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INTERACTIVE STRATEGIES FOR DEVELOPING INTUITIVE KNOWLEDGE AS BASIS FOR SIMULATION MODELING EDUCATION

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ABSTRACT

This paper investigates theoretically based instructional approaches for organizational training, education and knowledge acquisition for simulation modeling. It proposes different theoretical paradigms that bear a close relationship to the development of curricula for simulation modeling and practice. A curriculum model is promoted that has foundations, which are based on adaptive instructional paradigms. We advocate that a multiple approach to the delivery of instruction should be a dynamic process, set within a context which integrates both a theoretical and a practice-led curriculum. The objective is to examine the contents, framework, and instructional strategies for effective teaching and learning for simulation modeling.

1 INTRODUCTION

The application environments for modeling and simulation are numerous and diverse Law and Kelton (1991) and usually involve using simulation software as opposed to analytical methods. This has resulted in an increase in demand for user training to operate and support these products. Training activities can be directed towards providing hands-on experience required to apply simulation modeling processes.

A novice learner may prefer learning new simulation software "by doing" rather than learning from textbooks or manuals and gaining experience from continual practice. Using simulation modeling software is mainly a cognitive process with a small motor element. The process involves thinking about what entities, attributes and events to include in the model. Learning from mistakes may be one of the main natural methods of learning if it results in changes in behavior. Bruner (1966) postulates four aspects that a theory of instruction must address. These are: (1) learners' predisposition towards instruction, (2) the structure of the knowledge, (3) the sequence of the instruction and (4) the type of feedback. These can help define the various features for implementing an effective learning environment for simulation modeling.

Different universities have diverse programs of teaching that are likely to produce different types of knowledge. We are faced with the problem of teaching simulation modeling for "understanding" as opposed to teaching simulation modeling techniques. Proficiency in simulation modeling techniques will involve a large amount of practice. The pedagogical framework should determine the contents, scope and training objectives for the diverse learner. Learning outcomes could be enhanced if instruction can be adapted to the learner's needs, contents, learning style, and cognitive style (Labov 1982). Classroom activities give simple examples emphasizing approaches and technical problems from which problems can be solved. Classroom activities could be centered on the body of knowledge that the learner would require and with acquisition of new skill (Taylor et al. 1995). Classroom activities should therefore be directed towards improving skill and performance. This could be achieved by organizing instruction around clearly defined learning outcomes within a subset of the curriculum.

This paper starts by reviewing relevant psychological theories and instructional strategies, and proceeds to propose an instructional framework that is based on multiple approach to the delivery of instruction. The framework is based on a dynamic process set within a context, which integrates into a theoretical and practice-led curriculum. The advantage of this framework is to ensure that teaching standards for simulation are set and met consistently.

2 SIMULATION MODELING EDUCATION

The increasing use of simulation modeling has resulted in an increasing number of simulation modeling software products (Catalogue of simulation software, 1988), with a resultant need for more user training. Simulation modeling software presents diverse functionality that is used to accomplish various simulations and modeling projects. Typical applications of simulation modeling in manufacturing include factory layout planning, material flow analysis, scheduling and inventory analysis. Therefore continuous development of the learner can be achieved by the integration of classroom activities with simulation modeling tasks. A Department of Trade and Industry (1991) study identifies the scope of teaching of simulation in formal education in the United Kingdom as being limited and the quality and amount of teaching varies greatly. The difficulties of meeting training requirements could be attributed to the lack of technical and social resources to satisfy the learning environment. The reasons for this shortcoming are: (1) in some institutions, simulation teaching is characterized by relatively low class contact hours; (2) students have different concepts of simulation and a limited range of problem-solving strategies; (3) students have no freedom in the choice of content and method of learning; (4) the subject scope depends entirely on the flexibility of the curriculum; (5) the functionality of the simulation packages is not integrated into the curriculum; (6) inadequate resources; (7) there is also some conflict in the goal of teaching simulation techniques as opposed to theoretical understanding.

Simulation modeling is taught in many universities in the United Kingdom at M.Sc. level and to some final year students in Computer Science and related fields. The students are required to assimilate the knowledge acquired during the course and be able to apply it to “real life” problems. Inherent within this approach is the notion of student deterring their personal value and assessment methods. This method shapes the teaching of simulation and inhibits student’s participation.

