The design space for solving instructional-design problems

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Abstract. The development of design science is outlined in this article followed by a description of the concept of design space, which is illustrated by maritime design. The example is used to illuminate and situate the current state of instructional-design science. The article summarizes the developments of an instructional design science, both in Europe and in the United States of America. Following this discussion, instructional design is related to the general goals of education and the concept of situatedness is discussed. Attention is paid to the description of instructional communication and how to solve instructional design problems. Finally, an overview is given of the issues addressed in the other articles comprising this special issue.

Keywords: design space, didactics, instructional design science, psychology of learning, situatedness

Introduction

Many persons design and develop instruction either as part of a direct communication to promote learning or in a represented form such as a textbook, a video or a computer-based environment in which various learners' activities are anticipated. For centuries many persons have designed instruction either as part of their task as teachers in school settings or as part of their task in job situations. Instruction is an intended or intentional (goal directed) activity. The goal of instruction is that students will learn or acquire knowledge and skills. The ultimate goal to which instruction contributes is to assist a human being in fulfilling the need to understand reality in order to survive and to adapt to changing circumstances in the global community, but there are several short-term goals. In this article 'instruction' is regarded as equivalent to teaching and 'instructional design' is regarded as equivalent to teaching design or teaching method.

Solving a design problem will result in the sketch of an artifact that, when realized, will fulfil or help to fulfil a need. For example, a house will fulfil the need for shelter; a device for doing experiments in physics will help to fulfil

the need for understanding some particular physical reality; a car will fulfil the need for comfortable and fast transport.

When do design rules form part of a design science? The answer to this question will be illustrated by using maritime design science as an example. The article then will use the example to discuss the current state of instructional design science.

Rules of ‘good design’

All design sciences have developed some rules for good design in a particular domain. These rules roughly describe the ‘design space’, which is a space the borders of which ought not be crossed by a designer. If these borders are crossed the artifact will most probably not fulfil the need for which it is produced. An artifact that perfectly meets the rules of good design will most likely satisfy the user in fulfilling the need (or needs). The rules of good design are derived from the laws, patterns and theories that describe the behavior of a particular physical reality and that meet some rules of aesthetics and functionality that are generally accepted. For example the rules of yacht design (Van Kampen, 1956) describe the ‘normal proportions’ between the quantifiable variables of a yacht such as length, width, height, load displacement, draught and others. The combination of the ‘normal proportions’ describes the design space. Such rules are developed both from experience and from hydrodynamic and aerodynamic experiments with scale models in a towing tank. In a deep-water towing tank resistance and self-propulsion tests of ships, flow observations and various measurements of hydrodynamic forces can be accomplished. The application of this knowledge can improve the design and make a ship both seaworthy and fast. Combined with the designer’s knowledge of aesthetic rules and harmonic proportions, the design gives the yacht its beauty. Of course, ongoing hydro- and aerodynamic experiments may change the rules of accepted yacht design and provide rules that are more detailed than the existing ones. If the design is accepted and the yacht is built, sailing it should provide the crew and passengers satisfaction and gives them a feeling of safety.

From an historical point of view some rules of good ship and yacht design are ancient. Until recently local rules of good ship design were still applied, although the application of other general rules can be recognized in all ships regardless of region of the world and period in which the ship was built. As new rules of good yacht design were described, the use of which improved the qualities of a ship’s behavior, they were quickly adopted by the local community of ship designers. This has happened, for example, all over Europe since the Middle Ages. Other rules have developed more

recently, as a consequence of new construction materials and more detailed knowledge of the local realities, such as the depth of the water, the tides, waves, and new functions such as transporting oil. Based on experiments with small-scale prototypes in towing tanks, the behavior of a ship is better understood and design rules can be modified accordingly. The design rules for ships developed from the description of experiential rules to a maritime design science in which the interpretation of physical reality and the results of practical research with prototypes are combined. It is without a doubt that today's general rules of good ship and yacht design are accepted and used internationally. Nevertheless the freedom of the art of designing ships results in many different artifacts, but all of them meet the rules of good design.

