Research approaches and methods in technology-enhanced learning

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Abstract

This article offers an orientation on how research is done in technology-enhanced learning. Therefore, three different approaches to research in the interdisciplinary field will be presented first: hypothesis and theory testing, hypothesis and theory generating, and design oriented methods. Subsequently, some research methods are assigned to the research process - data collection, data analysis, development - and outlined. Finally, hints on the choice of a research method are given and a typical challenge in the field is mentioned.

Content

1. Introduction

Technology-enhanced teaching and learning encompasses "all learning and teaching processes and actions that use technical, mainly electronic (and mostly digital) equipment and applications (Ebner, Schön, Nagler, 2011, 2, own translation). From the perspective of **educational science**, technology-supported learning can be seen as a special form of learning, so that their research methods are applicable. There are two things to counter this: First, technology has developed forms of learning that may have little in common with traditional learning and teaching situations: They can be time-delayed and spatially distributed or they can also enrich reality ("augmented reality"). Using technology also enables new, innovative processes such as collaborative and simultaneous writing - which would in fact not be possible without the use of technology. Second, with the same argumentation and with principled reason, we can also regard **computer science** procedures as relevant and sufficient, since learning and teaching is only one form of application fields here.

Technology-enhanced learning and learning is a highly **interdisciplinary field** in which there are different research approaches and methods, depending on the disciplinary background of the participants. The fact that the disciplines involved deal with different issues partly explain these. This article presents three approaches to research in the field, based on different understandings of science. This is followed by an overview of approaches to data collection, evaluation and development.

There is only some literature that attempts to locate methodologically e-learning research (cf. Friesen 2009; Reinmann, 2005; Reeves, 2006, or the original German version of this article by Schön & Ebner, 2013). There is no real consensus on the approaches outlined below or a defined methodology so far.

Before you read on: Please take a paper and note as many research methods you know from your discipline!

2. Different understanding of research and research methods

Educational psychology with its scientific approach, media education with its humanities background and applied computer science with its technical understanding have diverse research approaches. How research is to be approached is not only a question of the concrete method used, but a consequence of one's own understanding of scientific work and the understanding of "research" in the initial discipline. This is where major differences between the disciplines become apparent. The knowledge about how methods work and which methods are suitable and justifiable under which circumstances is also called **methodology.**

Anyone who studies **psychology or educational science** today usually attends several (compulsory) courses on research methods. While psychology and educational psychology are usually more oriented towards research methods that are based on scientific standards with the primacy of experimental laboratory studies, education also introduces hermeneutical methods that originate in the humanities. Publications on research methods in technology-supported learning thus question the primacy of the experiment as the royal league of research methods (cf. Friesen, 2009). In addition, experts in technology-supported learning demand that, besides recognised research methods, development methods should be recognised as research procedures (Reinmann, 2005; Reeves, 2006; Amiel & Reeves, 2008).

In **computer science**, there is a discussion whether we should regard it as a science based on information science or rather as an engineering science (Broy & Schmidt, 1999). In recent decades, more and more disciplines have developed that rely on computer science, similar to the way many engineering sciences rely on mathematics (Kornwachs, 1997). Such "applied computer science" is emerging, such as medical computer science or business computer science as its most prominent representatives (Frank, 2001). According to this, and also in our experience, computer scientists who are active in technology-supported learning take an "engineering science" approach, use development methods and carry out checks in the form of tests.

Besides such insights into the training and discussion of the disciplines, **scientific publications** in the research field also provide us with indications what the (important) research methods in our research field are: Which research approaches and methods are frequently cited in articles in scientific journals and at conferences in technology-enhanced learning? Evaluations of the methods used in publications in the field show that only a part of the research work uses empirical approaches or even (quasi-)experimental settings: According to Abrami et al. (2006), this is true for only about half of the

contributions on e-learning in Canada. For scientific contributions to computer science education, this proportion is even lower: Only about one-fifth of the contributions from the 20 years up to 2004 use an "experimental" approach, meaning any approach in which an intervention is evaluated with some scientific analysis (cf. Valentine, 2004, 256). In the following years the proportion of such "experimental" contributions doubled (cf. Randolph et al. 2008, 146).

The contributions of many conferences in technology-enhanced learning and also articles in professional journals are freely available on the Internet, for example the ERIC database (https://eric.ed.gov/). Choose any three contributions and try to find out if and which research method the authors use.