The processes of constructing a simulation model are usually based on the users’ paradigms. It involves building a conceptual model and using statistical methods for analyzing the data derived from the empirical study. These paradigms shape the methods by which simulation modeling processes are taught in the classroom, and their textbook adaptation. Different paradigms of simulation modeling are used over a range of domains and this affects ways the learner’s construct their knowledge. The pedagogy of teaching/learning simulation is traditionally based on classroom lectures and using simulation software packages.

Increasing numbers of simulation languages and simulators are used in the manufacturing, business and military applications. The dynamic behavior of this simulation software and methods of representing the models are different. Simulation modeling courses should provide the student with opportunities of learning more than one simulation software package and this should be an integral part of the curriculum. For example, students should be able to recognize the application of a simulation software package by using different case studies. To illustrate this concept, the student could compare modeling a production plant or supermarket using Activity Cycles Diagrams (ACDs) and Visual Simulation Seven (VS7). The student could be asked to perform the same tasks by using either SimFactory or WITNESS. This approach replies on short learning activities that is problem centered

Taba (1977) states that a curriculum should consist of “key elements; aims and objectives, content, and learning experiences and evaluation.” The content may consist of a new concept, “paradigm,” or principles disseminated to the learner. The development of a “pedagogy” for teaching simulation should be centered around a curriculum framework, that is based on learning outcomes and recognizes “both that something is and what it is”, (Kuhn 1990). The lecturer’s “paradigms” could influence learning outcomes due to their classroom experience, knowledge, specific beliefs and instructional strategy. The teaching paradigms should integrate knowledge across various domains and facilitate the attainment of a specified learning outcome. Simulation modeling education should support and accommodate differences in the ways students construct their knowledge and should facilitate creative problem solving to meet both organizational and educational needs.

Most classroom activities are influenced by formalist vision of modeling and simulation. Learners conceive this approach, as the “correct” way in which to approach simulation modeling. Cognitive approach of teaching simulation focuses on the behavior to be learned. One good illustration of the emphasis of what is to be learned is presented by Gagne’s (1970) theoretical framework. Its application to teaching simulation modeling implies that instruction should result in developing new paradigms. He suggested that tutorial tasks could be organized in a pedagogical hierarchy according to their complexity and learning outcome.

These theories propose that each of the categories of learning outcome require a different set of conditions for optimizing learning, retention and transfer. Optimal conditions can be defined both in terms of the instructional environment and the learner’s behavior. This process involves learning by using attention, selective perception, short-term memory, rehearsal, long term memory storage and retrieval of previously learned information.

3 INSTRUCTIONAL OBJECTIVES

Training objectives for simulation modeling can be defined both in the content and scope of the skill required by the learner and the learning outcomes. Gagne and Briggs (1988) postulate that teaching consist of situation, execution, objectives and tools. The learning objectives can be summarized as follows:

- Problem solving skills and decision making, creating and developing alternative solutions. Applying simulation-modeling knowledge to solve different problems.
- Communications skills incorporating both verbal and non-verbal including visual aids such as graphics, animation, charts and models.
- Analytical skills, i.e. development of a conceptual and a simulation model of the system. The ability to interpret statistical results and the extent to which the results meet the simulation objectives. The ability to recognize and analyze alternative explanations and procedures.
- Social skills - team work and participation and the development of social-technical skills.

These objectives might provide the necessary foundation for students and may allow for progressive development in organizations/industries. For example, the teacher could pose problems requiring learner to solve. This approach may allow for the transfer of knowledge from the classroom to everyday practice.