Rules of 'good instructional design'

What are the rules of good instructional design? What changes can be perceived in their historical development and are they accepted and used by an international community of designers? The answers to these questions reveal a landscape different from that of ship design. Over the centuries many persons have designed instruction, but only occasionally have they explicitly and precisely described the rules that governed the design space in which they were functioning. In the first years of the 20th century some rules were derived from observed patterns of the behavior of learners and the interpretation of these in psychological theory, but general acceptance of these rules did not occur. Later, the interpretations changed which lead to abandoning many of these early behavioristic rules. Thus, no clear base of rules that make up a well-defined instructional design space can be found. There are different communities of instructional designers that develop their own rules of good instructional design often without much knowledge of what their colleagues in other groups are doing. Sometimes, based on theoretical conceptions, design rules are advocated without much empirical foundations or without a sound evidentiary basis (Anderson et al., 1996). The result of this is a diversity of instructional design 'theories and models' that rarely become integrated and often are used and further developed in isolation (Dijkstra et al., 1997; Reigeluth, 1983, 1999; Tennyson et al., 1997).

Although in the past millennia in the Western World many persons have designed and developed instruction, in Europe the label 'instructional design' as a design science has not been frequently used, but a change can be observed. The design of instruction was and is mostly covered by the label 'didactics' that is made operational by the phrase 'situations for teaching and learning'. The knowledge of design rules is divided into 'general didactics' to be used for all subjects and 'didactics for the subjects' such as

for mathematics, physics, economics and languages. Today even the label 'digital didactics' is used. Didactics were and are especially developed for elementary and secondary education, for which different didactical practices are described, such as explanation, problem solving and collaborative learning. All these practices are discussed and trained in colleges for teacher education. However, in elementary and secondary education the development of the child has priority, and, in relation to that overall goal, the education of the child as a person belonging to different communities is the primary goal. Because of this historical development in educational science didactics is typically mentioned together with the education of the child and sometimes even subsumed to that.

Knowledge of and rules governing the education of the child as a person and coaching the development of the child's personality are related to anthropology and to philosophies of life and religion. The advantage of this situation is that the development of didactical knowledge for teaching the subjects of the formal, empirical and applied sciences is not isolated from the education of the child as an individual person and not from the focus areas of philosophy, such as anthropology, ontology and epistemology (see also Spector's article in this issue). This situation, for example, also explains the interest in genetic epistemology: the development of knowledge and the status of knowledge as a process (Piaget, 1937). However, this situation may also be a possible disadvantage because instructional design of the content and problem-solving procedures of the formal, empirical and technical sciences as such may receive less attention (see Achtenhagen's article in this issue).

In the first years of the previous century the use of conceptions of the psychology of learning and memory and the first experimental results had some influence on the design of instruction in the Western World (Seel & Dijkstra, 1997; Tennyson & Schott, 1997). In general, however, anthropological and philosophical ideas dominated education and instructional programs both in Europe and in the United States of America.

In the previous century instructional design as a design science was developed in the United States of America. Both practical and theoretical reasons can be cited for this development:

1. *An industrial revolution in education.* Pressey (1926) found that a machine could teach and the question was asked whether an industrial revolution in education was possible to free teachers from routine work and enable them to spend more time on coaching and mentoring of individual students. The mass production of special teaching machines did not occur, but the use of a computer for teaching and learning can be considered as an industrial revolution that has profoundly influenced education.

