Current issues in new learning

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**Abstract**

A recurrent theme in both the research and popular literature pertains to new learning paradigms and tools. New information and communications technologies and research in cognitive science have prompted much of the discussion about new ways to think about learning. This paper takes a critical look at new approaches to instruction and new methods to support learning. One conclusion is that interest in and emphasis on complex subject matter (e.g., complex and dynamic systems involving things such as crisis management, environmental planning, social policy formulation, etc.) is part of what is new in the world of learning and instruction. What is crucial to progress in improving understanding complex and dynamic systems is the assessment of progress of learning. A framework for assessing learning in and about complex systems is presented along with initial findings with regard to the utility of this methodology.

*Keywords: assessment, complexity, expertise, instructional design and technology, learning science, mental models, principles of instruction.*

**1 Introduction**

What has come and will evolve from the many advances in educational research and instructional technologies made in the last twenty years? Responses include:

- New information and communications technologies (ICT) have led to promising computer-supported collaborative learning (CSCL) opportunities.
- New technologies have made it possible to realize life-long learning with learning on-demand, anywhere at any time;
- New technologies have made authentic learning possible by blending learning environments with work environments; and
New technologies have been used to improve understanding in highly complex problem domains.

The focus here is on the last of these responses with emphasis on the problem of assessing improved understanding. There is a temptation among advocates of educational technology to emphasize new opportunities and potential benefits of new technologies. The assessment issue compels one to ask what improvements in learning can be attributed to new methods and tools. When one asks such questions, one typically encounters pitfalls and serious challenges. Investigating the assessment of learning in complex domains may shed some light on the more serious pitfalls and challenges lurking behind the questions at the beginning of this section. Other fundamental issues such as the problem of identity, the problem of ownership and the problem of verity that are vital to progress are not addressed in this chapter. The argument here is that improved assessment methods appropriate for complex domains are a necessary condition for progress in learning and instruction, but improved assessment is not sufficient. Ensuring that learners, tutors and instructors are the individuals they claim to be is essential. Protecting the intellectual property of individuals and organizations is also essential, as is developing methods to ensure that digital information is accurate and reliable.

2 The varieties of learning experience

As a context for subsequent remarks, it is appropriate to examine what is called learning. Learning is not a single nor a simple thing. Learning is a complex phenomenon. Human learning begins at or before birth and continues until death. It is an ongoing process that may be goal directed – intentional - or that may occur accidentally - non-intentional. Many important lessons are of the latter variety; educational research typically focuses on the former, possibly because one can examine actual outcomes against intended goals. One outcome of recent work in the learning sciences has been the design and deployment of learning environments in which goals are not be made explicit to learners, although the designer has learning goals in mind. The rationale is that non-intentional learning often seems to have a lasting impact on learners; consequently, intentional learning environments ought to be designed to emulate some of the authenticity of non-intentional learning, although the evidence to supports this approach is not convincing.

One is inclined to say that learning has occurred when there is an observed and persistent change in the learner. The change may be in the learner’s attitudes, beliefs, behavior, mental models, knowledge, or skills. Moreover, if the change does not tend to persist, one is inclined to say that what was learned has been forgotten or that the learning has faded or even that learning failed to occur. Persisting change is essential to learning. Relevant changes may be observed or inferred. It is difficult to directly observe attitudes and mental models, although these are fundamental to understanding. Rather than abandon understanding as an overarching goal of learning and education, it then becomes important to find reliable indicators of improved understanding.
In addition to a product perspective in terms of outcomes, including, there is much discussion about learning processes. The process perspective of intentional learning has focused on the critical roles of language, peers and activity in learning. With regard to activity, it is well established that people learn what they do. As a consequence, much emphasis has been placed on providing learners with opportunities for practice and on providing timely and informative feedback with regard to that practice. Merrill [1] refers to this as the principle of application. With regard to peers, Vygotsky [2] and others argue that peers play a critical role in new learning. Vygotsky’s zone of proximal development – a time when children are ready for new learning – is marked by social engagement with other children in relevant activities.

