Learning in Simulated and Real Environments

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Farewell lecture

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Mevrouw de Rector Magnificus, geacht College van Bestuur, geachte Decaan, beste collega's, familie, vrienden en overige toehoorders. Ik ben verheugd vandaag deze afscheidsrede voor u allen te mogen uitspreken. Ik zal dat doen in het Engels omdat niet alle aanwezigen de Nederlandse taal beheersen.

During my whole career, I have been doing research on learning in real and simulated environments. People learn by performing tasks in the real world. In my research these are often professional tasks, and then the real world is the workplace. But people also learn by performing tasks outside the real world or the workplace, in a simulated environment. Such simulated environments are usually organized in schools or other educational institutes. The word "school" stems from the Greek word "skhole", which means leisure or free time. For the Greek, the basic idea was that the real world is serious business in which you must perform professional tasks, but the school is giving you free time to practice these tasks in a safe environment, using role-play, gaming, and all other kinds of simulation. The school is the place where you can do "as if" you are performing real-life tasks. Thus, the school helps you deal with real life.

In this farewell lecture, I want to share four key insights that I gained over the last 40 years of doing research. They pertain to (1) the importance of linking the real world to our teaching, (2) the key role of learner support, (3) the complexity of teaching and learning processes, and (4) the teaching of domain-general skills.

1 - Reality

My PhD research in the 1980s made me aware of the importance of bringing real life to the classroom. My research was on teaching computer programming. I started my research with observing and analysing programming courses taught in educational institutes. Most courses had a similar format. They were typically based on a book called "Introduction to BASIC" or "Programming in ALGOL-68". The books presented all commands of a programming language, such as IF...THEN for making choices, FOR i = 1 to X for doing iterations, PRINT X for printing the value of a variable, and so forth. In the lessons, the teacher would typically explain one or two commands and show some small toy programs to illustrate their use, whereafter students could try them out themselves. In the next lesson, the same procedure was followed for other commands, and this continued until all the commands in the book had been handled.

There was one big problem with these courses, namely that after the course students were not able to write a working computer program. They were aware of the different language commands, but unable to combine them in a meaningful way. I called this the problem of *fragmentation* in education. To solve the problem, I began to observe what professional computer programmers do. They mainly do things like debug existing programs, make changes to existing programs by adding new procedures, and sometimes write programs from scratch. I used these professional tasks as a basis for designing learning tasks in a new course. In this new course, students were confronted with simple but meaningful computer programs right from the start. They were invited to figure out what the programs could and could not do, to make changes to the programs, or to add new routines to them. The commands that needed to be used in the program were not explained by the teacher beforehand, but only once they were needed to understand the working of the program; that is, they were presented *just-in-time*. This new course where learning tasks were based on professional tasks proved to be much more effective than the existing courses; it solved the problem of fragmentation and greatly improved transfer of learning from school to the workplace[1].

I think connecting education to real life is fundamental to all types of education, but it is most obvious in vocational and professional education where real life refers to the workplace or clinical practice. The use of learning tasks based on professional tasks is then only one way to strengthen the connection between school and real life. Another powerful approach is *dual education*, which combines education at a vocational school with an apprenticeship in a work organisation in one-and-the-same educational program. Greet Fastré, for example, developed Care Village, which offers learning tasks for a nursing school[2]. The learning tasks always contain two elements: (1) activities that students had to perform at school, making use of available simulation facilities, and (2) related activities that students had to perform at their current workplace, which could be home care, a hospital, a rehabilitation centre, and so on. A great advantage of this approach is that it allows for a spiral curriculum, where students first practice simple tasks using different types of simulation and then continue practicing these tasks at the workplace; after mastery of the simple tasks, they practice more complex tasks using simulation and then, again, continue practicing them at the workplace, and so on until a level of task complexity is reached that a beginning professional should be able to handle. Thus, learning in school and learning at the workplace go hand in hand, optimizing transfer of learning.

Another example is provided by the work of Dewa Westerman in the simulation lab of our hospital. Healthcare professionals regularly visit the simulation lab to practice, for example, trauma care, specific medical procedures, teamwork and so on. The learning tasks or "scenarios" they practice in the simulation lab are based on professional tasks, but Dewa goes one step further. She asks the trainees to describe tasks they are struggling with before they visit the simulation lab and then develops simulation scenarios that explicitly address their learning needs. In addition, after practicing these needs-based scenarios in the simulation lab, learners are stimulated to continue practicing these tasks in clinical practice and to report back on their progress, that is, whether their learning needs have been met. In this model, learning needs in clinical practice are used to inform the contents of simulation training, and simulation training is a steppingstone to continue learning in clinical practice. This integrated model proves to be much more effective than a traditional model where simulation training is often isolated from clinical practice[3].

