2006-791: THE NCME INSTRUCTIONAL DESIGN MODEL: A CONSTRUCTIVIST APPROACH TO LEARNING

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Abstract

In January 1995 the National Science Foundation Advanced Technological Education (NSF-ATE) Program funded the creation of the National Center for Manufacturing Education (NCME) to develop curricular materials for a novel manufacturing education associate degree program. The primary deliverable included 62 instructional units (modules) that create a novel associate degree program in manufacturing engineering technology. The program was considered innovative in its pedagogy, organization, and content[1]. This paper focuses on the constructivist framework that supports the pedagogy (instructional design model), a supportive *Curriculum Assessment Checklist,* and the results obtained from our external evaluator, the Higher Education Evaluation and Research Group (HEERG)[2, 3]. The first tasks in the creation of this novel program revolved around the determination of the curriculum competencies — the what — and the philosophical underpinning for a new instructional design model, the how.

The NCME determine that a constructivist learning philosophy defined within fifteen learning statements provided the underpinnings for the Instructional Design Model. The learning statements and subsequently developed instructional design model go beyond the eight instructional principles and the three primary constructivist propositions defined by Savery and Duffy (1995, 2001) on how we come to understand or know, to include the learner's preferred learning modes[4, 5]. The instructional design model as shown in Figure 1 supports activity-based, contextual, industry-verified, whole-to-part learning. Each of the instructional modules contains more than one authentic learning task and a transfer activity. A key element of the module is a transfer activity at the end of each module, which provides a context for integrating all the competencies developed within that module, and to provide contextual linkage between modules. The most commonly used context is based on a virtual company, Robotic Grippers Inc.

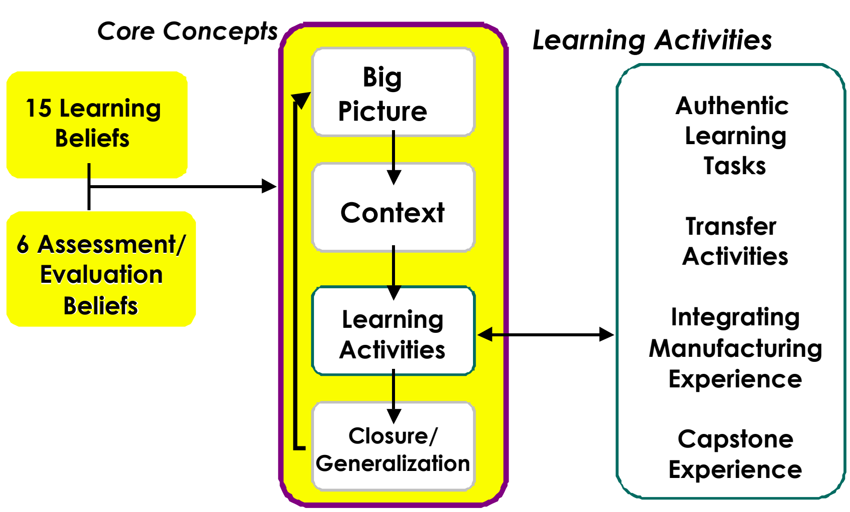

Figure 1. Instructional Design Model

Definitions developed by the NCME for the learning activities nomenclature can be found in the following table.

Table 1
NCME Learning Activities Descriptions[6]

Instructional Element	Description
Big Picture	The big picture is the framework for learning. Before specific theories and skills are tackled, instructors construct a framework by defining the value these theories and skills have and the ways in which they might be used on a day-to-day basis. The big picture encourages "whole to part" learning.
Authentic Learning Tasks	Authentic learning tasks are a series of discrete learning events that build experience and competencies related to the goals of the learning experience. Authentic learning tasks often replicate a real-world application, but they are more limited in scope. Their primary focus is to build specific skills or competencies.
Transfer Activities	Transfer activities represent a more complex learning activity designed to help students develop relationships among learned competencies and to encourage students to apply these in challenging, new ways. The primary focus of the transfer activity is to unite skill and theory in an occupationally verified manner. The transfer activity allows students to reinforce and extend competencies learned in the authentic learning tasks in a new context.
Integrating Manufacturing Experience	Ties together all of the manufacturing oriented transfer activities together by providing a manufacturing macro context, "Robotic Grippers Inc.", This macro context allows the participant to revisit the same context from different perspectives to aid in the integration of the overall manufacturing experience.
Capstone Experience	Provides a final learning experience, in which students demonstrate mastery of the expected competencies to a new, highly focused activity within a manufacturing setting.