3. Three approaches to research

There are three approaches to research on technology-enhanced learning that need to be differentiated: First, (a) hypothesis and theory testing procedures that verify existing explanations of the processes of learning and teaching in experimental settings and (b) hypothesis and theory generating procedures (see Bortz & Döring, 2006). We have supplemented this traditional presentation with (c) application-oriented and creative methods that develop and test novel systems and concepts, this approach is called design-based research.

Please highlight and check terms you do not understand in the following!

3.1 Hypothesis testing approaches

The traditional hypothesis testing procedure attempts to confirm and verify existing theories of technology-supported teaching and learning and, if necessary, to revise or adapt them. Theories are explanations of things around us, ideas of how the world "works". A scientific theory is "every scientific unit of knowledge in which facts and model conceptions or hypotheses are processed into a whole" (Schischkoff, 1991, 721f., own translation). Similar formulations can be found in educational psychology, which understands a theory as a system of statements "which serves the purpose of ordering and mentally completing individual knowledge in such a way that, via a certain area of reality (e.g. school, play), representations and explanations of the states or developments in this area become possible without contradiction" (Schaub & Zenke, 2004, 352, own translation). Minimum requirements for a theory are that it takes into account the rules of logic and grammar and that it is consistent, verifiable and empirically confirmed. Finally, it should have a practical use and not be unnecessarily complicated.

A research project with this approach will first justify the selection of a particular theory, derive hypotheses from it, present and implement a research design, and finally present results, using for example inferential statistical methods (see Fig. 1).

Fig. 1: The process of a theory-based and hypothesis testing approach

Please note: In computer science, the term "theory" is understood differently. The "theoretical computer science" deals with the fundamentals of application-oriented computer science, i.e. basic models and procedures, for example formal languages, database theory or logic. In theoretical computer science, for example, mathematics is used to prove whether they can solve a problem in a finite time frame (see Erk & Priese, 2001).

3.2 Explorative methods

The second research approach does not aim at comparatively concrete problem solutions, but tries to develop hypotheses, theories and recommendations for action. Thus, in the humanities, i.e. also in philosophically oriented pedagogy, there is an approach to finding explanations and models through understanding, discourse and analysis of practice. With the help of data on learner activities and behaviour, others try to develop fresh ideas about the conditions and phenomena and formulate hypotheses based on them, also using algorithms and statistical methods. These are only examined in more detail in further investigations. Many surveys of user data or surveys of media use are thus observational studies that are (regularly) conducted intending to be able to react to changes, for example, or to derive hypotheses from them.

Typically, such "explorative" or "exploratory" procedures are used when a research question is at stake or when there are source materials for which there are few existing theoretical assumptions. Here, the attempt is typically made to collect data on a rather "broad" basis, for example in case study comparison by collecting as many source materials as possible. The evaluation of the data leads to assumptions (hypotheses) and heuristics (see Fig. 2).

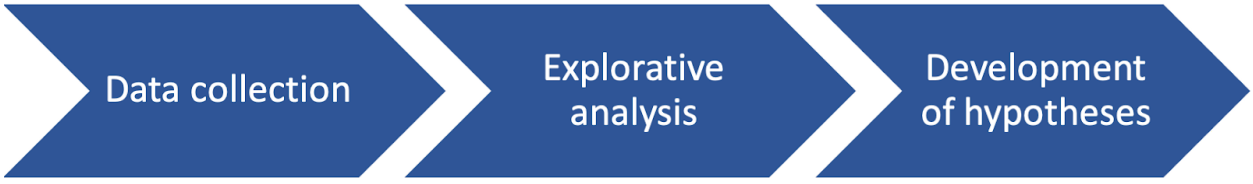

Fig. 2: The process of an explorative approach

3.3 Design-based research

Educational science and applied computer science are strongly application-oriented sciences that often deal with concrete practical challenges of technology-enhanced teaching and learning. In applied computer science, the engineering approach predominates, i.e. there are many procedures that systematically support the development and testing of concrete systems and applications. In educational science, there are always suggestions and encouragement to recognize the research approach of application-oriented design and evaluation as equivalent to the traditional hypothesis-testing procedure already presented. Reinmann (2005) thus pleads for a research approach based on design development to help shape innovations (design-based research, Reeves, 2006).

This is based on didactic assumptions on the one hand, and design development procedures are integrated on the other. From the perspective of applied computer science, an engineering approach that investigates, describes, systemically conceives and implements in context a solution of novel and non-trivial problems is accepted scientifically. There are many procedures in applied computer science, but also in educational science, which are used in the development of solutions for (new) challenges in technology-supported learning, for example in user-centred software development or in procedures and theories of instructional design.