Language is critical to social engagement with peers and is also critical in teacher-student/tutor-learner activities as well as in learning activities involving parents, colleagues, employers, clients and others. Language is an inescapable aspect of learning. Both formal and informal language communities develop around specific activities that become the focus of learning; see Wittgenstein’s [3] description of language games. The language used by such communities is flexible and evolves with use and innovation. Some learning is directly associated with learning the language of such communities. Some learning involve insights that occur from linguistic variations and innovations. The richness and variety of language directly contribute to the richness and variety of learning experiences.

When one considers the role of activity, peers and language in learning, regardless of whether it is formal, informal, intentional or non-intentional learning, one is led to the conclusion that learning is filled with variation, that learning is complex, and that there is much that we do not know about learning. The rich variety of learning experiences and our limited knowledge about those experiences has been called the Principle of Uncertainty by Spector [4].

3 Research on learning and instruction

What has research on learning and instruction established? The Principle of Application is well-established and can be found in behavioral, cognitive and constructivist research literature. Merrill [1] identified five principles that are widely accepted by cognitive scientists and instructional designers:

- Principle of Problem Centering – learning is promoted when learners are engaged with meaningful problem solving activities;
- Principle of Activation – learning is promoted when existing relevant knowledge is activated and brought to bear on the problem situation;
- Principle of Demonstration – learning is promoted when new knowledge is demonstrated to learners;
- Principle of Application – learning is promoted when learners practice and apply new knowledge and skills;
- Principle of Integration – learning is promoted when learners are able to make new knowledge and skills a meaningful part of their everyday life.

Similarly, Spector [4] argued for the following set of basic principles:
• Principle of Change – learning is fundamentally about change;
• Principle of Experience – changes begin with and are based upon experience (similar to Merrill’s Principle of Application);
• Principle of Context – meaningful experience is determined by context relative to the individual’s situation (also called constructivism);
• Principle of Integration – meaningful integration involves contexts that are multi-faceted and multi-dimensional; and,
• Principle of Uncertainty – learning involves a richly complex set of phenomena about which we know less than we are inclined to believe.

4 Understanding complexity

What makes things complex? Surely what one person finds complex may not be found complex by another. Nevertheless, there are some things inherent in situations and systems that make understanding them particularly challenging for many people with different backgrounds and preparation. Among these things are the following:

• The number of components involved – as the number of components increases, the complexity of the system or situation tends to increase;
• The nature of the relationships among these components – non-linear relationships, delayed effects and fuzziness are particularly problematic for human problem solvers as shown by Dörner [5], Sterman [6] and others.

This is generally consistent with how the system dynamics community identifies factors contributing to complexity. Clearly other factors contribute as well. Some of these involve individual differences, such as differences in backgrounds, differences in preparation in related subject matter, and the relative novelty of the type of problem encountered. The methodology proposed herein attempts to be responsive to differences in types of problems and dynamic situations and systems while being useful in a context that accommodates individual differences. The next section elaborates the assessment methodology.

5 Assessing learning in complex domains

5.1 The problem

Large investments are being made in the area of problem-centered learning, especially when technology is involved in the delivery of instruction. The learning research and educational technology communities have a history of promising that the latest approaches and technologies will significantly improve learning and instruction. Projects are proposed and funded; new instructional paradigms and technologies are implemented in various educational contexts; data are collected and reported; students graduate and researchers get tenure and promotion. Yet there is inadequate evidence to establish to what extent learning has improved, especially in complex domains involving problem-centered instruction and technologically advanced environments.

Have these investments in educational research and technology been worthwhile? Many have probably contributed to improved learning, although the
major finding is typically *no significant difference* according to Russell [7]. Common measures of learning include scores on standardized tests, subjective indications of interest and attitude, and identification/recall of concepts and simple procedures. While such measures only provide indirect evidence of improvement in higher order learning. There have been few direct measures of changes in higher order learning capabilities associated with learner progress from inexperienced beginner to accomplished expert in complex domains. A study conducted at the National Center for Research Evaluation, Standards and Student Testing (CRESST) is an exception; see Herl et al. [8] for details. That study indicated that knowledge mapping methods showed the most promise, but it did not address understanding of dynamic interactions of causal factors in complex domains. The methodology described herein extends knowledge mapping assessment methods significantly as it takes into account understanding dynamic causal relationships in complex problems situations.