The authors will further expand the elements of the Instructional Design Model and their links to the fifteen learning statements, and constructivist or other learning theories that support the elements. The analysis provided by HEERG will be cited, as well as pilot test feedback from students and facilitators.

Learning and Transfer

Extensive study over the past century has been directed toward understanding the cognitive processes and supportive instructional designs involved in learning and transfer. Instructional designers currently support three positions on learning and transfer: these are behaviorism, cognitivism, and constructivism. The behaviorist approach to transfer is supported by the associationist principle; and the cognitivist and constructivist approaches by Gestalt principle, with the constructivists asserting that knowledge is linked to the context in which it was learned[7].

The associationist approach proposed by Thorndike and Woodworth (1901) predicted transfer based on the number of identical elements[8]. Singley and Anderson (1989) extended the identical element research: predicting transfer of computer editing and programming skills based on the number of identical productions[9]. Their definition of "element" included cognitive representations and strategies. Their research demonstrated very large positive transfer between two skills that have the same logical structure. Anderson (2000) concluded "there is transfer between skills only when these skills involve the same abstract knowledge elements"[10]. In summary, the associationist approach based on the concept of identical productions or elements, which are typically declarative or procedural knowledge, produces the highest level of vertical or near transfer.

The Gestalt approach considers thinking as a process for recognizing relationships that exist between one problem context and another problem context. The Gestaltist view is reflected in the Meaning Theory of which Bartlett's schema conception is the best example. The Meaning Theory involved determining how a current problem relates to those concepts and ideas already present in memory[11]. Based on this theory, transfer will occur if the learner can relate the new problem to a previously organized schema. This horizontal or far transfer connects the structural features of the problem to two or more domains[12]. This analogical approach can be more successful on facilitating horizontal or far transfer than the associationist approach. Glick and Holyoak (1983) stated "the essence of analogical thinking is the transfer of knowledge from one situation to another by the process of mapping—finding a one-to-one correspondence between aspects of one body of information and another"[13]. The common elements cited in the literature are the importance of well-organized structural knowledge and sufficient experiences to be able to decontextualize the relevant knowledge.

The constructivist approach to schema development emphasizes the whole, the learner, the environment, the organizational factors, and the fact that the knowledge is linked to the whole context[14]. Latchman (2000), using constructivist-teaching approaches, obtained significantly higher scores in student achievement[15]. The knowledge and applications used involved near and far transfer of concepts. Real world contexts, learner control, and problem solving skills are all necessary to enhance transfer in ill-structured domains[7, 16-18].

The subsequent sections focus on the constructivist approach to learning and transfer and how the NCME implemented these approaches within their instructional design model.

Literature Review

Methodology

The methodology for researching this topic was threefold. First, the authors began the search for relevant journal articles by the use of ERIC and Wilson document searches using the keywords "constructivist" and "instructional design." The abstracts were reviewed and subsequently requests were made for articles. Second, extensive reading in *The Handbook of Research for Educational Communications and Technology* provided an overview of the topic and related areas and made it possible to locate relevant firsthand articles and cite authors for follow up. The authors accomplished the follow up by either searching for all works by a specific author or by requesting the articles cited in the handbook and then reviewing those primary articles for additional citations. Third, scanning the table of contents in frequently cited journals for relevant new articles completed the research.

The procedures used for first review of articles or books were based on asking the question: did this article discuss the relationship between constructivism and instructional system design or practice? If the answer was yes, then: Did it propose a theory and/or present empirical evidence to test that theory? If yes, then these documents became primary sources. If no, then a third question was asked: What contribution can this journal make to the understanding of the relationship of constructivism and instruction design? Several articles were cited as support for defining the problem and providing broader insight into the underlying question. The analysis section will address the findings of these questions.

Analysis

The analysis section begins by providing citations and discussion of constructivist followed by a summary discussion of cited best practices in instructional systems design that support constructivist activities and meet criteria for excellence in design. In a review of 13 sources on constructivist practices, 11 different practices were cited for a total of 38 times. These eleven practices can be grouped into three areas: context, method and outcome. Context comprised 47% of the total citations[4, 17, 19-27]. Method comprised 39% of the total citations[4, 19, 21, 22, 24-26, 28, 29]. Outcome comprised 12% of the total citations[4, 19, 21, 25, 29]. Table 2 provides a summary of the subject categories and their frequencies.