A typical contribution with this approach documents these developments based on the description of practical challenges (see examples in Scanlon, 2010). Besides researching, comparing and describing possible and existing solutions, researchers make a reasoned selection of a development method for a new/own solution. The result, i.e. a new instructional or technical concept and its application, is also formatively reviewed. This can be already done during development ("formative evaluation") and/or finally evaluated ("summative evaluation"). Everyday professional activities that undergo similar processes seem to differ from research activities in that they involve new challenges that do not correspond to standard situations and require more detailed research and documentation. The core task of this research approach is therefore the application of existing solutions in new contexts or new situations or the creation of novel concepts and system architectures (see Fig. 3)

Fig. 3: The process of a design-based approach

Please be aware that depending on the disciplinary context this third approach is either "standard", or a "hot potato": There can be colleagues who deny that these are methods that can be used for research. In research work, it is in one's own interest to clarify this issue, as long as there is no broad acceptance and quality criteria for such a formative research.

4. Qualitative, quantitative and method mix procedures

We have already described and mentioned different approaches to research. Before we present exemplary research methods, we would like to point out a predominant categorization of research methods based on the distinction between qualitative and quantitative data.

Quantitative methods are counting and measuring procedures and evaluations based on them, for example, with the help of statistical methods. Quantitative methods can be used, for example, to check whether the grade in English is statistically related to the possession of a smartphone by students.

Qualitative procedures deal with the quality of information: For this purpose, for example, texts are analysed regarding typical patterns of argumentation, or attempts are made, for example, to use interviews with students to gather information that can help explain the connections between the English grade and smartphone ownership. In an open discussion, for example, it could turn out that children with smartphones travel abroad more often with their parents and need to speak English there. Researchers who choose a qualitative approach deliberately do not see themselves as an "observer intent on independence", but as "factual or virtual participants, educators, advocates" (Lamnek, 1995, 259). To sum-up it simply: Quantities are measurable quantities; quality is about "content".

Qualitative and quantitative research methods are based on different methodological considerations. A **method mix**, i.e. the complementary use of quantitative and qualitative procedures to better answer a question, is therefore not unproblematic (Lamnek, 1995, 251ff.). However, there are a number of arguments in favour of procedures that make use of such "triangulation", and their interlocking also appears to be possible from a methodological point of view (Kelle, 2008). For example, there are procedures in which it is counted how often a particular argument or statement is made in texts (cf. Mayring, 2000). Triangulation is then regarded as an ideal of research: "just as the legs of a triangle are welded together, so qualitative and quantitative steps of analysis must be combined, they depend on each other in order to be able to produce a pure sound" (Mayring, 1999, 122, own translation).

5. Selected research methods

Deviating from the frequently chosen above distinction between quantitative and qualitative approaches, we will refer in the following to different research methods, which we will present regarding their location in the research process.

5.1 Methods of data collection

There are many ways of collecting data in technology-enhanced teaching and learning. The first is **observation**. Researchers observe the behaviour of learners under controlled conditions, also with the support of video and other technical aids, or collect data automatically (e.g. through tracking). Another form of data collection are **surveys**, which can be conducted orally (by telephone) or in writing (e.g. with a web questionnaire). Here, individuals or groups can be addressed (e.g. in focus group interviews). An important distinction here is the form of response or observation: Are open questions asked or do observation categories or response options ("standardized procedure") have to be specified? A special form of a survey can be a **test** (e.g. as a personality test). However, tests are also carried out in applied computer science if certain technologies are to be tested according to previously defined criteria (e.g. performance test).

Research is often used to try **to describe a certain state of affairs**, usually without intervening in the system. It is always particularly exciting when attempts are made to determine **differences or correlations**, for example, whether distinct groups or technologies produce different results, whether behaviour or performance is influenced by different interventions, or when correlations between characteristics are to be investigated. This usually requires data to be collected on several variables, often at different times or in different groups and with different conditions. The "ideal way" of a scientifically oriented approach is an **experiment**. In an experiment one variable, the "independent variable", is systematically changed and effects on the “dependent” variable are measured. The independent variable can be the background noise and the dependent variable the learning results of a short vocabulary training in an unknown language. The challenge here is to have all other variables "under control", such as prior knowledge, instructor-participant communication or light. If experiments are to be conducted for learning and teaching, it is often necessary to make concessions to the ideal experimental conditions. Often they cannot be carried out under laboratory conditions where all variables are "under control", but only in the "field", i.e. in a classroom, for example.