This leads me to my first insight. Learning in school or simulated settings must be strongly interconnected to learning in real life or clinical practice, and preferably, learning in real life affects learning in the simulated setting while learning in the simulated setting affects learning in real life – this reciprocal relationship will help improve transfer of learning.

Insight 1

Learning in school/educational institute and learning in real-life/workplace must be strongly interconnected to optimize learning.

2 - Learner Support

My second insight is related to the importance of providing *support* to learners. Just performing a task does not warrant the learning of this task. In order to learn, learners need support from instructional materials, their teacher, or their peers. This support can take many different forms, such as providing theoretical background information, just-in-time instructions, feedback, guidance and so forth. A powerful type of guidance is provided by worked examples, that can either show an example solution or an expert/teacher who is modelling how to perform the task and explaining how the solution is developed[4]. Much of my earlier research was on dealing with worked examples and asked the question if they provided effective support for learning problem-solving tasks. The answer was: sometimes they do, sometimes they don't. If you run 30 experiments comparing the use of worked examples with non-supported problem solving, you may find 10 experiments showing that worked examples are superior to non-supported problem solving, 10 experiments showing the opposite, and 10 experiments showing no difference at all.

In my thinking, such contradictory findings are more important for making progress in science than "significant results". Contradictory findings force us to think about explanations and to develop new theory. For example, research showed that worked examples do not work for learners with high prior knowledge because they already have sufficient knowledge in long-term memory to perform the task; the worked examples may then interfere with their already available knowledge. This phenomenon is also called the "expertise reversal effect"[5]. Worked examples and most other types of support that work well for low prior-knowledge learners show no positive effects or even negative effects for high-prior knowledge learners. The more general conclusion is that there are no "good" or "bad" instructional methods – the only thing we can say is that some methods are useful for particular learners, for particular learning goals, and under particular conditions.

This finding that the effectiveness of instructional methods always depends on learners' prior knowledge, learning goals, and conditions has important implications. First, it means that the effectiveness of instructional methods changes over time: When we are teaching, we should start with instructional methods that are suitable for learners with low prior knowledge, but as learners acquire more knowledge and skills, we should gradually change to instructional methods that are suitable for learners with higher prior knowledge. This basic principle that support should be decreasing as learners acquire more expertise is also called *scaffolding*, like a scaffold that is going down as the building nears completion[6]. Furthermore, at each point in time, or each point on the continuum from novice to expert, we should provide learners with the "right" amount of support – not too little and not too much. Ideally, the amount of support must fit their *zone of proximal development*. This concept originally developed by Vygotsky indicates that learners learn most when they are confronted with challenging tasks that are a bit out of their reach and that produce desirable difficulties, but we enable them to successfully complete the tasks due to the given support by their teacher, peers, or instructional materials[7].

A second implication goes one step further and aims to provide the type and amount of support that meets the needs of the *individual* learner. Individualized instruction goes under many different categories and names, such as personalized learning, adaptive learning, differentiated instruction, and so forth. It sometimes feels like we keep on inventing new categories and names for it because we are not making any fundamental theoretical progress on how to meet learners' individual learning needs. On the one hand, we should answer the question what relevant learning needs are and how they can be measured. For a long time, the focus has been on knowledge gaps and misconceptions, but it is becoming more and more clear that equally important needs are related to emotion, stress, and motivation. For example, in a recent project with Mary Dankbaar, Tjitske Faber and Joy Lee studied how stress measures in serious games can be used to advice learners to take pauses[8]. On the other hand, we should also answer the question how the type and amount of support should change in response to identified learning needs. Again, our knowledge is scarce and largely limited to how to respond to learners who are making errors or showing misconceptions; much less is known on how to deal with a broad set of learning needs, including needs outside the cognitive domain.

These considerations lead me to my second key insight. People can only learn to carry out tasks when they are supported through the provision of theoretical background information, just-in-time instructions, feedback, guidance, worked examples, and so forth. What good support is depends on their prior knowledge, affective state, learning goals and many other conditions. Thus, good support is at least tailored to the needs of a homogeneous group of learners or, preferably, to the needs of individual learners.

Insight 2

Providing the right type and amount of support to learners, not too little and not too much, is critical to optimize learning in simulated and/or real environments.