In order to provide a context for the problem of assessing progress of learning in complex domains, it is useful to briefly review relatively recent changes in instructional paradigms and educational technology. According to many authors, there has occurred a paradigm shift in learning and instruction in the last 20 years that is commonly and uncritically labeled constructivism. The theoretical foundations for this shift can be traced to a socially-situated learning perspective that draws heavily on the views of Bruner [9], Collins [10], Lave [11], Piaget [12], and Vygotsky [13]. In this perspective, learning is viewed as an active process of knowledge construction in which learners are typically involved with other learners in authentic, problem-solving situations. The need to learn that is created when a group of learners is confronted with a realistic problem provides motivation, promotes interaction, and is likely to result in transfer of learning; for an elaboration see Jonassen et al. [14], Merrill [1] and Spector [15].

Problem-based learning has never been implemented in a pure form such that all concepts to be learned are introduced in an authentic problem-solving context; this is simply not practical nor is it efficient. However, integrating problem-solving activities into the curriculum has firmly established itself as a worthwhile educational practice according to Merrill [1]. Advances in educational technology have evolved with this shift to problem-centered approaches. There have been three broad periods in the modern use of technology to support learning. In the first period (through the 1960’s), there was a great deal of enthusiasm for technologies such as radio, programmed texts and television to replace traditional classroom teaching. It is possible to cite success stories and identify some improvements in learning. However, there was a tendency in this first period to focus simply on using a new technology and making it available to support teaching rather than on exploring how specific technologies might be linked to specific learning goals and activities. With the advent of personal computing and networks, a new generation of educational technology came into being that was marked by emphasis on specific technologies in support of particular types of learning requirements (e.g., simulations to support operator training). As a consequence, much was learned in
the last part of the 20th century in the area of effective technology integration. This second generation witnessed some of the same replacement strategies for technology integration that were prevalent earlier, but there was a growing tendency to focus on the process of using specific technologies to support specific learning objectives in this period. Technology in the current third generation of educational technology has evolved to include more powerful and affordable computers, broadband networks and wireless technologies, more powerful and accessible software systems, distributed learning environments, and so on. The current generation of educational technology provides many valuable affordances for the problem-centered instructional paradigm. The learning paradigm has appropriately shifted from learning from computers to one better characterized as learning with technology. Consequently, the focus has shifted to larger concerns, including: (a) viewing technology support as part of a larger process of change and innovation, and, (b) using technology to support higher order learning, particularly in complex and less well-defined domains; see Spector and Anderson [16].

In this new generation of educational technology, learning environments and instructional systems are properly viewed as parts of a larger system rather than as isolated places where learning might occur. Moreover, learning is occurring in more dynamic ways than was true in the teacher/system-led instructional paradigm of earlier generations. There are a greater variety of learning activities made possible by technology and this further complicates determining how, when and in which circumstances learning activities promote improved understanding. It is clear that lessons learned in previous generations of educational technology should be taken into account. Simply putting sophisticated technologies into situations involving complex learning activities is not likely to be either efficient or effective. Moreover, what should be studied is not the effect of a particular technology on attitudes, motivation, and simple knowledge tests. Such studies perpetuate a wrongheaded debate about the educational efficacy of media. What should be measured is the impact on learning in terms of improvements in student inquiry processes and other higher order aspects of learning directly relevant to understanding challenging and complex subject matter.

The problem context for this methodology involves learning goals pertaining to understanding complex phenomena and situations. Example problem-solving situations include: diagnosing a medical problem, developing an environmental management policy, and designing a piece for an orbiting spacecraft. In such cases, information is often incomplete, many interrelated factors are involved, and more than one reasonable solution may be possible. Such problems are often avoided in school-based instruction, but the real world is filled with them. Learning in complex problem-solving situations is not directly measurable by a particular solution. Rather, learning is better treated as an ongoing process in which problem-solvers become increasingly expert-like in their problem-solving activities. Measures of learning should be directed at this process and its progress against admittedly difficult to establish standards. The general problem with regard to evaluating problem-centered approaches to learning in these domains is
that there is not a well-established and reliable methodology to determine learning outcomes. As a consequence, previous evaluations have focused on: (1) an analysis of efforts and resources required to successfully implement a particular approach (e.g., cost-benefits); and/or, (2) an analysis of the immediate and easily observed effects reported by those involved in such efforts (e.g., student reactions).