2. *The systems approach in military training and later in university education and training.* Because of both world wars, military organizations needed to train many personnel, and this influenced the development training design. Molenda (1997, p. 42) wrote that “during the postwar period each of the U.S. military services had developed its own model for training development, all of which were based on the systems approach.” In later years this approach was developed into instructional systems design models, which are heuristics that include phases and activities to solve any (large-scale) education and training problem. These heuristics and phases typically include: needs assessment, description of goals, design and development of instruction, and, finally the summative evaluation of the knowledge and skills acquired.
3. *Developments in the psychology of learning.* From the psychology of operant conditioning that was strongly supported by the results of laboratory experiments with rats and pigeons a generalization was made to learning in schools. From this behavioral theory of learning, rules for programmed instruction were derived (Skinner, 1954). The instruction was printed in frames that could be presented to students in a window of a teaching machine. The students could write their answers and receive immediate feedback. The application of the design rules seldom led to the expected results. The rules were soon abandoned. In the subsequent decades, the psychology of learning evolved its theoretical foundations to accommodate cognitive psychology. Other categories of learning, such as concept learning, were studied extensively and theories of cognition became dominant. Instructional design both followed these developments and contributed to them. Nearly all designers of instruction derive or base their rules of good design on theories of cognition and, after the rediscovery of the significance of epistemology, often on rules that are derived from an integration of both. (Gagné & Briggs, 1979; Jonassen, 1999; Perkins & Unger, 1999).
4. *Development of the computer and its use in education.* Soon after its invention, the possibilities for use of the computer in education were recognized (Coulson, 1962). Nearly all the hardware developments from the beginning of the digital revolution until the current status of information and communications technology have been applied to the design of instruction. Undoubtedly these developments strongly stimulated instructional design as an applied science. Moreover the hardware functioned as a framework to test the instructional quality of computer-based instructions, problem solving, computer simulations of processes and tele-coaching of students.

Particularly the digitalization of all kinds of visual and auditory information into common formats, the fast transport of that information all over the world and the use of hypermedia to control one's own search for information have created new possibilities for the design of instruction. The media revolution forced instructional designers to reflect on their assumptions and fundamental principles. Moreover, they also are forced to reach more precision in the description of rules for good instructional design in order to provide useful guidance for the effective integration of technology into teaching and learning.

Changes in theories of problem solving, learning and cognition, in epistemology and the media revolution have caused changes and extensions in the rules of good instructional design. For example, emphasis on interactivity, discovery and navigation in hypermedia worlds have become reasonably well established. These changes also influenced the European instructional design community that wished to integrate information and communications technology into didactical practice.

While the assumptions and theories of cognition have been extended and epistemology has been rediscovered, information and communications technology have provided a renewed interest in instructional design science. Nevertheless, differences in instructional design rules and practice persist and have perhaps increased, unlike the general acceptance of rules and principles for good instructional design discussed earlier. This is most probably influenced by the different goals instructional designers have about the results of the curriculum for a human life outside school and about how the world outside school should be 'situated' inside school (see also Seel's article in this issue). Being a successful life-long learner is not nearly so well defined as being a fast learner.

Goals of education and instructional design

The acquisition of knowledge and skills is usually accepted as the goal of education. Further specifications and elaborations are usually made, such as the acquisition of general knowledge and skills by all citizens and the acquisition of special knowledge and skills for those who work as professionals in a certain sector. The knowledge and skills to be acquired are described in such a way that their acquisition can be measured and decisions can be made whether a person has sufficient knowledge of a certain subject and is able to perform a task in a skilled way. Curriculum and instructional design make a reduction of the available information and problem-solving procedures into subjects that appear in a curriculum. Within those subjects further reductions are made into concepts, principles and theories, and design rules. These are

the 'elements' of the content subject matter and as such the 'elements' of instruction. They are also 'elements' of the content for research on learning and problem solving. The use of the interpretations of problem solving as well as learning and cognition in psychological theories can be applied to the acquisition of the content of these elements and to combinations in more complex subjects.

Instructional design rules and principles are derived from studies of acquiring and mastering the content of such elements in various circumstances and under different conditions. While this approach is legitimate, the knowledge and skill of a specific subject is not typically the ultimate goal of an educational program. Many goals in institutionalized education are short-term goals and are preparatory for other goals. The knowledge and skills that are acquired in association with short-term goals should become integrated with more general goals, such as fulfilling the need to understand reality and learning to interact with physical and social systems in order to survive and to adapt to changing circumstances. Specific knowledge and skills can be conceived in terms of those more general goals and extended to life-long settings beyond the walls of schools. These general goals are sometimes hidden and thus complicate instructional design. Moreover, they sometimes lead to discussions about ideal learning environments.