Collins et al. (1989) postulated a model that has four building blocks - "content, methods, sequence, and sociology." This model can be put together to define an effective and adaptive learning environment. The *contents* consist of a simulation modeling curriculum framework that focuses on concepts, facts, and procedures of modeling. *Methods* - the instructional method should provide the student with the opportunities to participate in, develop, or discover expert strategies in simulation modeling contexts. This includes strategies that would encourage student exploration and independence. *Sequencing* - learning could be organized so that the learner can build the multiple skills required in expert performance and discover the conditions under which they apply. This requires a sequence of instruction, providing diverse problem-solving situations, and hierarchical learning processes. *Sociology* - the learning environment should reproduce the technological and social characteristics of real world situations. Group projects should require students to work with others and work together to solve problems and carry out tasks. The student will in the process reinforce each other's perception of the task and reject discrepancies, although this might be impeded by individual difference amongst the student. The pedagogic for simulation modeling should integrate knowledge across different domains. These learning objectives can be improved by adopting any of the following strategies during instruction: (1) The learner should be allowed to interact directly with the simulation software package during instruction. (2) The learner should be allowed to develop their own experience by working with other students and on their own. (3) Classroom activities should start with skills that are relatively easy and should be focused on performance. (4) Standards of performance should be embedded in the learning environment and should be evaluated. Evaluation should compare the attained learning outcomes against the stated outcome.

4 PEDAGOGICAL ENVIRONMENT

The pedagogical environment for simulation modeling involves classroom activities that can result in a mastery of a predetermined set of core instructional contents. Traditional models of learning simulation are based on the acquisition of knowledge. These viewpoints can be influenced by philosophy and the assumptions of various professions and by their characteristics. Classroom activities should expose the learner to intuitive aspects of simulation modeling and the knowledge embedded in the practice plus its applications over a range of domains.

Shannon (1975) suggested that a novice would require "at least 720 hours of formal classroom instruction plus another 1440 hours study effort" to acquire basic skills in simulation modeling. This amount of contact hours could put a strain on resources in either an industrial or an academic environment. A viable option is to use a computer based instructional system (Atolagbe and Hlupic, 1996). The mapping activities, events, queues and their operations into a simulation model involves cognitive and analytical skills (Atolagbe and Hlupic, 1996). These skills include knowledge, comprehension, application, analysis, synthesis and evaluation, (Bloom, 1972). For instance, some of these skills are used during problem definition, conceptual modeling, model development and output analysis. The cognitive load in the model development processes affects students. They perceive the cognitive load associated with model construction processes as relatively large compared with the cognitive contents of the "real" tasks. The cognitive loads on some simulation software are minimized by automating some of the model development process. Figure 1. depicts framework for developing pedagogy for simulation modeling. The pedagogy supports both simulation modeling methodology and simulation software. This allows for modular partitioning of the contents and to adapt teaching to reflect new knowledge or methodology.

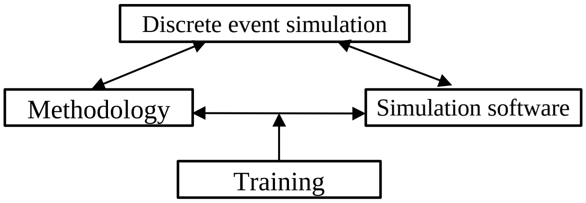

Figure 1: Framework for Pedagogy Development

Howell and Cooke (1989) note that the changes in technology increase the demand on the learner during instruction. Instead of performing simple procedural and predictable tasks during instruction, they are becoming more responsible for inferences, diagnosis, judgements and decision making often over a limited time period. Bruner (1966) suggests that three important variables are vital for the successful delivery of training, namely: the learner, the knowledge to be learned, and the learning process. These variables could provide ways of arranging teaching processes in relation to the practical aspects of learning.

A novice learner is prone to distort the building of a simulation model and the analysis of the simulation results. This can be attributed to: (1) an inability to determine the possible cause of inconsistencies in the model representation; (2) an inability to abstract operations from the problem definition; (3) an inability to establish the overall structure of the problem and the user operational structure; (4) an inability to identify the functionality of the software package and utilizes it accordingly.

Some of these factors could be attributed to the possibility that some courses and textbooks teach "abstract" simulation modeling processes and these may not provide adequate *concrete experience* to the learner. Instruction for simulation modeling should prepare the learner for a variety of real-life problems solving situations and should enhance their "concrete experience." Learning experience could start with the development of concrete experience (Kolb, 1984). Kolb's stages of learning could foster the development of pedagogy for simulation modeling. The first stage involves a learning experience, which begins with instructional activities and developing simulation modeling experience. The second stage involves reflection on the modeling experience and understanding its application and the third stage involves behavior modification and the generalizing of new ideas. At this stage, learners might begin to construct their own knowledge. The final stage involves applying new knowledge or paradigms to real-life problems. Kolb's learning circle can enhance the building of a learner's knowledge and skills in a simulation modeling course.