Table 2
Categories and Outcomes of Cited Constructivist Practices

Factors Cited	Number of Citations	Percentage of Group
Context		
Authentic tasks	8	44%
Anchored or situated learning	6	33%
Open ended learning environments	2	11%
Ill structured contexts (cognitive flexibility theory)	2	11%
Method		
Collaborative learning	6	40%
Cognitive apprenticeship	4	27%
Scaffolding	3	20%
Coaching	1	7%
Active learning	1	7%
Outcome		
Authentic assessment	3	60%
Transfer (cognitive flexibility theory)	1	20%
Integration	1	20%

The top four factors cited (authentic tasks, anchored or situated learning, collaborative learning, and cognitive apprenticeship) account for 63% of the total citations. These four elements require further comments from the cited articles to assist in the understanding of their use.

Discussion

Jonassen (1991) advocates "In situated learning the instructor fills the role as coach and analyzer of the problem solving strategies and the importance of real world problems as the basis for learning"[22]. Ross (1998) and Savery and Duffy (1995) favor situated learning when a student works on an authentic task in a real setting[4]. Ross documented the use of employee-student ill-structured work related projects as the basis for contextual projects in a graduate course in instructional technology[17]. Specter (1999) advocates the use of collaborative learning communities for the learning of complex domains especially in a distance-learning environment. Grabinger (1996) proposes instructional strategies that create a constructivist-learning environment called "rich environments for active learning (REAL's)"[19]. This strategy is supported by Savery and Duffy (1995) to "design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning"[4]. Supporting documents that directly discuss cognitive apprenticeship and transfer include the works of Dick, Carey etc., Winn and the Cognitive and Technology Group at Vanderbilt (CTGV). Dick, Carrey & Carrey (2001) cite the importance of "transfer from the classroom to the performance site as one of the most critical concerns of educators and trainers"[30]. Winn advocates instructional designers need "to do a better job of teaching transferable knowledge and skills… to teach skills that cut across all situations and be capable of self-modification." Winn also advocates the need for instructional designers to develop "worthwhile ways for students to serve 'apprenticeships' in school as learners; designing experimental experiences that bring into the classroom activities that are authentic; and situated in the real world"[27]. The Cognitive and Technology Group at Vanderbilt developed anchoring or situational instruction called "macro contexts." These "macro contexts" allow the creation of collaborative learning environments that lead to an individual's ability to transfer the knowledge and skills acquired[26]. Also discussed were the several different kinds of transfer. These include transfer to "new analogous problems," "partial analogous problems," "what if problems," "outside the classroom setting" and "transfer as efficient learning"[26]. The constructivist elements sited in the previous document lead us to the next search for constructivist instructional systems designs.

Constructivist Instructional Systems Designs

Criteria for Design

Beyond the constructivist criteria developed and discussed in the previous sections, Alexander (1979) established characteristics for excellent designs or models. He stated, "Patterns … exist at all scales." Therefore an instructional design model or pattern should work at the activity level, instructional unit level and the curriculum level. "Each pattern is a three part rule, which expresses a relationship between a certain context, conflicting forces and a solution." All designs must meet this characteristic. "It is only possible to make a design alive by a process in which each part is modified by its position in the whole. In nature, a thing is always born, and developed, as a whole." All systems based designs must look at the whole and the sequence of activities in order to have a coherent design[31]. The literature search provided three examples of constructivist system models that meet the characteristics provided by Alexander and the key constructivist elements found in Table 2. The first is from the National Center for Manufacturing Education (NCME), the second from Jonassen and Rohrer-Murphy, and the third VanMerriënboer's (1997) 4C/ID based instructional design. Briggs (1977) and the Michigan State University's Instructional Design Model cited by Thompson, Simonson and Hargrave did not meet Alexander's pattern criteria previously outlined [32, 33]. The next section contrasts the Jonassen and Rohrer-Murphy (1999) activity theory, and VanMerriënboer's (1997) 4C/ID based instructional designs with the NCME instructional design model.

The Jonassen and Rohrer-Murphy model shares many important characteristics with the NCME model. Both models can be applied to both the development of the instructional design, and the instruction itself. Both models work at all levels of the design: system, macro, and micro. Both models develop a solution after context and problem definition. Both models focus on whole-to-part versus part-to-whole in the implementation process. Both models focus on the importance of sequence.

VanMerriënboer's 4C/ID model characterizes two types of learning activities, part- and whole-task practice, which are equivalent, respectively, in the NCME model to the Authentic Learning Tasks (ALTs) and the transfer activities. Both the transfer activity and the whole-task-practice in the cited models stress the importance of providing the learner with an opportunity to integrate their skills learned in the smaller activities within a new context. The next section details the efforts for the development of an assessment checklist that defines the primary characteristics of the NCME instructional design model.

Application of the Model and Checklist

Over the past ten years many colleges have adopted a continuum of application of the instructional model from developing a specific two-hour constructivist activity to incorporating up to 50% of the available sixty-two instructional modules. As an aid in the development and evaluation of adopter created instructional materials one of the current Principal Investigators developed an evaluation instrument.

