Constructivist Epistemology in Action

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ABSTRACT: In alignment with the challenges of knowledge-based economies of today, teachers are compelled to constantly revise traditional notions of learning in order to motivate students to find delight in the active creation, exploration, and discovery of disciplinary knowledge. In examining innovative philosophies of education, constructivism stands out as one much heralded alternative that has been widely promoted in recent times in attempts at moving away from old ways of instruction and their attendant limitations. By empowering learners to be self-directed, in theory, a learning model underpinned by constructivist principles undoubtedly offers an array of attractive pedagogical benefits. However, the real-time implementation of such a model within the constraints of classroom contexts could potentially be problematic. In this paper, some of the conundrums associated with the application of constructivist ideas in learning environments are discussed. A constructivism oriented instructional framework that tries to bridge the chasm between theory and practice is also elucidated in this paper. This framework suggests a repertoire of heuristic instructional strategies that facilitate students' independent construction of various classes of scientific knowledge.

RÉSUMÉ: En parallèle avec les défis de l'économie reposant sur la connaissance d'aujourd'hui, les enseignants sont en permanence contraints, de revisiter leurs notions traditionnelles en matière d'étude afin de motiver les étudiants à trouver du plaisir dans la création active, l'exploration et la découverte de la connaissance basée sur la discipline. En examinant les philosophies innovatrices de l'enseignement, le constructivisme se détache de la masse comme une alternative véritablement proclamée qui a été grandement promue ces derniers temps afin d'essayer de se défaire des vieux concepts sur l'enseignement et de leurs propres limites. En permettant aux étudiants de s'autogérer dans le domaine de la théorie, un modèle d'étude étayé par des principes constructivistes, offre indubitablement un ensemble d'avantages pédagogiques attrayants. Cependant, la mise en application d'un tel modèle en temps réel avec les contraintes qu'implique le contexte de la classe,

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pourrait être potentiellement problématique. Dans cet article, certaines difficultés associées à l'application des idées constructivistes dans un cadre scolaire, sont discutées. Un cadre d'enseignement orienté vers le constructivisme et qui essaie de combler un gouffre entre la théorie et la pratique, est aussi expliqué dans cet article. Cette structure demande un répertoire de stratégies heuristiques en matière d'enseignement qui permet aux étudiants de construire facilement et d'une façon indépendante des cours divers reposant sur la connaissance scientifique.

Introduction

Research has shown that students who perform well in standardized tests are often unable to successfully apply memorized facts and formulae in real-life situations outside schoolroom environments (Yager, 1991). Practical application knowledge (common sense) and school theoretical knowledge are becoming mutually exclusive with many students being unable to make the connections between what they learn in the classroom to real life scenarios (Resnick, 1987). Moreover, traditional instructional approaches where teachers are sole information purveyors and students are passive receivers appear outdated. Such modes of learning emphasize rote learning of answers rather than exploration of questions, memory over understanding in context. There is little room for student-initiated questions, independent thought or interaction between students (Caprio, 1994).

One suggested epistemological panacea has been the emphasis to change the focus of classroom learning dynamics from teacher dominated to student-centered by using a constructivist approach. Constructivism encourages learners to actively process knowledge, link it to previously assimilated knowledge, and make it theirs by constructing their own interpretation (Cheek, 1992). Steffe (1990) argues that constructivism looks at learning as the adaptations learners make in their functioning schemas and world-views in order to neutralize perturbations that arise through their interactions with the external world. Constructivist dimensions of learning posit that meaning is intimately connected with experience. Students come into classrooms with their own prior experiences and embedded cognitive structures based upon those experiences. Learners will re-analyze their existing internal cognitive schemas only if new information or experiences are integrated within existing knowledge formations in memory. In short, the learner must actively construct new information onto his or her existing mental

framework for meaningful learning to take place (Hanley, 1994). The teacher's role now transforms to that of providing stimulating and motivational experiences in the building of knowledge bases (Wheatley, 1991).

Such knowledge forms could be broadly categorized as declarative knowledge and procedural knowledge. Declarative knowledge is factual or conceptual knowledge that a person has, whereas procedural knowledge refers to how a person does something (Anderson, 1993). Declarative knowledge relates to the physical and strategic aspect of knowledge. It requires knowing how, what, where, and when. It encompasses the descriptions or statements consisting of factual statements about objects and their properties. Procedural knowledge is the functional aspect of knowledge. It results from the intellectual skill of knowing how to do something.

