Potential of teaching and learning supported by ICT for the acquisition of deep conceptual knowledge and the development of wisdom

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Introduction

In everyday discussion universities are often seen as environments in which wisdom is developed. However, it is the humanistic tradition of universities that is seen as the source of wisdom and often people seem to think that there is a tension between wisdom and technological research and development. This is also apparent in the discussion about educational technology. The opportunities provided by educational technology have been emphasized in thousands of articles dealing with the teaching of skills, facts or organized knowledge structures in education. However, there are hardly any scholarly articles that even mention the development of wisdom and educational technology in the same paper. The few studies connecting wisdom and educational technology are dealing with the learning challenges caused by an increase in complexity, ill-defined problems and ambiguity. In these studies technology is seen as a tool for developing learning environments that can optimally prepare people for life in an ambiguous and complex world [1]. Before I analyse deeper the role of technology in (higher) education, I will shortly discuss the use of the concept of wisdom in scientific literature.

In the extant research literature wisdom is typically considered to be a feature that is related to aging and wisdom education is seen as the aim for educational services for elderly people [2], but some authors have analysed how education can create a basis for future wisdom [3–5]. Historically, wisdom has been dealt with in philosophy and religious studies. Recently, however, interest in the topic of wisdom can be found in a wide spectrum of disciplines, ranging from philosophy and religious studies, to cultural anthropology, political science, education and psychology [6].

Baltes and Staudinger [6] distinguish between implicit and explicit psychological theories of wisdom. The implicit or folk-psychological conception of wisdom is an idea that carries a specific meaning that is widely shared and understood in its language-based representation. According to this idea wisdom is

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an exceptional level of human functioning and is related to excellence and ideals of human development. It also includes some kind of balanced interplay of intellectual, effective and motivational aspects of human functioning. Two important aspects of the folk-psychological conception are a high degree of personal and interpersonal competence, including the ability to listen, evaluate, and to give advice and good intention to use these abilities for the well-being of oneself and others.

Explicit psychological theories of wisdom aim to go beyond the characterization of wisdom in folk-psychological terms and focus on behavioural manifestations or expressions of wisdom. Baltes and Staudinger [6] have divided explicit theories of wisdom into three groups:

- The conceptualization of wisdom as a personal characteristic
- The conceptualization as postformal and dialectical thought
- The conceptualization of wisdom as an expert system dealing with the meaning of life.

When thinking of wisdom from the point of view of education and learning the personal characteristics approach is not as relevant as the others. The postformal or dialectical thinking and the expert system definitions come closer to the aims of academic and scientific studies.

Baltes and Staudinger [6] have defined wisdom as an expert knowledge system of the fundamental pragmatics of life. According to them this definition includes knowledge and judgment about the meaning and conduct of life and the orchestration of human development toward excellence while attending conjointly to personal and collective well-being. This requires:

- Rich factual knowledge (general and specific knowledge about the conditions of life and its variations)
- Rich procedural knowledge (general and specific knowledge about strategies of judgment and advice concerning matters of life)
- Life-span contextualism [knowledge about the contexts of life and their temporal (developmental) relationships]
- Relativism (knowledge about differences in values, goals and priorities)
- Uncertainty (knowledge about the relative indeterminacy and unpredictability of life and ways to manage)

It is an intriguing task to analyse how modern powerful learning environments [7] and particularly learning environments powered by information and communication technology can fulfil the above described requirements of wisdom development.

Sternberg [8] has conceptualized wisdom as the application of tacit knowledge toward the achievement of a common good through a balance among multiple personal (intra-, inter- and extra-personal) interests and environmental conditions. The conceptions of wisdom by Baltes and Sternberg share many aspects of characteristics typical for expertise [9]. However, whereas for Baltes and Staudinger [6] wisdom is a special 'field' of expertise, Sternberg [4] sees wisdom as going beyond the classical definitions of expertise.

The promise of educational technology

Our desire to develop more powerful learning environments is a consequence of the many changes currently taking place in society. The rapid development of technology and work practices is challenging the traditional aims of education. At the same time the advancement in theories of learning and new technologies provide us with qualitatively new methods for coping with these challenges. Knowledge and technical tools for creating, storing and manipulating knowledge are the most critical resources for social and economic development in the advanced information society. Distributed expertise and networked activities characterize more and more of the emerging types of work. Self-regulated skills for searching producing and managing knowledge will be essential for all individuals, as well as organizations, in an emerging knowledge society. The skills needed include the ability to solve increasingly complex problems in a variety of knowledge-rich domains, to participate in knowledge work and to engage in various socially embedded or networked knowledge-building activities [10]. Every citizen will need to be able to engage in education and professional development throughout his or her life.