NCME PI Anderson (2002) developed a *Curriculum Assessment Checklist* that evaluates instructional designs versus the key elements in the NCME instructional design[2]. These elements are summarized in Table 3. It has been observed through the implementation, primarily within college level courses, of the instructional materials based on the NCME elements that the metaskills and communications skills are reinforced by the application of core competencies. These core competencies focus on how students think, how they communicate, how they interact with others, and how they use knowledge. Each collaborative, team, and problem based activity provides closure while the facilitator guides the discussion back to the overall "big picture" in order to provide a broader view of the applicability of the skill set. This instructional design approach is supported by Prince's (2004) metastudy of the effectiveness of problem-based learning to improve student achievement, which found that the following had the largest positive impact: cooperative tasks 0.54, instruction in problem solving 0.54, use of small groups 0.31, and using problems 0.20[34]. The competencies supported by the instructional design architecture are by their construction aimed at developing higher level thinking skills. HEERG (2003), an independent evaluation group from University of California Berkley, provided these comments about the activities: "To prepare students for a standard condition of uncertainty, ALTs place students in confusing situations for which there is no single correct solution." HEERG further commented, "students are required to make decisions, produce recommendations, compare, balance competing factors, identify variations, justify, make changes, and/or develop and evaluate plans. The modules present realistic challenges for which students use group consensus to solve problems"[3].

Conclusion

In conclusion, the ALTs and transfer activities developed using the NCME instructional design model effectively produce learning strategies that develop higher order thinking skills typically applied to experiential, inquiry, and problem based learning.

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Table 3

NCME Curriculum Assessment Checklist Elements

Instructional Element		Characteristics
Big Picture		
Context	-	Students are assessed for preparedness in terms of prerequisites.
Diagnostic Assessment	-	The learning experience begins with an overall understanding of the big picture, outlining the breadth of possible contexts and applications. Learning goals are clearly stated.
Competencies	-	Competency statements identify those specific abilities that students should be able to demonstrate upon completion of this learning experience. Competency statements are phrased with action verbs, identifying what students should learn instead of what faculty should cover. Competencies are observable or measurable.
Employer Verification	-	Employer representatives verify the relevance of the overall learning experience. Examples are provided that illustrate how specific companies utilize these competencies. This verification is documented and shared with students
Authentic Learning Tasks		
Activity-based	-	Activities lead students in the development of competencies through a series of focused authentic learning tasks.
Context	-	Each activity begins with the setting of a context. The context describes the setting of the activity and describes the real-life application of the competencies.
Activity	-	Students construct their own knowledge through guided discovery. Activities allow students to apply concepts and principles in order to learn the competencies relevant to the particular authentic learning tasks. Students are actively engaged in the learning process.
Closure	-	To help students apply competencies in other situations, each authentic learning task concludes with a closure segment. Students begin to project new skills and knowledge to other lessons and real-world situations.
Assessment	-	Student learning is assessed in a formative manner during the authentic learning tasks. The methods of assessment are authentic, allowing the students to demonstrate their level of competence in a manner similar to that which they will be expected to perform in industry.
Assignments	-	Homework assignments support student learning of the competencies.
Transfer Activity		
Context	-	The transfer activity begins with the setting of a context. The context describes the setting of the activity and describes the real-life application of the competencies. The context of the transfer activity is different than the contexts of the authentic learning tasks, to promote transfer of knowledge.
Activity	-	Students re-apply all of the competencies in one project-based activity, this time in a different context. Students are actively engaged in the learning

		process.
Collaborate Teamwork	-	Students collaborate with others in a team effort to accomplish the transfer activity.
Integration	-	The transfer activity is an opportunity for students to blend the competencies in a project that requires their integration.
Closure	-	To help students apply competencies in other situations, the transfer activity concludes with a closure segment.
Assessment	-	Students continue to generalize and project new skills and knowledge to other lessons and real-world situations.
	-	Student learning is assessed in a summative manner during the transfer activity.
	-	The methods of assessment are authentic, allowing the students to demonstrate their level of competence in a manner similar to that which they will be expected to perform in industry.
Overall		
Faculty Role	-	The primary role of faculty is manager of the student learning experience. Traditional lecture mode is minimized.
Textbooks	-	If textbooks are used, they serve as supporting reference materials for the achievement of competencies.
Documentation	-	The learning experience is documented so that a third party can understand the methods and replicate the process for other groups of students.
Integration	-	The learning experience promotes integration among related subject areas to help students take a holistic view of their field.

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