However, what does constructivism mean in terms of an epistemological orientation in action in classrooms? Having a theoretical understanding of the learning benefits of a constructivist model of instruction does not automatically translate to mean that its implementation in real-time will not be fraught with problems or dilemmas. How does one bridge the gap between theory and practice in the application of constructivist perspectives to teaching and learning? How does a constructivist teacher pedagogically function to avoid the pitfall of relegating constructivist strategies to a routine set of prescribed methods as is often found in traditional classroom interactions? How could instructions for declarative and procedural knowledge building processes be organized within an integrated curriculum centered upon a constructivist epistemology of learning? These are some of the pertinent issues that will be explored and discussed in the discourse of this paper.

A Proposed Constructivist Curriculum Model

Theoretical Underpinnings of Model

The proposed model in this paper is buttressed by the conceptual ideas of Nickols (2000) in his framework for thinking about knowledge. A critical evaluation discourse of his knowledge management oriented framework from a constructivist instructional design perspective will also be delineated in rationalizing the component elements of the proposed model. The following flowchart visually encapsulates the key principles advanced by Nickols:

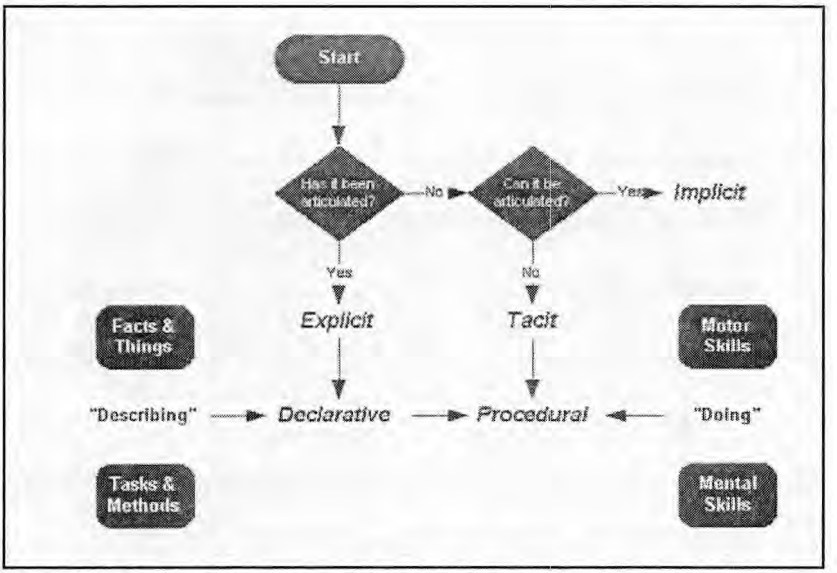

Figure 1. Nickols framework for thinking about knowledge.

Nickols explicates his views on how knowledge can be classified as either declarative or procedural which he equates respectively with explicit and tacit knowledge forms. Some of the criteria for classification include context, purpose, orientation, and scope of the subject matter being studied. His views resonate with accepted principles of pedagogy.

> I choose to classify all descriptions of knowledge as declarative and reserve procedural for application to situations in which the knowing maybe said to be in the doing ... declarative knowledge ties to 'describing' and procedural knowledge ties to 'doing.' Thus for my purposes I am able to comfortably view all procedural knowledge as tacit just as all declarative knowledge is explicit. (Nickols, 2000, p. 4)

Further expounding on the attributes of procedural, tacit knowledge, Nickols cites the example Nonaka (1991) presents in his widely publicized article of how a product developer, Ikuro Tanaka apprenticed herself to a hotel chef who was famous for the quality of his bread.

During the apprenticeship training, Tanaka learns how to make delectable bread expertly including an unusual kneading technique.