The immediately observable effects often reported are changes in attitudes, which may be relevant to sustaining interest in an area and to promoting change. In general, there is evidence to suggest that problem-centered approaches can have a positive effect on learner attitudes and interests and contribute to improved motivation. However, once again there is only indirect or suggestive evidence of improved learning outcomes by those conducting these kinds of evaluation studies.

Learning outcome measures typically collected for simpler domains (e.g., scores on knowledge tests or performance of steps in a procedure) are only indirectly relevant to higher order problem solving and understanding complex problems. The limitations of these kinds of evaluation are well known. One may perform very well on a knowledge test about disease indicators but still not do well with regard to diagnosing particular cases. Attitude, change agency, cost-benefits, and knowledge measures are relevant in an overall evaluation. However, the critical aspect of improved higher order learning is often overlooked because it is difficult to determine what progress students are making in understanding the complexities involved in more advanced problem-solving areas of science education and domains.

According to the principles described by Merrill [1] and Spector [4], an experiential, problem-centered environment with rich opportunities for collaboration with peers will often be effective. Such an approach has been reflected in the most promising systems developed in the 1990’s. However, these collaborations break down when students are asked to derive hypotheses from data or engage in serious reflective discourse (i.e., exemplify higher order thinking). Moreover, well-educated and highly motivated adult learners have difficulty in making strategic decisions about complex systems, as shown by Dörner [5]. In order to show that particular instructional approaches are effective, it is essential to develop and validate a methodology to determine higher order learning outcomes appropriate for these domains. This research builds on research done at CRESST and reported by Herl et al. [8] using knowledge mapping techniques for problem-centered assessments.

5.2 The DEEP methodology

Validating this assessment methodology involves three different domains (engineering design, environmental decision making and medical diagnosis) with different levels of learners. The methodology is based on a view of learning as becoming more like an expert. The methodology, called the Dynamic Evaluation of Enhanced Problem-solving (DEEP), involves:

1. identifying characteristic complex problems;
2. eliciting expert patterns for characteristic problem-solving activities;
3. representing expert patterns in both textual and graphical formats;
4. determining salient features of these representations;
5. establishing measures of similarity in salient features of expert representations;
6. eliciting novice patterns for the same problem-solving activities;
7. representing novice patterns in the same formats used for expert responses;
8. identifying the presence or absence of salient features in novice representations;
9. establishing measures of distance from expert patterns for each salient feature; and,
10. tracking and analyzing changes in learner responses over time and through instructional interventions.

Subjects are provided with a problem scenario relevant to a problem-centered module. They are asked to indicate what they believe may be relevant to a solution, and then they are asked to provide a short description of each item along with a brief explanation why it is relevant. They are also to indicate assumptions about they are making and they are asked to represent their conceptualization of the problem space in terms of: (a) a list of key facts and causal factors influencing the problem situation; (b) documentation of each factor - what it is and how it influences the problem; (c) a graphical depiction of how these factors are linked; (d) annotations of each node and link); and, (e) an indication of other considerations or approaches.

Many examples of medical instructional units constructed around problem solving in the context of patient cases can be found and typically consist of a problem scenario with a patient description, recent history of symptoms and some findings from a physical examination of the patient. The learner is asked to develop a diagnosis and prescribe treatment. The learner’s response is then analyzed and compared with a standard solution to the problem. This method builds learner experience in the context of problems but assessments have been aimed at short-term goals, such as an appropriate decision for the specific problem at hand, rather than at longer-term goals involving higher order thinking and an understanding of the dynamic interaction of causal factors that might be involved in apparently similar cases which would warrant different diagnostic procedures or treatments.

Preliminary research suggests that there are noticeable differences in expert and novice responses. Differences include: (1) the number of causal factors taken into consideration; (2) the relationships among the causal factors; and, (3) the depth of response in the annotation of the sample node. The expert response reflects more nodes, more complex interactions among nodes, and a more specific justification for performing the initial test. A pilot test of this methodology involved using annotated causal influence diagrams as the graphical representation of what a person believes about a complex problem scenario. Subjects in the study conducted by Christensen et al. [17] were asked to
indicate the key factors influencing the problem and a solution and to develop a graphical representation of the problem using a modified form of causal influence diagrams.