The "cognitive strains" on building a simulation model is exacerbated by the model representation techniques used by different simulation modeling software packages. The techniques commonly used for discrete event simulation include activity cycle diagrams and event, activity and process approaches Law and Kelton (1991), Paul and Balmer (1993), Pidd (1992), Shannon (1975). These approaches require the acquisition of concrete experience rather than abstract experience.

Simulation modeling processes involve conceptual model formation and subsequent analysis of data. These require the use of procedural knowledge, i.e. *problem solving capabilities* and some degree of declarative knowledge, i.e., an *understanding of the concepts*. These could be attained by specifying learning outcomes during the instructional development stages, by using an effective pedagogy structure and by the sequencing of tutorial units. Optimal conditions for teaching simulation modeling can be defined both in terms of the instructional environment and the learners' knowledge. Instruction for simulation modeling should involve a dynamic integration of learning outcomes, curriculum framework and appropriate simulation software. Other factors such as pedagogy content, the learner's knowledge or teaching approach could be associated with these factors.

5 ADAPTIVE INSTRUCTION

The processes of building a conceptual model require the student to use an appropriate simulation modeling strategy. Some students will require adequate guidelines in order to understand the course material presented to them during the course. Adaptive training activities could adapt its contents to both the student's knowledge level and didactic style.

Ausubel (1969) applies the cognitive approach to learning based on assimilation theory, which suggests that a meaningful learning results from the interaction between new concepts, which learners have acquired, and the cognitive structures they possess. We postulate that the learner's previous knowledge, providing an adaptive teaching style and a clearly defined curriculum structure could improve the learning outcomes for simulation modeling. The pedagogical content should integrate simulation and modeling knowledge with practice skills.

Gagne's (1985) instructional design framework can be adapted in developing an adaptive teaching style for teaching simulation modeling. It suggests that learning tasks should be classified into a hierarchy of structured tasks, didactic and interactive styles. Lecturer intervention could be required during the introductory classes, or during the analysis of the behavior of the model. Adaptive instruction is postulated based on the following:

- Simulation modeling processes embody deterministic procedures.
- Conceptual modeling tools such as activity cycle diagrams, automatic program generators, visual interactive simulation, simulation program generators, simulation software tools, the handling of stochastic input and output, and model confidence require different cognitive processing.
- The dynamics of the model will change during its life cycle.
- Didactic planning is based on the learning outcome and sequence of instruction.

Adaptive instruction could meet the needs of different needs and skill levels. We adopt the following procedures for implementing the system: (1) the curriculum is structured so that all the contents and instructional strategy reflects the functionality of the software, (2) the curriculum relates to information on the simulation modeling theory at the appropriate level in the tutorial, (3) it identifies and describes models that are supported by the simulation software application and demarcates between these models, (4) A hierarchical representation of building the model differentiates conceptual representation and statistical analysis.

These would allow instruction to be adaptive and meet different cognitive needs. An adaptive teaching strategy would allow the student to adapt a suitable learning style at various stages of simulation modeling processes.

This method of instruction could adapt its contents to different types of learner and to their level of skills. Desirable types of adaptive teaching styles are:

1. Instructor-oriented - the lecturer/system controls the presentation of information and the method of learning (Taba 1977). Different methods of instruction may be adopted from the curriculum framework.
2. Guide Discovery - this method of instruction is suitable for learning simulation software and for model development.
3. Exploratory - The learner choose which topic to learn or can navigate the topics freely. This method is suitable for intelligent tutoring systems representation.
4. Student controls - the student control the tutorials and can choose their own style of learning. This method relates directly to the student's model.

Figure 2, illustrates the different strategies that could be used during instructional development and how learner could be influenced by it. Different factors could influence the instruction method and could be altered by personal paradigms. It could also be adapted for computer based learning.