> Tacit knowledge cannot be articulated. Thus although Nonaka's product developer was clearly able to devise a set of product specifications based on what she learned while apprenticed to the chef in question, it seems doubtful that she articulated the chefs tacit knowledge or her own. It seems more likely that she articulated some rules or principles or descriptions of procedures, that is, she created some declarative knowledge that subsequently proved useful in the design and development of the bread making machine. (p. 6)

Again these arguments on the inherently tacit nature of procedural knowledge formations are plausible and in alignment with pedagogical theories. However, his repeated references to knowledge representations, both procedural and declarative as being acquired or appropriated mark a significant departure from generally accepted constructivist notions on learning. One relevant example of this line of thinking includes his argument that it is possible to enact the systematic or facilitated acquisition of knowledge (Nickols, 2000). Such a viewpoint though valid from a knowledge management perspective seems to be largely ignorant of vital constructivist axioms on learning and appears to be predicated on the information delivery theory of instruction. The information delivery theory of instruction argues that teaching predominantly consists of dissemination of chunks of information through rote learning. Pedagogically such an argument lacks validity and credibility, especially in light of educational research developments. For instance, Clark and Mayer (2003) successfully counter argue that the information delivery theory is based on an incorrect conception of how learning occurs by assuming that the minds of learners are empty vessels which can be filled with unlimited amounts of information, similar to the ways in which computers operate. Such a reasoning is flawed and fails to take into account the authentic processes of active meaning-making, cognitive modeling, and construction of mental schemas central to a constructivist philosophy of learning. The use of the word "acquisition" connotes a passive style of learning disposition where the learner merely absorbs information within a learning environment that promises little or no learner empowerment and autonomy.

However, constructivist theorists such as Dewey (1937/1997) have vociferously criticized such limiting notions of learning as being erroneous. According to Dewey, a positive educative experience "arouses

curiosity, strengthens initiatives, sets up desires and purposes that are sufficiently intense to carry a person over a dead place in the future" (p. 38). Dewey's principle of continuity of experience calls for learning to be a continuous process of reconstructing experiences. On the other hand, a mis-educative experience "has the effect of arresting or distorting the growth of further experience" (p. 25). The principle of continuity posits that "every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after" (p. 35). A constructivist instructional design ensures that the learning progress of an immature learner to be systematically guided through an instructional sequence built upon a continuum of educative experiences. These educative experiences enrich the learner's scientific and conceptual understandings in order to realize sustained intellectual growth. Otherwise, failure to make connections between what the learner already knows and what needs to be taught could result with the teacher facing what Dewey calls the "problem of discovering ways and means of bringing them within experience" (p. 73).

In defining the subject matter for a curriculum that incorporates learners' prior knowledge and situates learning within the context of a continuum of generative experiences, what should be the epistemological sequencing of instructions for learning declarative and procedural knowledge? What instructional strategies could be effectively adopted to strategically achieve these learning goals?

Some low-level skills domains merit the bottom-up approach to learning where procedural knowledge is learned and then declarative knowledge appropriated. On the other hand, development of most other skills especially those that are cognitively complex and structurally interdisciplinary such as in the physical sciences and computer programming require the learning of declarative knowledge prior to the construction of procedural knowledge. This then enables one to perform the complicated task associated with the skills with no access to the declarative knowledge and without conscious awareness of the specific details and intricacies involved. This follows the logic that initial foundation declarative knowledge facilitates the transfer of skills, speeds up the learning process in new settings, and enables the communication of knowledge and skills to others (Willingham, Nissen, Bullemer, 1989; Sun & Peterson, 1998). Declarative knowledge lays the knowledge foundation in place which when acted-upon in a contiguous manner through practice becomes proceduralized and converted to a tacit, procedural form (Anderson, 1982). This transition happens in gradual,

concurrent ways through continuous experiential learning and when actualized and internalized, the learner is able to competently and automatically perform the actions of the task though he or she is unable to analytically and heuristically express or communicate the whys and hows of carrying out the procedures within the task. Such preliminary, prerequisite declarative knowledge could be activated within learners if they have the prior knowledge or otherwise it needs to be communicated to them before they attempt to learn new procedural knowledge.

Explication of Design Elements of Proposed Model

In this proposed model declarative knowledge is classified into two broad, functional forms – that is, basic and connected/extended factual knowledge. When verbal information which is originally in an abstracted form gains a meaningful representation as organized bodies of knowledge it becomes transformed into usable, declarative knowledge. Knowledge is the output of information processing. Unlike information, knowledge is a dynamic mix of information embedded in context, experience, insight, and values (Brooks, 2000). Such knowledge could be characterized as being either specialized or generalized (Gagne, Wager, Golas & Keller, 2003). Specialized knowledge is possessed by individuals within their own fields of expertise or work whereas generalized knowledge is a body of cultural and historical knowledge that has a societal imprint in it being well acknowledged by all citizenry as being desirable for the educated class to be learnt. Such generalized knowledge serves as the foundation for creative, reflective thinking and critical reasoning.