Even if all instructional designers agreed about those general goals, this would not lead to the design of the same learning environment for the same set of goals from a common set of rules for good instructional design. Conceptions about the way to reach the goals and to operationalize rules and principles can still differ. More general issues can be identified. How should outside realities be 'situated' in schools? How can learners be supported in understanding descriptions and interpretations of the 'real' world (outside school settings) and become motivated to solve real-world problems given to them. How can knowledge be generalized and how can associated skills be developed such that school-learning is not inert and can be applied effectively in other situations? How can learners be supported in understanding the use of signs (icons and symbols) and how they are used to represent the relationship between objects and processes? These are all questions that are addressed in a situated instructional-design model.

The design of instruction becomes especially complicated if special qualities of the knowledge and skills are required. Examples of such challenging learning goals include: students should be able to transfer the knowledge and skills to solve new problems; students should become competent to apply the knowledge in their worlds, in their jobs and improve the products they are required to make; the knowledge and skills developed in students should

be related with the development of their personalities and integrated with anthropological and ethical issues.

“How to help people learn better. That is what instructional theory is all about” (Reigeluth, 1999, p. ix) (see also Van Merriënboer and Kirschner in this issue). How can instructional designers put this guiding principle into practice? How is it possible to evaluate that learning was improved by applying new and more detailed rules of good instructional design? Should learners acquire the knowledge and skills in a shorter period of time? Should they remember more for longer periods of time? Should they be able to transfer the knowledge and skills to new situations? Should they enjoy learning more thoroughly? Can the need to learn be fulfilled in different ways leading to different qualities of satisfaction as is possible in the case of fulfilling the need for food? From the aforementioned discussion of goals and their variations, it follows that the criteria that the knowledge and skills should meet should be made clear in advance. It should also be made clear in advance what restrictions and conditions are imposed on the learning goals. Together this will lead to a selection of design rules that will help to realize an environment that makes the essential learning process possible.

Instruction and instructional design

Instruction

The purpose of instruction is to help people to develop knowledge and skills. Instruction is an activity that is intended to foster the learners' activities. It is a part of a communication between an expert (or expert system) and one or more novices (or apprentices). In an instructional communication, the teacher (expert, tutor, mentor, instructional program, etc.) helps the learner to structure the reality into objects (entities) and to interact with these objects in order to develop conceptions about these objects. The conceptions include how to categorize them and to find relationships between them, to understand how they change and to learn how to design new objects and what to do with them. The concept of 'object' or 'entity' is necessary for the description of a reality and includes the following: (a) real objects such as pebbles, plants, houses, the moon; (b) 'inferred' objects, such as atoms and molecules; and, (c) systems of objects, such as the solar system (Dijkstra, 2000). Learners are expected to profit from the instruction and show this by giving answers, asking questions or performing a task. The acquisition of knowledge and skills can only temporarily be seen as an objective in itself but ultimately it should be seen as serving more general goals of life. This is how life-long

learning can be provided with broad, social interpretations that should guide and inform what instructional designers, educators and trainers do.

Instructional design

Information and problem-solving procedures are the stored results of human problem-solving activities that are publicly accessible. Dijkstra and Van Merriënboer (1997) distinguished these kinds of problems: (a) categorization or description; (b) interpretation; and, (c) design. Solving these problems results in: (a) conceptual knowledge how to categorize objects and which relationship between objects exist (b) hypotheses and theories why and how objects change; and, (c) design rules for sketching and developing artifacts or new objects. The three types of problems and the information and problem-solving procedures that are the result of solving the problems can be used as a framework for the description of knowledge and skills, for assessment of these and for the design of instruction. The problem situations can be used for clarifying the goals of education and for guiding the students' activities within the subjects.

An instructional design problem belongs to the third group of problems, but the knowledge that is the result of solving an instructional design problem is used for solving problems that belong to all three groups.