3 - Complexity

My third insight is related to complexity. If my previous two insights revealed one thing, it is that educational research is extremely complex. In this respect, I fully agree with David Berliner who wrote an influential article in 2002 in the journal *Educational Researcher* that was titled: *Educational research: The hardest science of all*[9]. He discusses why it is hard to make progress in the educational sciences: Different research paradigms and contexts lead to different findings and there are "ubiquitous interactions" between educational methods. As a result, there are no instructional methods that do or do not work; that is to say: everything works somewhere, nothing works everywhere. As I argued before, the only thing we know is that some methods work for particular types of learning under particular conditions to reach particular goals. Research should be aimed at increasing our knowledge and understanding of how educational methods work and how they interact with other methods, goals, and conditions. This understanding should then be expressed in educational theories that acknowledge the complexity of education.

Notably, this view is very different from a popular movement known as evidence-based education or, in the medical field, evidence-based medical education[10]. Evidence-based education basically assumes that there *are* good and bad educational methods, and that we should only use educational methods that have proven to be effective, that is, there should be evidence for their effectiveness. An example is the *what-works-in-education clearinghouse* of the US department of education, but over the last 20 years the movement also became popular in Europe and the Netherlands. Although I fully agree that we must only design education that is effective, I reject the idea that this can be reached by gathering evidence for the effectiveness of specific methods. I see that as a dangerous oversimplification, for the simple reason that due to the "ubiquity of interactions", one method might be highly effective in one situation, but ineffective in another situation. Some people try to solve this problem by using the term evidence-informed education rather than evidence-based education, but I also reject the idea that there is something like "evidence" in education. Evidence might be a useful concept in mathematics and exact sciences, but it is useless in the social sciences. In educational research, we test whether our understanding of teaching-learning processes is in line with our empirical observations. If it is, we gather empirical support for our understanding; and if it is not, we must revise our understanding.

We could also say that evidence-based education describes teaching and the design of education as a *simple skill*, which is mainly dealing with the selection of evidence-based educational methods[11]. This is what Olsen and Rasmussen call a rule-based process[12] and what I call in my 4C/ID model a recurrent skill. In my perspective, in contrast, teaching and the design of education are highly complex skills, characterized by problem solving, reasoning and decision making. This is what Olsen and Rasmussen call a knowledge-based process and what I call in my 4C/ID model a complex skill in which non-recurrent constituent skills, which heavily rely on our schematized knowledge of a domain, are dominant[13]. Ideally, the knowledge that we use in our teaching is supported by empirical data and thus has the form of a scientific theory. Such a theory does not simply describe what effective educational methods are but explains how and under which conditions methods work and do not work and how they interact. Sound theories help us make informed decisions based on deep understanding and to stay away from cookbook education.

My view has implications for research as well as educational practice. It can be summarized in the saying of Kurt Lewin that there is *nothing so practical as a good theory*. For research, we should not expect that individual studies have practical relevance for education. They must only contribute to theory development, and the practical implications then come from this theory. I think that is good news. Most of the PhD projects I supervised contained four or five studies and the typical pattern was that the second study showed findings that were inconsistent with the first study, so that remaining studies were necessary to figure out what was going on. Such projects do not have direct practical implications, but rather make important contributions to theory that does have practical implications. For educational practice and teacher training, we should not give too much weight to the findings of individual research projects. Practical implications should only be based on educational theory that is empirically supported by the findings of numerous projects, carried out by different researchers in different contexts.

This leads to my third insight. We must acknowledge the complexity of education and accept the fact that there are no good and bad educational methods. There is no cookbook teaching as suggested by evidence-based education. Instead, teaching and the design of education should be based on scientific theory that is supported by empirical findings, and that allows designers and teachers to solve problems, reason, and make decisions based on their deep understanding or knowledge of teaching-learning processes.

Insight 3

We need empirically supported educational theories that help us understand teaching and learning processes and make sound design decisions that optimize learning in simulated and/or real environments.

4 - Domain-general skills

My fourth and final insight relates to another aspect of complexity in education, namely, the teaching of domain-general skills. So far, I have only been talking about domain-specific skills, such as performing a particular surgical operation, diagnostic reasoning or doing math. But many people will argue that there are also domain-general skills, which are not bound to one learning domain. They include *learning skills*, such as self-regulated and self-directed learning, *literacy skills*, such as ICT and information literacy, *thinking skills*, such as problem solving and creativity, and *social skills,* such as communication and collaboration. These domain-general skills have also been called generic skills, higher-order skills, or, nowadays, 21st century skills. As I argued before, when we give many different names to the same thing this often indicates a lack of theoretical progress. That is certainly true for the teaching of domain-general skills.