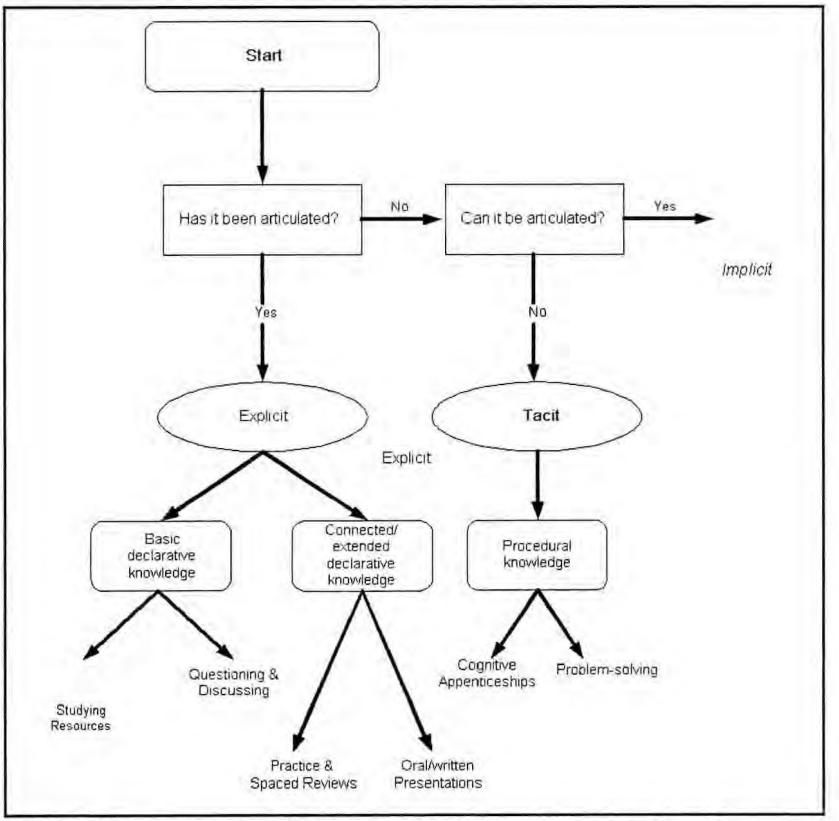

Figure 2. Integrated Framework of Constructivist-based Curricula Design

In this model the order of instructional sequencing is organized such that declarative knowledge in its basic form is acquired first by learners followed by learning of connected/extended declarative knowledge. Both of these categories of knowledge lay the epistemological groundwork for learners to interact with the objects of declarative knowledge through a range of learning activities and instructional tasks. This then enables learners to imbibe the intrinsic, procedural knowledge of processes and skills involved in automatically performing the series of steps required of the tasks.

Basic declarative knowledge constitutes verbal or written statements that express relations between two or more named objects or events and details about their properties (Gagne, Wager, Golas & Keller, 2003). Such information could also be details on episodes, cause/effect sequences, time sequences, or general principles. Examples of such statements include "Plants are usually green in colour," "The war was lost due to lack of logistical planning," "Length is defined as the physical distance between two points," "Boiling point is defined as the temperature at which a liquid turns from a liquid state to a gaseous state," "President Kennedy was assassinated on November 22, 1963." Such statements convey meanings that could be related to other existing facts and integrated to build-up a larger set of knowledge or extended to learn new facts in multiple contextual situations. This second category of knowledge could be labeled as connected/extended declarative knowledge in recognition of the fact that such knowledge is a natural expansion of basic declarative knowledge. When acted upon to execute a set of actions, involving either mental or motor skills such basic declarative knowledge then becomes transformed to procedural knowledge. Connected/extended knowledge includes the learning of a variety of concepts, rules, and principles to gain intellectual processing capabilities. For example when the concept of length is understood in mathematics, it could be logically extended in its usage to understand Pythagoras Theorem and its associated application. In science the basic principle of boiling point could be further extended to explore how various environmental variables could alter the boiling point of a liquid. Formulating and organizing a school curriculum both in terms of its content and practice in the direction of the above discussed continuum of progressive epistemology and knowledge development stimulates the intellectual and cognitive growth of an immature learner in a systematic manner.