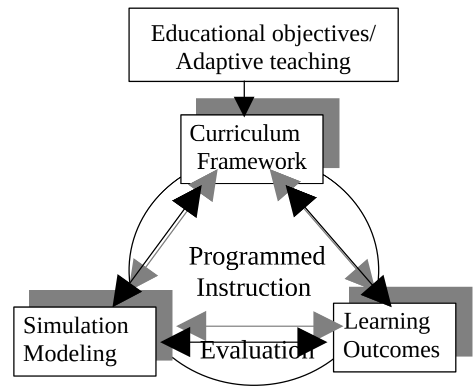

Figure 2: Triangular Integration

6 PEDAGOGICAL FRAMEWORK FOR TEACHING SIMULATION MODELING

We proposed a pedagogy framework that is centered on the development of strategic knowledge applied to modeling and simulation, which might be required by a learner. It centers on producing a learner-oriented instructional framework, which requires a predetermined level of skill attainment at every level before proceeding to the next tutorial unit.

An essential consideration, is what paradigms would be most effective for the attainment of these learning outcomes? The learning outcome was adopted from an M.Sc. course in simulation modeling at Brunel University (Paul and Hlupic 1994). The pedagogy structure and the contents depict the essential procedures and skill associated with simulation modeling. It focuses on instruction and skills acquisition, it incorporates the principles of curriculum framework (Taba 1977), transfer of learning (Ellis 1969), experimental learning (Kolb 1984), with a problem solving strategy. The competence level within each tutorial unit could be adaptable to both the teaching objectives and the learners' preferred learning style. The pedagogy sequence could facilitate a systematic progression, usually from basic skills to the more complex (Bruner, 1966, and Taba, 1977). The proposed curriculum structure is shown in Table 1. It depicts the course module and its adaptation into a curriculum. Each domain describes the skill and knowledge required for each module. It depicts the ways in which a pedagogy framework can be incorporated into the core concepts of simulation modeling. The advantages of the framework are: (I) It provides the learner with the tools by which to explain and understand simulation modeling behavior and validity during instruction. (II) It provides ways for finding solutions to the problems that could be posed by the behavior of the simulation objects at various levels of modeling. (III) It could be used to generate knowledge that is grounded in the explanation of the simulation problem. (IV) It allows for the teaching of transferable skills and it allows for the alignment of the curriculum structure to a specific learning objective. (V) It provides an alignment of the sequence of instruction with a learning outcome. (VI) It incorporates practical knowledge with the learning outcome and with the simulation model developmental life cycle. Knowledge and experience of a expert user can be elicited by the application of this structure.

The curriculum framework is structured into the following: Theoretical and practical applications of simulation modeling; (2) Management of practical exercise and case study; (3) Professional and ethical issues. These could facilitate the development of theoretical knowledge and enhance the development of practical skills. The curriculum model allows for the development of a student group project.

The proposed curriculum framework and the learning outcomes can be implemented at a "micro or macro level". It could be implemented as computer based instruction or as an intelligent tutoring system. The assessment of learning outcomes could be integrated as this could support effective instructional practice.

Central to this framework, is the need for evaluation. Evaluation should test the student's progress and should test the extent to which he has understood the domain topics in relation to the stated learning objectives. The tests should provide an assessment of abilities, which have been found to be required in organizations.

Table 1: Curriculum Framework for Simulation Modeling

Topics	Learning Outcomes	Interactive Strategies
Problem definition	To be able to recognize the needs their operations and Functions. To collate data and classify the operations and services into a task classification structure. To be able to Relate task operations to the behavior of the organization /operations. To be able to structure user systems into subsystems with distinct functions	Episodic, problem identification and classification. Use visual cues, graphical methods with multimedia support, 3D modeling and animation. Practice
Conceptual modeling	To apply different conceptual modeling tools such as an activity circle diagram, automatic programs generators, visual interactive simulation modeling, simulation program structures, simulation software tools, the handling of stochastic inputs and outputs, etc. into a scenario. To be able to justify the choice of a tool.	Structured approach, direct manipulation of objects and problem centered. Interactive model diagramming techniques and automatic generation of model design specification report. Using different schema.
Computer model development	Design, construct and document various models using program and random number generators, statistical sampling etc.	Episodic, problem centered, on-line help facility, automatic routine algorithm.
Design of experiments	Apply experimental factors and responses into a scenario. Choice of input and output variables and levels. Selections of appropriate experimental design, identifying logical attributes and the structure of the problem.	Immediate feedback, use existing knowledge for replication, and automated consistency checks.
Model validation & verification	To be able to check the consistency of the model and its functionality and to establish if computer modeling can solve the problem. Apply technical and analytical strategies.	Syntactic and semantics checks for consistencies, automatic checks. On-line help facility.
Simulation project management	Use acquired knowledge to build simulation models of real-life problems. Apply a theoretical framework and encourage consistency in the use of the above techniques.	Demonstrations with real-life examples, practice and automatic disaster recovery controls and security.
Profession and Ethics	Apply professional standard and ethical reasoning into a case study. Identify environmental, ethical and moral issues. Awareness of other professional bodies, e.g., operational research society.	Practice, group project and feedback.