How can one design instruction that leads to the development of knowledge and skills that can meet (some of) the qualities aforementioned? A description of a design problem in general and how to solve it will be used as a frame of reference in answering this question.

The result of solving a design problem is a sketch of a new object or artifact (a bridge, a car, a house, a textbook) and as such is a general notion of a solution. The assignment to solve a design problem can be given by different agents such as an industry, a principal, a commissioner or a publisher. The agent has to accept the sketch of the artifact before it can be realized. It often happens that changes to the first sketch are requested. The artifact should fulfil a need of the individual or the need of a group of persons. Of course a designer can also design and develop an artifact and try to sell it based on an existing or imagined assessment of needs. An agent can ask to design and develop an artifact and try the same thing.

For solving design problems, an artifact must be imagined and a first sketch, outline or plan has to be created and made. Concepts and theories about the behavior of the pertinent reality or external system form the knowledge that is used to solve design problems. For example, knowledge of a chemical process is a prerequisite condition that a process engineer must have in order to design a chemical processing unit. Knowledge of a problem-

solving procedure is a condition that a teacher must have in order to design an instructional communication about that particular problem domain.

A design problem has different sub-problems which are dependent on the 'life cycle' of the artifact: (1) the design; (2) the realization; (3) the use and maintenance; and, (4) archiving, restoring, discarding or recycling. Objects to be designed and realized should meet four different sets of conditions and criteria: (1) principles and rules of a good design which means that they should meet pertinent laws and principles of the domain (e.g., a house should not fall down, a car should be stable on the road, an instructional program should satisfy recognized principles of learning); (2) functional requirements – designs should be functional and objects should fulfill the special human need involved; (3) aesthetic concerns – the artistic value of a design should satisfy the tastes and preferences of a group of people that often will vary over time; and, (4) financial constraints – the financial means that are available should be used efficiently (Dijkstra, 2000).

In the case of solving a design problem, the relevant cognitive constructs are the images of the artifact and the rules and criteria that have to be met in order to achieve a good design. For solving an instructional design problem, the design phase is an especially difficult and challenging phase. The instructional designer will typically first imagine a design space for the solution. This includes the content subject matter, how that content will be structured into situations, objects, examples and problems, and what is known about how to learn such content. The designer will also typically imagine an outline – which category of problems to be solved first for the development of the learners' knowledge and skills and which category learners have to solve next (sequence of the content) – and the strategy to be used (see Merrill's article in this issue). The designer will also imagine how the knowledge and skills can be integrated with those previously formed in prior lessons, courses and life experiences. Finally, the instructional designer should imagine and outline how the knowledge and skills are preparatory for and can and should be integrated into the anticipated future tasks likely to be encountered by learners. The result of the design is a 'prospectus' with an outline and a few examples that is submitted to those persons who requested it. If the commissioner (sponsoring agency) accepts the prospectus then the design can be developed. If time is available, it should also be tried out and refined and revised in a process known as formative evaluation.

Overview

The articles in this special issue all relate to the first and second phase of solving an instructional design problem. All the articles contribute to an

instructional design science as an integration of the theories of cognition and learning and practical rules for making plans and outlines. They describe both rules of good instructional design and rules of learning environment design.

Merrill first defines and discusses primary knowledge components for entities, actions, and processes. These are combined with primary instructional strategy components, such as ways of presentation and variants in student actions. Illustrations are provided. Merrill states his assumptions for instructional design. The instructional components are supposed to be a theoretical tool that can be embedded in different instructional architectures and based on a variety of different philosophical orientations.

Scandura developed an instructional design science that integrates theory of learning and the technology for learning, together with software development environments. First, Structural Learning Theory is outlined followed by the description of a Tutor that includes content knowledge and diagnostic and tutorial expertise. The article also pays attention to the technology and gives a description of Scandura's *Softbuilder* and *Autobuilder* design environments.