Another use of this methodology was reported by Seel and colleagues [18] who used the technique to study changes in mental models. Progress of learning was followed for a short period after instruction in this study, which suggests that the basic hypotheses in the DEEP methodology are reasonable.

In order to establish that the DEEP methodology is reliable and robust, it is necessary to determine: (a) whether or not experts in fact exhibit recognizable patterns of responses to complex problem scenarios in the various disciplines studied in this research; (b) that measures of nearness to expert patterns can be reliably derived from novice responses; and, (c) that these measures are likely to change as learning progresses and subjects acquire experience in solving problems in the domain of interest. These constitute the primary goal of this effort.

5.3 Initial findings

Instruments were developed and tested with a small group of intermediate level people in each of the three domains. Instruments included a background survey with basic demographic information, two sample problems for each domain, data collection software for representing problem conceptualizations and associated word processing files for alternative representations, and an open-ended question to collect reflections on the problem solving experience. The problem scenarios were judged sufficiently complex to be likely to evoke noticeable differences among respondents.

Minor adjustments were made to the relevant instruments and then novices (15 per domain) and experts (5 per domain) were given two scenarios in each of three domains: engineering design, environmental decision making and medical diagnosis and asked to represent how they thought about these problems. There does appear to be a pattern to expert responses in all three domains. Experts generally provided more nodes and richer descriptions in their responses than did novices, with one noticeable exception in the engineering domain. One expert respondent there provided only 4 nodes which was fewer than the other experts and many fewer than most novices. However, that expert respondent provided the greatest level of detail in the description of nodes (based on a simple word count). Interpretation of data is continuing on three levels: (1) surface analysis of the response; (2) structural similarity of one response compared with another; and (3) semantic analysis of description of nodes and links. The surface analysis consists of simple counts of nodes and links, the first three nodes created, and the existence of a noticeable pattern in the diagram (e.g., circular, hierachical, spiral, spoke, star, spiral, etc.). These determinations are easily automated and may prove useful in making an initial, fast, and reasonably reliable assessment of a response.

Structural similarity proceeds to analyze one response in comparison with another. In this study, it is the analysis of a novice response with that of another novice or with that of an expert. In a curriculum or evaluation study, the
structural similarity analysis could compare the same subject’s responses before and after certain instructional interventions. At this level, the goal is to see if the same or similar nodes are identified and if so whether or not they are linked in the same way. This kind of analysis also lends itself to automation.

The semantic analysis examines the descriptions of nodes and links provided by respondents. As already indicated, such an analysis is notoriously time-consuming and not easily automated. To add to the robustness of findings, a doctoral student is using the same scenarios with Ericsson & Smith’s [19] think-aloud protocol analysis methodology to see if similar problem conceptualizations emerge with a different semantic analysis methodology. The reason for including semantic analysis in this study is to determine the extent to which the first two levels of analysis (surface analysis and structural analysis) may reliably predict the third level of analysis.

At this point in the data analysis, expert patterns in problem conceptualizations do exist for the domains and problems studied, and novice patterns are noticeably different from expert patterns in all three levels of analysis for these problem scenarios and the subjects involved. The key hypothesis of whether or not the first two levels of analysis, which lend themselves to automation, will be reliable predictors of the third level of analysis has yet to be determined.

6 Challenges and future directions

The immediate next step is to determine whether or not the data collected thus far supports the important third hypothesis that simpler levels of analysis of problem conceptualizations are predictive of relative level of expertise or mastery. A doctoral dissertation currently underway at Syracuse University should provide important data in this regard. Once this is determined, additional problem scenarios should be examined with different levels of respondents.

In summary, this assessment methodology appears promising and lends itself to automation and use in a variety of contexts ranging from intelligent tutoring systems to program evaluations. Work on the related critical issues for new learning identified at the beginning of this chapter should proceed in parallel so that the potential benefits of new learning can be maximized while minimizing the potential pitfalls.

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References