6.1 Learner-oriented Teaching

Many simulation modeling textbooks describe various processes for simulation modeling (Law and Kelton 1991, Paul and Balmer 1993, Pidd 1992, and Shannon 1975). They describe aspects of practical knowledge and skills that are necessary for simulation and modeling processes. It generally involves different “iterative” processes. Learner-oriented teaching could allow the student to be gradually introduced into a simulation modeling process and use different strategies for delivering instruction. Banks (1991) suggests that building a simulation model is an interpretative development process and requires analytical steps. This style of teaching would allow the student to achieve a minimum level of skills at various stages during instruction. This would allow the learner to develop the ability to make judgements and use different strategies during model development processes. A learner-oriented teaching style is suitable for pedagogically structured tasks, as the learner might require a different learning style at various levels in the pedagogically structured tasks. This method assumes that the student will achieve a specified taxonomy classification level and develop their own paradigms.

The following strategies could be used for developing the learner-oriented teaching strategy:

- The sequence of instruction, consisting of classified, structured knowledge elements (Gagne, 1982).
- The content knowledge provides the learner with opportunities to practice the skills acquired at specific stages during instruction.
- It is structured around a formal simulation development of life cycle and allows for learner participation during instruction.
- It allows for the building a simulation model using different simulation software packages.

The teaching session should be broken down into chains of simple procedures and tasks, which can be learnt quickly. Learner-oriented teaching could result in the development of simulation practice skills, and allow for the enhancement of theoretical knowledge, which could be transferred to other domains. It could also be directed towards providing “knowledge about the problem domain, knowledge about the simulation modeling, knowledge about the programming languages and knowledge about statistics” (O’Keefe, 1986).

6.2 Evaluation

Evaluation of tutorial activities can provide opportunity for introducing quality into classroom activities. Evaluation compares the actual learning outcome with stated, desired outcome in relation to the needs of the organization and for making decision about aspects of the course (Patrick, 1992). Evaluation should measure the extent to which the learning objectives are been achieved by the student. It is generally accepted that many students learn best by doing the task and gaining experience from continuous practice. It is not conceivable that the ultimate standard of performance will be acquired in the classroom. The evaluation system is to focus on making improvements by redesigning the learning objectives and having a standard quality indicator. The quality indicator should involve retrospective evaluation of the outcome of simulation modeling course.

7 CONCLUSIONS

This paper has highlighted instructional methods for simulation modeling and the teaching paradigms that could influence the learning outcomes. Various classroom exercises can help the student to acknowledge and integrate a variety of perspectives to a problem. The process of associating learners’ cognitive and learning outcomes could produce greater educational results. The learner-oriented approach for teaching simulation modeling could allow the learner to reflect on the problem solving processes as a whole and to select those procedures, which are most effective. This may enable the attainment of modeling skills and help the learner to gain a full understanding of the concepts.

In conclusion, a fundamental requirement for creating a simulation modeling course should help the student to construct new knowledge and provide immediate advice on how to correct errors. Simulation modeling software tend to favor a particular environment and it will be desirable to teach the student different methodologies of these software. Therefore, the learning objectives should be continuously refined and change to meet the prevailing paradigms.

Simulation modeling as a problem-solving tool will continue to evolve and the frontier will be enhanced by continuous improvement in paradigms and the way it is taught. Educational frameworks for simulation modeling should be focused and directed towards clearly defined learning outcomes. They should integrate knowledge and competence across various domains and facilitate the accomplishment of learning outcomes.

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