The article written by Kuyper, De Hoog and De Jong discusses the construction and use of an instructional model based on the principles and interpretation of discovery learning. Discovery learning involves learning from the regularities that can be observed and experienced by students when they study the behavior of an empirical process, for example the relationship between the change of velocity and position of a vehicle. The instructional model is used to develop a simulation model that leads to an interaction model in a process environment. This environment, labeled *Simquest*, is an authoring and development tool that can be used for the design of a variety of discovery learning environments. Their article describes the components of the environment and the different instructional functions these have.

Achtenhagen first pays attention to the tradition of European didactical research and development. He also makes a few critical statements about this tradition. He then thoroughly discusses model theory. He distinguishes the modeling processes of 'reality' with regard to the 'corresponding scientific description of goals and content units' from modeling teaching procedures and learning processes. In the second part of his article, he shows and illustrates how this model framework is used for the design of a complex teaching-learning environment. The environment, which is fully embedded in information technology, can be categorized as an example of situated instruction. It should be used for practicing real problems until a criterion of mastery is reached. The criteria must be defined in advance, of course.

In the first part of his article, Spector emphasizes the long-standing relationship between the focus areas of philosophy on the one hand and education and the design of instruction on the other. He provides the reader with an

overview of the main features and issues of this relation from Plato to Dewey, Piaget and Vygotsky. The reader is shown how changes in the main issues of philosophy have influenced education and the design of instruction. Spector argues that it is “worthwhile to revisit foundational concerns linking philosophical perspectives and learning theory and to explore what implications may exist for the design of instruction.” In the second section of his article Spector shows the philosophical influence on the design of a complex situated learning environment called the Model Facilitated Learning framework that can be used for the simulation of processes that range over long periods. Such environments will help students become aware of and sensitive to the likely effects of human actions on the environment, on external realities and in general on future generations. The complex environment includes features from situated and collaborative learning and can be designed in such a way that other features can be added. He categorizes complex environments according to the students’ competencies from situations in which they can only manipulate the existing environment to those in which they can formulate complex problems to those in which students can redesign the model or environment.

Seel thoroughly addresses the concepts of situated cognition and mental models. Situated cognition is supposed to be ‘a central concept for instruction, as is the closely related concept of the construction of mental models.’ There are different kinds of construction and change of mental models in a situational context, one of which is to provide the learner at the start of the instruction with a conceptual model that can and should be changed. The question is raised how such a conceptual model changes and whether the effects of the changes are stable? Seel describes an exploratory study on the change of a model of an open national economy that is presented to the students at the start of the learning process. It could be shown that the models are changed “in dependence on the demands of the learning situation” though there were considerable individual differences. The assessment technique of drawing causal diagrams was used. In addition the technique of receptive interviews was used to produce verbal data for the assessment of the student’s mental models.

Van Merriënboer and Kirschner finally categorize and comment on the theoretical and practical position the authors have taken on instructional design. Using their own assumptions and Seel’s framework they formulate a thoughtful perspective on the further development of the instructional design science that is likely to be useful to future generations of instructional designers. Indeed, the success of their comments can be immediately assessed by how they have been embraced by those who have participated in subsequent meetings and exchanges based on this initial exchange of ideas.

Discussion

In the foregoing paragraphs the design space for solving instructional-design problems is outlined and the different kinds of design are discussed and elaborated.

For fulfilling the many needs that humans have, a wide variety of artifacts are designed, realized and used. When needs can be described in terms of clearly stated goals and when the rules of good design for a domain have a strong empirical foundation, a design science becomes established. The rules of good yacht design and the development of a maritime design science are provided as an example. Over the centuries, yacht and ship design has led to better designs and artifacts. However, even if better artifacts are available, the use of them does not release a person of the responsibilities to meet the conditions that lead to safety during fulfillment of needs.

It is without any doubt that the design rules that are provided by the maritime design science are internationally accepted and applied, and that this design science is well established and highly respected. This well established design science provides a way to situate and understand instructional design.