The maturation of the learning process results in the development of vital procedural knowledge or knowledge in the doing. Encompassing psychomotor and cognitive components, procedural knowledge is inherently functional in enabling performance of varied tasks. Such procedural knowledge is the consummation of declarative knowledge which originally being descriptive is now employed to execute a set of actions to accomplish a task. Such tasks include psychomotor activities such as diagnosis, troubleshooting, and repairing of mechanical systems as well as cognitive activities such as learning a foreign language. The performance behaviours of an expert possessing procedural knowledge

are so well-endowed internally and of second nature that the expert is unable to express be it orally or in writing the nuances of the hows and whys of executing the steps and procedures. This is why it can be argued that almost all forms of procedural knowledge are tacit and unable to be codified and articulated. The skills and processes embodied in the learning of procedural knowledge are in essence intrinsic and complex. Thus, the expert is able to enforce the course of action and the corollary procedures of the task intuitively and sub-consciously, such that he or she is unable to communicate to others the functional mechanisms of procedural knowledge. Nickols who is also of this opinion refers to Nonaka's example of the product developer who developed specifications for a bread making machine in support of his views. Though the developer was able to devise a set of product specifications based upon what she learnt in the course of apprenticing the chef it was hardly likely that she captured in expressed writing the chefs tacit knowledge. What she was able to articulate was some declarative knowledge that consisted of rules or principles that could be useful in the design and development of the bread-making machine.

Heuristic Strategies for Facilitating Knowledge Building

In this section some of the instructional strategies and methodologies that could be employed by educators who desire a pedagogical approach to curriculum development with constructivism as its underpinning epistemology. Such an approach constitutes fostering a learner-centered educational environment where the educator plays the role of a facilitator in guiding learners' construction of knowledge. Accordingly the locus of learning shifts from the teacher to the learner. This is unlike traditional classroom environments where the educator is the arbitrator of knowledge and dispenses large amounts of information in the name of teaching. A constructivist learning environment is structured to allow the learner to autonomously construct systems of meanings based upon prior knowledge and educative experiences. Such an instructional structure facilitates incremental learning where the learner continuously builds new ideas and concepts upon existing mental models or schemas. Gagne, Wager, Golas and Keller (2003) suggest that the mental models or networks of propositions, as they identify them, encompass new constructed knowledge being linked to larger propositional networks already existing in memory. For example, the instructional units for a history lesson can be organized with students first learning the framework of a historical timeline of key world events

which can serve as the referent allowing students to actively insert details of events covered later during the progression of the lesson.

Active knowledge construction is more appropriate in terms of application and context for both connected/extended declarative knowledge and procedural knowledge structures than for basic declarative knowledge forms. Basic declarative knowledge being elementary in its scope does not require a high level of cognitive processing nor analytical reasoning for comprehension and thus there is not much scope for construction of meanings. In fact adopting a constructivist epistemology to acquaint learners with fundamental information and ideas could prove to be counter-productive and might unnecessarily complicate the learning process. An information acquisition mode would suffice in the learning of facts and principles constituting basic declarative knowledge since the complexity of understanding at this phase is of a rudimentary level. If the basic declarative knowledge needed for the lesson has been learnt before, this prior knowledge can be activated through techniques such as questioning and recalling. Otherwise, learners could be encouraged to acquire the new prerequisite basic declarative knowledge concepts through analysis of a variety of resources. For learners who are unfamiliar with the subject matter or are at a lower level of intellectual development, these resources could be provided for by the educators whilst learners who are cognitively better equipped and are capable of directing their own learning could be encouraged to seek out their own resources either online in the Internet or in the libraries. However at the end of the stipulated reading period of these resources, it is important that as a class educators thoroughly discuss with learners the content of these resources and explicitly teach if need be the foundation disciplinary principles and facts necessary to build up the extended and procedural knowledge structures of the lesson.

