Neuroscience Basis of Context in Multimedia Enhanced Problem-Based STEM Learning

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Abstract

The role of context in problem-based learning (PBL) in science, technology, engineering, and mathematics (STEM) education is briefly explored from the point of view of ongoing developments in neuroscience. Context of learning plays a very important part in how people learn meaningfully in PBL situations. An understanding of the nature and design of the human-computer (or technology-cognition) interface is also important to understand the relationship between the hippocampus, context, and multimedia in PBL. With cautious optimism, the neuroscience aspect of how multimedia augmented contexts support PBL could be viewed as a promising area for research and development not only in STEM education, but also in other subject areas.

Key Words: Context, Multimedia, Neuroscience, Problem-Based Learning, STEM

1. Introduction

In this paper, the neuroscience basis of context in multimedia-enhanced problem-based learning (PBL) in science, technology, engineering, and mathematics (STEM) education is explored. According to the National Research Council [1], a desired goal of STEM education is to increase the number of students pursuing STEM careers. One of the goals of STEM education is to prepare students for life by developing the cognitive skills necessary to deal with real-world problems. Unfortunately, most classroom learning experiences are passive. Whitehead [2], in the "Aims of Education," was concerned about passive learning when addressing inert knowledge. Inert knowledge is recalled under explicit conditions, but not applied spontaneously in solving problems. It is believed that inert knowledge is part of the semantic memory which lacks autobiographical references. One way to overcome inert knowledge is by providing the learner with a meaningful context to facilitate mental associations (schema) necessary to form autobiographical references to new information [2]. For example, multimedia-enhanced problem-based learning contexts have been found to improve student learning [3, 4, 5]. The neuroscience basis of context in learning is a growing area of interest, and for this paper, context may be operationally defined as the environment where learning occurs.

2. Neuroscience Basis of Context

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Advances in neuroscience have improved our understanding of the neurophysiological basis of cognition in learning situations [6]. Non-invasive imaging technologies such as functional magnetic resonance imaging (FMRI) have helped researchers to study learning processes. There is a growing body of evidence from neuroscience to support the importance of the context of learning centered on the hippocampus. The hippocampus is the enfolded cerebral cortex in the lateral fissure of the cerebral hemisphere associated with long-term memory [7]. It has a role in the formation of new memories and in sensing new stimuli, occurrences, and surroundings. Episodic and semantic memories are "consolidated" in the hippocampus [6]. More specifically, clinical and experimental studies show that the hippocampus processes episodic memories by analyzing contextual information with temporal and spatial references [8, 9]. "Episodic memory refers to the ability to recall specifics of past events in our lives. An essential aspect of events is timing when things occur during an episode. A number of recent studies have shown that the hippocampus, a structure known to be essential to form episodic memories, possesses neurons that explicitly mark moments in time" [9, p. 18351]. Sakon et al. have shown that in experimental animals "hippocampal neurons not only track time, but do so only when specific contextual information (object identity/location) is cued. These time context-sensitive neurons represent a novel way in which the brain unites disparate streams that comprise an episode and will aid in our understanding of how we store and retrieve episodic memories" [9, p. 18351]. Research by Smith and Mizumori [10] (2006) suggests that the hippocampus has a key role in the contextual representation of episodic memories.

Based on the fact that context influences hippocampal functions, it could be inferred that it also facilitates meaningful learning, thus overcoming inert knowledge. In problem-solving situations, inert knowledge is a factor inhibiting success [2, 3]. It is worth exploring how the context of learning could be enhanced to improve meaningful learning and move away from inert knowledge. There are many creative approaches to enhance the context of learning. For example, the use of parables as exemplified by the Lord Jesus Christ over two thousand years ago, noted in the Bible [11] is one approach. A parable is a method of instruction using allegorical illustrations and it has human characters (e.g., Good Samaritan), and it differs from fables where animal characters and inanimate objects are used (e.g., Aesop's Fables) [12].
The application of theme based learning proposed by John Dewey is another approach [13]. The use of case studies suggested by Charles Gragg [14] is yet another approach. The use of multimedia anchors to portray and/or simulate authentic episodes is a current approach to enrich the context of problem-based learning [3, 15] thanks to unprecedented developments in the Internet, multimedia and electronic communication technologies.

3. Learning with Multimedia Technology

A compelling argument for using multimedia technology to promote thinking has been made by researchers and educators [16]. "We may distinguish two senses in which technology and learning are intertwined. The first is thinking with technology; the second is thinking about technology. The second twist of phrase is crucial for technological literacy and technical education and is the topic of recent standards for student learning. But thinking with technology is far more important historically and substantively, for it is in this sense that technology is an instrument of knowing, reason, culture, and humanity itself" [16, p. xv]. One of the most practical ways to promote thinking with technology is rooted in approaches to learning through problem solving with technology. According to the Board on Science Education of the National Research Council in the United States, "at the root of all science investigations are complex and compelling problems. In order for problems to be effective for supporting learning, they must be meaningful both from the standpoint of the discipline and from the standpoint of the learner… Students may relate more easily to the curious phenomena they observe in their daily lives, such as what causes an empty juice box to crunch up when you suck continuously through a straw" [17, p. 127-128]. The authenticity of the learning context is one of the crucial supporting environments for meaningful science learning, particularly in problem-based learning. It should be noted here that the use multimedia to augment the context of learning should not be construed as minimizing hands-on learning experiences in STEM education.