ICT (information and communication technology) has played a noteworthy role in both the development of new theoretical approaches and in testing old theories of learning and instruction. Computer technology opened opportunities to implement behaviourist theories, and the adoption of constructivist epistemological principles has particularly encouraged learning scientists to analyse how technology-based environments would provide learners with new opportunities for activities that are beneficial for knowledge construction.

Levels of learning and technology-based learning environments

Wisdom is often discussed as the highest end of the continuum that goes from data to information, from information to knowledge and from knowledge to wisdom [11]. All these levels refer to representations with which people can create, communicate and learn. However from the human learning point of view these levels are quite different.

In this section I try to show how different forms of ICT can support different levels of learning. In the history of educational technology there have been several innovative ideas about how information technology can be used in enhancing learning. In a previous article I have referred to these ideas as utopias of educational technology, as it is typical that these ideas have often been introduced as general solutions for all kinds of educational problems [12].

According to Ackoff [11] information consists of data that are processed to be useful. Information provides answers to 'who', 'what', 'where' and 'when' questions. Learning of data and information is based on the formation of neural networks through repeated experiences, conditioning and reinforcement or some basic level of intentional memorization [13]. Already during the first years of computer technology many applications for education and training were developed.

Computers were seen as tireless trainers and the instructional designs created for them were mostly based on the ideas of repetition and reinforcement. Computer technology made it possible to fully implement the theoretical ideas of behaviourism that were the dominant approach in learning research in the middle of the 20th Century. So-called drill-and-practice programmes were and still are quite effective in training simple skills, which are necessary to learn, but which do not require any deeper conceptual understanding. Particularly in the early years of computer-assisted learning these applications, based on behaviourist ideas of conditioning, were widely developed and used [14]. These applications are meant to support learners in learning facts and simple skills as fast as possible by providing repetition, feedack and reinforcement. Information and comprehension of basic skills can be seen as a prerequisite for higher mental processes including wisdom. However, the aims of this kind of computer-aided learning environment (e.g. drill-and-practice programmes) are quite far away from the principles of education that would enhance wisdom.

Knowledge is separated from information and it refers to organized, integrated and meaningful structures of information that answer 'how' and 'why' questions [11]. A fundamental feature of knowledge is that it is always connected to other knowledge. Thus the learning of knowledge cannot be independent from existing knowledge. The learning of knowledge entails conceptual construction taking place on an individual or social level. This includes the activation of relevant prior knowledge and the intentional construction of new mental models which can mean extension and integration of prior knowledge or a more radical restructuring of existing beliefs and knowledge structures [15].

There have been many attempts to develop technology-based learning environments to support the intentional construction of higher-order knowledge structures [16]. The development of cognitive and constructivist theories of learning has been closely related to designing computer-based learning environments in which these theoretical models have been implemented. In the spirit of constructivism Papert [17] introduced the 'microworld' concept, which refers to open computer-based learning environments offering students opportunities for exploration and discovery. According to this approach new concepts are not directly instructed but students can invent them in these computer environments. Later the idea of the microworld has been particularly developed in mathematics education [18]. Simulations share some basic features with microworlds but are not so strictly connected to (extreme) constructivist ideas [19]. Simulations are typically more focused on training special skills and these have become very important tools in professional training in many fields (e.g. flight and patient simulators). Open environments for exploration and discovery can in many ways enhance the development of higher-order thinking and reflective attitude that are personal features emphasized in folk-psychological conceptions of wisdom.

Another educational technology tradition, which is also closely related to the development of cognitive theories of knowledge and learning, has focused on developing intelligent or cognitive tutors [20]. In this tradition specific findings of cognitive psychology and artificial intelligence are used in developing learning environments. The goal in intelligent tutoring is to model, through computers, the cognitive structures of the learning tasks and the possible learning trajectories and misconceptions of the students. Many of the well-known intelligent tutoring systems are planned to guide students to follow exactly the optimal path towards the mastery of the target skill. For example, Anderson and Lebiere [21] have developed tutoring systems that are based on a model of two separate knowledge systems: factual or experiential declarative knowledge and procedural knowledge, consisting of a system of if–then production rules. Each skill is modelled in terms of production rule sequences and the tutoring systems guide students to learn these sequences. Production-system-based applications have proven to be effective in, for example, teaching demanding mathematical procedures. How promising are these environments from the point of view of education for wisdom? Even though good comprehension of these kinds of procedures can be a part of wisdom, it is evident that automated procedures, however demanding they may be, are not features connected to wisdom either in implicit or explicit theories.