Also, it is often (for ethical reasons) not possible to select participants in experiments "randomly" or to assign them to groups, these are then "quasi-experiments". The prerequisites of an experimental design can rarely be realized when learning and teaching with technologies. In research practice it is often difficult to form **comparison groups** or apply “A/B tests”. For example, the differences in two school classes (teachers, pupils, distributions) are often already too big to be able to assess the effects of two different interventions or two different learning Websites. Although field studies are an indispensable procedure in the research field, since the results often differ significantly from laboratory experiments,

they are also much more difficult to systematize. If it is only about pure technologies, for example performance tests under certain conditions, these difficulties do not exist.

5.2 Methods of analysis

Data is available in different formats, for example, as texts, tables or even as photo or video material. There are different analysis options, but they also depend on the specific materials.

For example, for data that is available in the form of numbers, the first option is **quantitative approaches**. Descriptive statistical procedures provide an overview of distributions, for example, averages or rankings. The calculation of the correlation coefficient thus makes it possible to check whether two data sets are statistically related. Cluster analysis is an algorithmic procedure that can indicate "clusters" of data with similar characteristic values. Social network analysis, for example, evaluates network structures with regard to decisive nodes in the network of relationships or communication flows. For comparisons of data sets, for example group comparisons or pre- and post-data, so-called inferential statistical methods are used. These allow statements to be made as to whether differences in the groups can be explained by chance or are statistically significant. Another attempt is to clarify the extent to which two factors are interdependent. Here, for example, the statistical correlation measure of the correlation coefficient can be calculated. Such and similar multivariate procedures such as “cluster analysis”, “discriminant analysis” or “decision tree” analysis are also used in exploratory evaluations, to identify potential relationships or patterns. A special application area of quantitative approaches in technology-enhanced learning are “**educational data mining**” and “**learning analytics**” (Baker & Inventado, 2016).

In **qualitatively oriented procedure**s, data is evaluated with regard to content aspects, for example, text and content analyses are carried out with regard to certain motives, argumentation structures, patterns or statements. Sometimes these criteria are only developed during the evaluation. Thus, the procedure of "**Grounded Theory**" (Glaser & Strauss, 1967) describes the development and emergence of theories based on the evaluation of qualitative data (usually texts). Groups can be compared by identifying special features. Case study analyses, for example, often attempt to identify success and/or failure criteria of new media usage in classrooms.

5.3 Methods of development

Finally, many methods are also used in the systematic development of novel concepts and systems, which prescribe more or less precisely how this development should take place to achieve the desired positive results, to make economic progress or to get innovative processes.

In applied computer science, principles such as iterative software development, prototyping, analyses of application potentials or user-centred application development are to be mentioned here, whereby the latter, for example, with the help of the "persona method", fit well to the different requirements and user groups. There are also many suggestions on how to achieve successful learning environments and materials, for example, by the ADDIE or ARCS model or by designing architectures of such information systems. There are also innovation development methods such as "lead user workshops", which can provide guidance here. Special methods in usability research (for example "thinking aloud" or "heuristic evaluation") help to better understand, especially the human-machine interaction. Finally, evaluation methods allow us to optimize the development or to point out strengths and weaknesses.

Take the collection of research methods you have made at the beginning. To which of the three outlined research approaches can you assign them? Which of the research approaches and methods mentioned here have you not considered?

6. On the choice of research methods

After a literature search and evaluation of the state of research it should be clear which questions have been clarified, where there are open questions, which theories are used and which research methods are predominant. Particularly in the interdisciplinary field of technology-supported teaching and learning, we experience repeatedly that an exchange with experts is very important: There are many theories and research traditions that can be linked to, but which have so far hardly been used or only to a limited extent. It is also helpful to ask specifically for related technical terms or synonyms: for example, in addition to the concept of the "flipped classroom", there is also a group that discusses the term "inverted classroom".

7. New technologies as a research challenge

Independent of the research method chosen, we would like to conclude by pointing out a challenge of research on technology-enhanced learning: There seem to be some typical "bias" that should be taken into account in the evaluation or discussion, which essentially revolve around "new" technologies. Amiel and Reeves (2008) thus raise the fundamental question of whether we are in a phase of excessive expectations. New technologies are per se associated with positive changes and results, according to Schulmeister (2009) they contain a 'promise for the future'. This can also lead to the fact that negative results are published less frequently (cf. “file-drawer-effect” according to Rosenthal, 1979).

More

This text and a video with examples for the different research approaches can be found online as well. Enjoy!

See: https://sansch.wordpress.com/?p=8065

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