The main problem with domain-general skills is that they do not exist *per se*. We can describe and teach them at an abstract level, but we can only apply and practice them *in* a concrete learning domain. For example, we can teach "about" general problem-solving skills, but we can only teach problem solving "as a skill" in math, or in medicine, or in physics. On the concrete level, and on the level of knowledge representation, problem solving in mathematics is simply different from problem solving in medicine. Indeed, research has shown that courses aimed at teaching general problem solving or creativity, outside a particular learning domain, consistently fail[14]. Therefore, the teaching and learning of domain-general skills such as creativity, information literacy or self-regulation skills must always be intertwined and integrated with the teaching and learning of domain-specific skills[15]. That is not an easy task. Suppose we are teaching a new surgical procedure in combination with information literacy skills. Then, we provide learning tasks to practice the *domain-specific* surgical procedure, but we also teach our learners the *domain-general* skill of how to find relevant and reliable information about that surgical procedure on the Internet or in the library. Too often, this is not done for reasons of efficiency. But as a result, our learners will never develop proper information literacy skills.

The intertwined teaching of domain-specific and domain-generic skills has important implications for the provision of learner support. Suppose you are an expert on the heart-lung system and a student comes to you. She says that she is writing a paper on a particular heart-lung disease and is asking if you are familiar with relevant articles on this disease that she can use. You can then support her on two levels. On the domain-specific level, you can simply give her some relevant articles to use. This is support on the domain-specific level, which I also call first-order scaffolding. As an alternative, on the domain-general level, you can teach her how to use the library and particular databases to find relevant papers herself. This is support on the domain-general level, which I call second-order scaffolding. It is not easy to say what your best reaction is. If the student has no prior knowledge about the heart-lung system, it is probably best to just give her the papers because her lack of domain-specific knowledge will make it impossible to do a good search in the library or online. But if she already has some knowledge of the heart-lung system it is probably best to teach her how to find relevant articles herself. Together with Adrie Visscher and other colleagues at the University of Twente I did research on differentiation skills that expert teachers use. It is interesting to note that teachers who are most successful in differentiation are also the ones who provide most second-order scaffolding[16]: As in the Montessori system, they teach learners who are ready for it "how to do it themselves".

My view on the teaching of domain-general skills is different from the popular view that teaching domain-specific knowledge is becoming less important, because this is readily available on the Internet, while teaching domain-general skills is becoming more important, because this will help learners to acquire new knowledge and perform in a flexible way in the future. I see that as wishful thinking. Although I agree that the teaching of domain-general skills is important to prepare learners for a fast-changing world, these skills can only be learned *within* a particular domain, where the acquisition of domain-specific knowledge and skills is indispensable. This has important implications for curriculum design. Suppose you want to teach citizenship skills or, in Dutch, burgerschapsvaardigheden. In my analysis, it will never be possible to teach such skills in a separate course; at best, a separate course can explain what citizen skills are on a conceptual level. If you want your learners to develop citizenship skills they need to be fully intertwined and integrated in subjects such as social studies, history, cultural studies, or geography.

This leads me to my fourth and final key insight. If we want our learners to function in a quickly changing world, it is important that they acquire domain-general skills such as learning skills, literacy skills, thinking skills and social skills. But we cannot teach them as such! They can only be acquired in selected learning domains where learners already have sufficient domain-specific skills. Thus, the teaching of domain-general skills must always be fully intertwined with the teaching of domain-specific skills.

Insight 4

The teaching of domain-general skills must be fully intertwined with the teaching of domain-specific skills to optimize learning in simulated and/or real environments.

This concludes my reflection on the main insights I gained over the last 40 years. I discussed the four insights in the chronological order of my career. Let me stress that the insights are not new or original. They have been expressed before by great thinkers about education. It just took me a long time to become fully aware of their utmost importance; about 10 years per insight. It should also be stated that my insights are mainly normative: they describe what should be done but not *how* it could be done. We know surprisingly little about the how-questions: How to interconnect learning in real and simulated environments? How to adapt instruction to a broad set of learning needs? How to connect educational theory and practice? And how to intertwine the teaching of domain-specific and domain-general skills? The more I learned about education, the more I became aware of how little we really understand about teaching and learning. To further develop our understanding, much more research and, eventually, much more educational theory is needed.

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