Extended/connected declarative knowledge could be learnt through instructional strategies where learners' active construction of new knowledge is enabled through modes of self-discovery and experimentation that increase learners' ability to grasp, transform, and transfer content being learnt. One such strategy is affording opportunities for varied practice and spaced reviews. Traditional practice sessions and spaced reviews are essentially of a drill and practice nature where learning is emphasized through remembering, repetition, and recalling information in isolated or unrelated contexts to retrieve acquired information from memory. However, a constructivist

approach to practice and spaced reviews involves task-oriented learning activities where learners are exposed to a spectrum of cognitive processes involving comprehending, applying, creating, elaborating, managing, critiquing, and cross-referencing the body of organized prerequisite basic declarative knowledge to build upon new extended/connected knowledge structures. A key component of these activities could be the requirement for learners to either verbally or in writing explain the rationale of their thought processes in construing meanings out of the content being analyzed. These oral or written descriptions could serve as think-aloud protocols and enable facilitators to ascertain students' intellectual development and highlight to learners the necessity to be aware of metacognitive strategies. Metacognition being an internal processing act makes use of and governs a system of cognitive strategies to monitor, regulate, and control learning and memory processes (Flavell, 1979). For example a lesson on Pythagoras theorem could be designed based upon task-specific practice activities which tease out students' understanding and learning in structured ways. First, the facilitator activates students' prior basic knowledge of the definition of length and other related information such as units of measurements and how lengths can be measured. If such foundational knowledge is found lacking in the students, the facilitator explicitly needs to teach such content at the onset of the lesson. Following this, students could be allocated some hands-on time to apply the basic knowledge by manipulating a variety of triangles of different sizes and measuring the lengths of the sides of the triangles. In the course of students working on the task, facilitators could provide verbal cues to prompt students to probe and reflect deeper on the relationships between the lengths of the sides of the triangle. Students are thus progressively guided to draw their own inferences from their personal learning experiences to gradually come to understand the principle of Pythagoras Theorem.

Procedural knowledge as has been argued for earlier is inherently tacit and resides in the minds of the experts. Thus, it cannot be transferred through articulation or communication from the experts to novice learners. However, constructivist curriculum designers could employ some instructional methods for facilitating learners' construction of procedural knowledge. Planning for cognitive apprenticeship is one such method (Gagne, Wager, Golas & Keller, 2003). Historically, apprenticeships are learning situations where the learner works alongside the experienced individual. This instructional technique

includes observation, coaching, practice and feedback to the learner. Cognitive apprenticeships do not imply the exact transfer of mental models from the expert to the novice since such a transfer is not plausible. Through keen observation and constant feedback from the expert, the novice learner develops an in-depth conceptual understanding of issues and develops his or her own mental networks of new procedural knowledge (Collins, Brown & Newman, 1989)

Yet another instructional strategy that could be effectively employed by educators to facilitate tacit, procedural knowledge construction involves problem-solving. Problem solving is a highly dynamic and multi-faceted learning activity that is embedded with context-rich, experience-based problems. Based upon a typology of contextual problems, problem solving tasks are normally student-centric and situated reflecting the complexities of real-world situations. The problems could also differ in their demands for the levels of cognitive processing and higher-order thinking required in solving the given problems. The problems could range in a continuum from being well-structured to being ill-structured.

A problem solving approach principally involves three epistemological processes that educators need to be aware of in order to optimize learning outcomes. One is modeling and this deals with demonstrating to learner how and why certain activities need to be performed for the completion of a task and its objectives. This can be accomplished by providing examples of the desired task performed and the underlying reasoning and decision making required to successfully completing the task. The next process is that of coaching and involves intervening at critical points to provide learners with encouragement, diagnosis, directions, and feedback. Finally, scaffolding entails the facilitator/educator to adjust the task for the learner to match his or her level of performance. The facilitator provides appropriate cognitive scaffolds by taking into account systemic factors such as task complexity, nature of the learning environment, learner styles, intellectual and cognitive capabilities of learners (Jonassen, 1998, 2000).

Conclusion

Constructivism promotes learning to be an active process in which learners construct new concepts based upon prior knowledge. Learners select and process information through constructing hypotheses, decision making, and giving meaning and organization to experiences. And instruction needs to be in alignment with principles of constructivism for

optimal learning to occur. Instructions need to be linked to experiences and contexts that motivate students to want to learn. Instructions must be structured to take into account the cognitive demands of different disciplinary fields and the structural nature of declarative and procedural knowledge representations. Appropriate instructional strategies need to be framed in order to facilitate learning of declarative and procedural knowledge through constructivist pedagogy and attain desired educational outcomes.

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