4. Problem-Based Learning (PBL)

PBL is a pedagogical strategy where students are engaged in small groups to participate in problem-solving activities that they can relate to in an authentic context [4, 18, 19]. For example, elementary school students can engage in making a consumer decision involving sunscreen selection, between sunscreen with and without nano particles, in a web-anchor supported PBL nanotechnology project, as reported in Kumar [15]. The context here is authentic, and the processes involved in solving the challenge of choosing between the two kinds of sunscreens include: the scientific method involving data-based decision-making, critical thinking, and analytical thinking. The cognitive foundation of PBL is that it enables the activation of prior knowledge which is vital to processing new information; as students engage in discussing a problem case, they are able to make multiple cognitive associations between new and old concepts. Learning takes place in an authentic context similar to real-world situations, helping the learner receive prodding cues in accessing prior knowledge [19]. Thus, students see the inter-connected nature of STEM. By carefully centering on a problem-based situation, multimedia technologies could be designed to embed specific, well-defined problem-solving tasks in a broader context, raising real-world societal and economic issues for consideration and discussion in STEM education [4, 5, 15].

5. Enlarging the Context of Problem-Based Learning with Multimedia

Information-rich contexts, often referred to as "macro-contexts," encourage the active construction of knowledge by learners, and differ from "micro-contexts" (information-poor, mostly unrealistic) found in traditional educational technology applications [3]. Often, it may not be feasible to bring real-world problem situations into classrooms to enrich the context of learning. One of the ways to present real-world contexts for PBL is through multimedia. The following example draws from the 'Golden Statuette" an uncopyrighted experimental work of Professor Robert Sherwood produced in the 1980's may shed some light on how an enriched context may be developed for a particular learning experience.

The "Golden Statuette" test video anchor was developed with the intention of providing a real-world problem-based learning context (as an episode) for introducing the concepts volume by displacement and density. In the episode a misguided chap who wanted to generate some money the wrong way to buy an electric guitar spray painted an old lead statuette gold and went to a pawnshop. He was telling the shop owner that his mother needed money for surgery and asked him to sell this treasured golden antique which his great grand father got from a potentate in the Middle East in exchange for a portable radio. Being worried sampling by scraping would reveal the true nature of the metal he was telling the owner "don't you go cutting into it or anything… it's pure gold and real soft," In order to estimate its value, the shop owner first determined the mass of the statuette and determined its volume by displacement method. The calculated density came out to be that of lead 11.35 gm/cc, and the shop owner gave the chap 20 cents. The startled chap who realized that he could not fool the pawnshop owner remarked "what can I buy with 20 cents?" and the owner replied "not much." Undergraduate science education students when challenged first with the "Golden Statuette" video followed by hands on activities in volume by displacement and density expressed a greater appreciation for science as they were able to see its connection to societal applications in an authentic context [20].

Multimedia technology provides a hypermedia platform for linking text, figures, audio and video information without requiring the user to physically leave the environment where she/he is located in order to access, manipulate, and interact with them. It is designed on the Internet, creating a network of internally and externally connected platforms to represent a collection of ideas for students to explore. Multimedia technology on the Internet has generated much interest in education thanks to convenient ways to represent knowledge structures in line with some of the learning theories [21]. Some of the advantages of multimedia include visual, dynamic, spatial, veridical representation of information, random access, and greater user control [22]. For details on how multimedia technology has been used to enlarge the context of PBL, see "Problem-Based Learning in Nanotechnolgy" [15], "The River of Life" [23], and "Adventures of Jasper Woodbury" [3]. These multimedia applications also involve hands-on learning and provide classroom teachers the flexibility to make necessary adaptations based on their local curricular needs. As noted earlier in this paper, information-rich meaningful contexts might work towards facilitating hippocampal functions in the process of learning [9, 10], leading to meaningful learner outcomes in STEM education.

6. Concluding Thoughts

Ongoing developments in the field of neuroscience show an emerging connection between the critical role of context and learning. Enriched contexts are essential to engaging students in problem-based learning in STEM. Multimedia platforms are quite suitable for developing enriched contexts to enhance problem-based learning in STEM education. The scope of this brief note is limited to exploring the neuroscience base of contexts and how multimedia-enhanced learning contexts could be developed to support PBL in STEM education. Most neuroscience studies involve laboratory animals, translating results from animal studies to situations involving human beings, hence demanding high inference. Also, the nature of the technology-cognition interface [24, 25, 26, 27] and its effect on multimedia-supported STEM learning is not addressed in this paper. To gain a clearer picture of the effect of multimedia-augmented contexts on information processing in the hippocampus, our understanding of the technology-cognition interface also needs to improve, and how human computer interfaces are designed also must be taken into consideration [26, 27]. This is a complex relationship and should not be overlooked when thinking about neuroscience developments, contexts, and multimedia-enhanced learning. As research advances our understanding of the relationship between the brain, learning, context, multimedia technology, and the technology-cognition interface, it could be anticipated, with cautious optimism, that better ways of designing and developing meaningful learning environments to facilitate PBL, not only in STEM education but also in other subject areas, would emerge.

7. Acknowledgements

The “Problem Based Learning in Nanotechnology” instructional platform was developed with funding from the Ewing Marion Kauffman Foundation. The views expressed are not that of the funding source. "The Golden Statuette" is an uncopyrighted experimental work produced by Professor R. D. Sherwood at Vanderbilt University in the 1980s. Thanks to Ms. Chelsea Dittrich and Ms. Sharon Booshi for editorial feedback.

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