing instruction so that students have the opportunity to work in both preferred and non-preferred learning styles is best.

Technology and Constructivism

Technology and constructivism have enjoyed a symbiotic relationship characterized by growth in the depth and breadth of learning experiences available within the classroom. With advancements in technology, learners are afforded the opportunity for dynamic exploration that
is key to constructing knowledge. Further, a growing number of tools are available for the demonstration of educational growth and understanding.

The challenge for education is to design technologies for learning that draw from knowledge about human cognition and from practical applications of how technology can facilitate complex tasks in the workplace. Like training wheels, computer scaffolding enables learners to do more advanced activities and to engage in more advanced thinking and problem solving than they could without such help. (Bransford et al., 2000, p. 214)

Most practitioners can provide examples of the growing trend toward constructivism, but there are more concrete ways to demonstrate the prominence of constructivism and technology in education. While a search for “constructivism” at dictionary.com and Merriam-Webster Online provides just a definition or two about a nonobjective art movement in Russia, a search on About.com yielded ten links, five of which related to education. In contrast, a search of books on Amazon.com provided 17,930 results. Of the first 300 results, 64.3% related to education/philosophy/psychology, 24.3% related to Art, 29% related to politics/foreign policy, and 2.3% were about other topics. More importantly, a review of literature by Kang, Choi and Chang (2007) identified issues and trends related to constructivism in educational technology. In Korean and International refereed journals, from 1990-2006, keywords in titles were used as a basis for categorizing articles pertaining to constructivism.

Kang et al. (2007) conclude that in the last ten years, research emphasis moved “from a ‘theoretical or philosophical review and reflection’ toward the application of constructivist concepts and ideas in various settings, coupled with media or ICT-related issues such as multimedia, open-ended learning environments, integrated learning systems, and interactive
learning environments” (Kang et al., 2007, p. 401). One key to successful integration of technology into a constructivist learning environment is the role of the teacher. Another study examined how teacher’s technology use impacted instructional practices, and research confirmed “that teachers who have solid basic skills and comfort levels with technology and those who use computer technologies in their classrooms are more likely to use constructivist teaching practices” (Rakes, Fields & Cox, 2006, p. 422).

Adequate training and ongoing professional development will enable teachers to better utilize technology in the development of constructivist learning tasks. Duffy and Cunningham (1996) present a comprehensive discussion of the impact of computers and technology on constructivist learning:

- Focus is on the learner; technology supports new understandings and capabilities.
- Technology as a teaching tool will “provide more effective and efficient delivery of instruction and hence more effective and efficient learning” (Duffy & Cunningham, 1996, section 7.4.10, para. 2).
- Technology allows the teacher to “more effectively present problems to the learner and identify and remediate misconceptions” (Duffy & Cunningham, 1996, section 7.4.10, para. 2).
- This “richer and more exciting (entertaining) learning environment … will better engage the student in learning the material being presented” (Duffy & Cunningham, 1996, section 7.4.10, para. 2).
- Amplify Instruction – More effective and efficient processes.
- Augment Instruction – Reorganize/extend cognition, off-load basic cognitive demand.

Also, “the technology may offer genuinely new representations or views of phenomena
that would not otherwise be possible, and hence provide new understandings” (Duffy & Cunningham, 1996, section 7.4.10, para. 5).

- “The task of the learner is no longer seen as static-the computer as applied to the task-but rather it is dynamic: The computer opens new opportunities and makes available new learning activities” (Duffy & Cunningham, 1996, section 7.4.10, para. 8).

With technology serving a critical need within constructivist learning environments, "considerable interest has surfaced recently in using the notion of technological pedagogical content knowledge as a framework to understand teachers' knowledge required for effective technology integration" (Harris Mishra, & Koehler, 2009, p. 396-397). TPACK emphasizes the multiple connections and interactions among:

- Pedagogical Knowledge (PK) - Teacher methods/techniques and learner needs/preferences.
- Content Knowledge (CK) - Subject matter content and habits of mind.
- Technological Knowledge (TK) - Ever-changing; for information processing, communication, and problem-solving.

"Teachers need to develop fluency and cognitive flexibility not just in each of these key domains … but also in the manners in which these domains interrelate, so that they can effect maximally successful, differentiated, contextually sensitive learning” (Harris et al., 2009, p. 402).
Conclusion

Constructivism and technology play significant roles in today’s schools and educators need clear guidance to help them apply best practice to day-to-day teaching and effectively use available technologies. Theories and practices proposed by conflicting camps of constructivists are often in opposition and provide few guidelines for effective classroom application. An understanding of cognitive function, particularly the various effects on working memory, will provide guidelines against which constructivist learning tasks may be evaluated. Further, use of tools like the Index of Learning Styles, will facilitate incorporation of students’ learning styles into the design of adaptable instruction, resulting in a more effective and motivating learning environment. Technology provides tools and resources for authentic constructivist learning tasks and research provides the data necessary to drive decision-making.

Thus the contribution of psychology is to help move educational reform efforts from the fuzzy and unproductive world of educational ideology – which sometimes hides under the banner or various versions of constructionism – to the sharp and productive world of theory-based research on how people learn. (Mayer, 2004, p. 18)
References


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