In some intelligent tutoring approaches the possibilities of artificial intelligence have been used in developing learning environments in ways that have many elements of wisdom-enhancing environments. One of the aspirations for the educational use of ICT is that with the help of information technology it is possible to develop environments that present complex problem situations while, at the same time, providing students with a rich variety of tools which effectively support their attempts to control the complex relationships of learning tasks. Lesgold et al. [22] have developed technology-based learning environments that simulate extremely complex and ill-defined problems typical for advanced expert practices. Intelligent tutoring in these systems does not give immediate feedback or direct instructions but instead acts as a wise mentor, guiding learners towards reflection and the use of multiple perspectives. This is related to Sternberg's [4] view of education toward wisdom. He points out that wisdom is not so much taught directly but learned as a by-product of the activities in practical situations and working or learning environments.

However, it is clear that even though some may facilitate wisdom development, all of the above described ICT applications are designed for meeting the demands of typical educational situations and they focus on supporting teaching of predefined facts, knowledge and skills without explicit or implicit aims to facilitate the development of wisdom. There are, however, research and development traditions in technology-based learning environments that are meant to promote learning that goes beyond the traditional educational aims. During the last decade many educators and researchers have developed educational approaches termed CSCL (computer-supported collaborative learning) [1,23]. The concept of wisdom is not often explicitly used in the CSCL tradition, but the aims and principles developed are quite similar to those proposed by advocates of wisdom education.

In his article about the balance theory of wisdom, Sternberg [4] pointed out that wisdom emerges in a series of processes that are typically cyclical. These processes are related to so-called 'metacomponents' of thought, including:

- Recognizing the existence of a problem
- Defining the nature of the problem
- Representing information about the problem
- Formulating a strategy for solving the problem
- Allocating resources to the solution of a problem

- Monitoring one's solution of the problem
- Evaluating feedback regarding that solution.

The development of wisdom means a:

"*balance among three kinds of interests: (a) intrapersonal (one's own), (b) interpersonal (other people's), and (c) extrapersonal (more than personal, such as institutional) interests, over the short- and long terms, as (d) informed by values*" ([5], p 7)

Many authors who have developed models for CSCL have presented approaches that aim at meeting most of the challenges presented in Sternberg's definition of the balanced theory of wisdom. For example, knowledge-building by Bereiter and Scardamalia [24] or progressive inquiry learning by Hakkarainen et al. [10] propose cyclical processes that are quite close to the metacomponents of thought presented by Sternberg. These approaches emphasize that learning should not only be an acquisition of predefined content but the creation or designing of something new on the social level. With the knowledge-building concept, Bereiter and Scardamalia [24] aim at facilitating the process of producing externally visibly 'knowledge objects' such as scientific concepts and theories. The idea is that students' collaboration could be compared with the typical socio-cultural processes taking place in science where theories are progressively developed through professional discourse.

The progressive inquiry model of Hakkarainen et al. [10] presents a detailed description of the steps or elements of a research-like process in a school environment. This model is partly based on Bereiter and Scardamalia's [24] knowledge-building approach, but it is elaborated further by using dynamic and pragmatic conceptions of inquiry emphasized in the philosophy of science [25]. The model relies strongly on the interrogative inquiry theory of Hintikka and Hintikka [26] which highlights the gradually sharpening of questions as a fundamental aspect of scientific practices. The progressive inquiry model includes the following subtasks:

- Creating the context
- Setting up research questions
- Constructing working theories
- Critical evaluation
- Searching deepening knowledge
- Generating subordinate questions
- Constructing new working theories

These steps can be fulfilled in a flexible order and repeated several times. During all these phases ideas should be shared among the peer group by using a suitable network-based platform supporting collaboration.