The rules of good design that are available for the design of instruction differ significantly from one organization and setting to another, and much the same is true for the artifacts that are designed and developed for the same purpose and for the same domains. For the further development of an instructional-design science, the causes of the differences in rules and artifacts should be identified and discussed. This may lead to a firm foundation of the rules in the psychology of learning and motivation and in epistemology, and to a possible integration of the different rules that are used now. Of the issues that will be involved in the discussion that threads through this special issue, a few are mentioned in this article.

1. *The goals of education.* The content of the programs of institutionalized education at all levels are preparatory for some situations outside the institution that require graduates for different categories of goals. The programs rarely provide a perfect match between the situation in which a subject is learned and in which the knowledge and skills can or should be used in practical settings. Moreover, possible future goals, such as being a good scientist, a good practitioner or a good citizen, often are much more complicated than the goals the institution can realize. The problem for both curriculum and instructional design is how outside realities should be “situated” in schools in such a way that the goals of education are preparatory in the best possible way for the goals humans have outside the schools. How can a common curriculum support the many different practical settings to which graduates will migrate and

also support the less well-articulated educational goals such as becoming reflective practitioners and responsible citizens?

2. *Reduction.* Curriculum and instructional design make a reduction of the available information and problem-solving procedures into subjects that appear in a curriculum. Much information is defined in an abstract way. Irrelevant and less critical features of objects and situations are removed. If the targeted knowledge is acquired, the practical advantage is that it can (in principle) be applied in different situations, but a possible drawback is that students may not understand how to use the abstract or more general knowledge because the direct relationship with a specific reality may be missing. Situated instructional-design models make up the core of this point. How can a curriculum be designed so as to provide meaningful links to many different specific situations in which learners are likely to work?
3. *Analysis and integration.* For the purpose of studying the effectiveness and efficiency of the instructional design for the acquisition of knowledge and skills, some content subject matter will first be analyzed into accepted ways of describing knowledge (e.g., concepts, laws, models, hypotheses and theories). If this content is acquired, it should become integrated into complex units of knowledge and skills. The analysis does not mean that the content, as described in the formal, empirical and applied sciences, will be isolated from its possible use. The approach clarifies the relationship between the interpretations of problem solving as well as learning and cognition in psychological theories and the design of instructions. The approach also can help to understand how learners can be supported in understanding the use of signs (icons and symbols) and how they are used to represent the relationship between objects and processes. For example, in learning chemistry students should be able to imagine the world of atoms and molecules, the world of symbols and formulas, and the real world of chemical substances; moreover, students should be able to switch between those multiple representations to solve practical problems. How can the curriculum be structured to provide multiple representations and promote the use of those representations in problem solving settings?
4. *Qualities of knowledge and skills.* If the purpose of an instructional design science is to make better designs for the acquisition of knowledge and skills than are now possible, then the qualities of the knowledge and skills that are critical for an evaluation should be made explicit. These are, for example, the competence of the students outside schools, self-efficacy, time needed for learning, retention, transfer, affective reception of the artifact and maybe other qualities. How can such a variety of

qualities be embedded in a meaningful way in a standard curriculum for a subject domain?

These issues are related. More general goals influence the more specific goals and often the more general goals are not made explicit, but they will influence the design of the learning environment and the conclusions drawn. Reduction and analysis of information and problem-solving methods is necessary for understanding problem solving, cognition and learning. This knowledge is needed for the design of instruction. However the rules of good instructional design the application of which will help learners to integrate knowledge into complex units should be specified as well. The qualities the knowledge and skills should meet and the way in which this should be assessed have to be described in advance.

If the more general goals are not made explicit and the criteria that should be met are not described in advance the users of the artifacts will be unable to evaluate whether an instructional design is in fact a better design.

If instructional design science desires to reach a position similar or equivalent to technical design sciences, then the rules that are derived from epistemology and the psychology of learning and motivation (goal setting theories) have to be integrated in systematic and systemic ways, and instructional designers, and those who deploy and deliver instruction must become more committed to the development of a genuine and meaningful international community of practice. The intent of this special issue is to take a step in that direction.

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