Sternberg [4] also argues that wisdom requires analytical thinking, but it is not the kind of analytical thinking typically emphasized in schools. Rather, it is analytical thinking that is needed in conflicting dilemmas or in complex, ill-defined and often messy authentic problems for which there is no one solution. The authenticity of the learning situations and tasks is assumed to be an important factor that can facilitate higher-order learning [27]. Many learning scientists assume that information technology and particularly computer-supported collaborative learning can be used to mediate real-life problems and dilemmas with the traditional school-based learning environment in a form that makes it possible to connect the practical problem solving, learning of theoretical ideas and understanding of rationales of different perspectives and opinions [28,29].

The use of technology-supported collaborative learning in dealing with complex authentic problems can make visible different beliefs and the gradual elaboration of knowledge. At its most effective level it also highlights the necessity to understand other participants' perspectives and to continuously reflect on one's own previous knowledge and beliefs. Because of these features technology-supported collaborative learning is an example of learning environments that can be used for supporting wisdom development.

Conclusions

In this chapter I have discussed the potential of different technology-supported learning environments for facilitating the development of deep conceptual knowledge and wisdom. The analysis shows that there are remarkable differences in the aims of distinct technology-based learning environments. Some are focused on the rapid learning of facts and automatization of simple skills, whereas others are deliberately meant for supporting deep learning of complex concepts and knowledge structures. Even though wisdom development is not mentioned as an aim, the most advanced uses of technology in learning environments seem to include individual and social activities that are very similar to those emphasized in theories of wisdom.

The above discussion is based on theoretical arguments and very little is said about the empirical evidence of the benefits of technology in learning and the development of wisdom. Thousands of experimental studies on the educational impact of ICT have been carried out since the first attempts to assess the educational use of information technology in the early 1970s. These results have been summarized in dozens of review articles and meta-analyses. Our overviews of these reviews covering more than 1000 original experiments allow for a few general conclusions [1,14,30,31]. In summary, the reviews and meta-analyses of the experiments show that ICT students have learned more and faster than students in control groups. In these experiments ICT has also improved student motivation and social interaction. The quality of learning depended on the type of ICT application. However, there are many limitations in the experimental designs that are of great importance when the practical relevance of this evidence is considered. When interpreting review articles and meta-analyses we must keep in mind that they may contain errors that give an overly positive picture of the effects of using information technology in education. It is important to remember that before a research article is published, it goes through a critical evaluation process that usually screens out articles that present 'null findings'; articles that obtain results in accordance with their hypotheses have a much higher likelihood of getting published.

One of the important features that clearly emerged in the meta-analysis of Khaili and Shashaani [32] was the duration of the experiment. In experiments that lasted longer than 7–8 months the effectiveness of ICT began to decrease. In the meta-analysis of Cavanaugh [33] positive effects were found in studies that lasted less than 15 weeks. In longer studies the effects disappeared. The introduction of a new method or technique brings new interest to the learning situation, which increases motivation and improves achievement once people learn to work with the new system. When the new method or technique has been in use in the classroom for somewhat longer, the novelty fades out [14].

Khaili and Shashaani [32], and Cavanaugh [33] obtained an additional important finding. Experiments performed with very small student groups produced higher effect sizes, whereas the effects shrink significantly once the group sizes in the experiments increase. The duration- and size-effects found in experimental studies explain, at least partly, the controversial findings of experimental studies and field studies in regular educational settings. In contrast with the positive findings of experimental studies, several large national and international studies have shown not only that educational technology applications are used much less than expected, but also that the frequency of technology use explains almost no variation in learning outcomes [34,35]. Very recent studies, however, indicate that the use of online and virtual learning models is increasing [36].

Many researchers have stressed that it is difficult to make any generalized conclusion about the effects of educational technology. This is partly due to the many qualitatively different ways of implementing ICT in teaching–learning situations [14]. Salomon [37] has emphasized the complex systemic changes that take place in the classroom processes when ICT applications are implemented. Thus it is impossible to isolate the specific effect of the technology because it is always connected to general teaching–learning arrangements and pedagogical approaches.

It is possible that traditional evaluation methods cannot make visible the new forms of learning that are made possible by the increasing use of educational technology. Generally speaking standard methods of assessment are not suitable for measuring deeper conceptual learning in students supported in new learning environments, with or without technology [38]. Typical assessment methods used in formal educational situations do not necessarily manage to reveal the development of wisdom resulting from the use of innovative technology-based learning environments.

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