Education and Information Technologies (2022) 27:12793–12810
https://doi.org/10.1007/s10639-022-11139-9

MethodViz: designing and evaluating an interactive learning tool for scientific methods – visual learning support and visualization of research process structure

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Received: 3 January 2022 / Accepted: 26 May 2022 / Published online: 8 June 2022

Abstract
In this study, we focussed on designing and evaluating a learning tool for the research process in higher education. Mastering the research process seems to be a bottleneck within the academy. Therefore, there is a great need to offer students other ways to learn this skill in addition to books and lectures. The MethodViz tool supports ubiquitous aspects of the research process in their scientific works higher education students follow. Moreover, the tool facilitates and structures the process interactively. In this paper, we describe the creation process of the artefact and examine the characteristics and scope of MethodViz alongside the traits and ideas of design science research. The evaluation's results are encouraging and show that MethodViz has the potential to improve students' learning achievements.

Keywords Interactive Learning Tool · Research Process · Scientific Methods · Visual Learning Support

1 Introduction

All students in higher education who are to receive a degree at the bachelor's, master's or doctoral level must write an independent work, or a thesis, which requires them to learn and understand the scientific process and methods. An academic degree means that students have to prove they have knowledge, ability and skills in the scientific craft, namely the core of research. However, too many students are struggling with their theses, and many are failing. Research (cf. Ding et al., 2016a, b), national evaluations (UKÄ, 2019) and proven experience show that the most difficult parts for

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university students are generally the science methodology and writing the thesis satisfactorily. A relevant question is therefore how students' learning can be facilitated in the research process.

In this situation, the next problem arises, namely that of the theory of science and academic writing. A review of 50 textbooks (8,000 pages) on scientific method used in Swedish universities shows that they contained approximately 97% text and 3% pictures or illustrations (Boström & Sjöström, 2021). One question to ask is which pedagogy is used and which other strategies are available in the teaching context. Our overall experience of teaching in higher education occurs in a traditional form, with lectures, textbooks, discussions and writing exercises. Because the educational landscape today increasingly focusses on design for learning to create a sustainable way of learning, multimodal forms of representation could provide students better opportunities to learn and could partly blend into today's digital structures. In educational contexts, visual expressions have great potential as didactic tools in all subjects (Häggström & Örtengren, 2017), and the need exists in higher education to support students in learning through various representations, text, pictures, sounds and learning by doing (Bell & Hoston, 2021). Academic studies and academic work increasingly require multimodal competencies, and universities and colleges should be able to offer them to students and researchers (Agostinho, 2011). That visualization has a given place in academic teaching. Visual learning tools are increasingly interesting to teaching institutions as the visual representation is an alternative way to communicate knowledge to the students. Examples of visual learning tools are, among others, Sensavis Visual Learning tool that visualizes 2D and 3D models to enhance learning in subject such as mathematics, chemistry, anatomy, and more; and GeoGebra that is an interactive tool to learn mathematics by visualizing geometry and graphs. To our knowledge, there is no prior learning tool within the specific context of research methodology benefitting visual communication and utilizing successive learning in layers and interactive questions. Learning is clarified by Biljon & Osei-Bryson (2020), and they point to the communicative power that visualizations have in academic writing in particular. Furthermore, research requires that new technologies with modern teaching methods are implemented in higher education (Fushova & Korenova, 2019). With our multidisciplinary research background, we have identified a research gap regarding two aspects: the design of a teaching aid that gives students more opportunities to learn about the research process and research that describes this type of interdisciplinary development work.

Our intention was to design and evaluate an interactive learning tool to facilitate, strengthen and improve students' learning regarding scientific methodology. To improve students' learning, we targeted their academic literacy (cf. McWilliams & Allan, 2014). The learning tool should include visual support for learning in the form of representative illustrations and visualizations of the research process's structural constitution but also include a dynamic presentation and learning in several layers. The dynamic presentation should include a framework of the complete research process, describing connections and order between the process steps and their boundary conditions as well as their respective meanings and associated actions. The pedagogical idea was to give students insights into the organised steps of the research process through problem-based learning in the form of targeted tasks linked to the respective process steps and boundary conditions, by which the students describe their own research and build the research process in its entirety.

This study's objectives are (i) to create a learning tool useful both as a supplement in teaching and as a tool for research design for the individual student and (ii) to continuously evaluate the artefact considering both its pedagogical and technical aspects to create a useful learning tool and thereby enhance students' academic literacy.

The research question was.

Q1. How can a research design be implemented to design and evaluate an interactive, ubiquitous visualization-based learning tool for scientific methods?

Q2. What are the important pedagogical, and technical considerations in designing and evaluating a useful learning tool?

In this article, we report the answer to the research question during two years of development work. The study's results can be useful to students, educators, system developers and teaching-aid manufacturers.

1.1 Definitions:

Academic literacy refers to being proficient in reading and writing about academic subjects and includes summarizing, comparing, contrasting, and synthesizing ideas and related information from a wide variety of sources (www.tophat.com/glossary). According to Jefferys et al. (2018), academic literacies are skills, and "these literacies are viewed as sets of practice, the focus shifts towards ways in which students learn to participate and make meaning within an academic context*"* (p. 81).

Design Science Research (DSR) is *"*a problem-solving paradigm that seeks to enhance human knowledge via the creation of innovative artifacts" (Brocke et al., 2020, p. 1). The goal is to extend boundaries between humans and organizations by designing new innovative artefacts and to generate knowledge about how these artefacts could be constructed. In this study, one aim was to construct a learning tool built on visual representations to teach scientific methods.

Visual representations are central in this study, and our definition is in line with that of Ingerman et al., (2009): *"a model that represents a phenomenon, situation or constructs (or parts of them) in a particular way, namely bringing certain aspects to the fore while allowing other aspects to recede in the background"* (p. 3). In this study, we use pictograms and flowcharts as models to represent crucial steps and processes in the research process.

2 Some aspects of previous research

Capturing previous research in the field is not easy. A search in the Google Scholar, Primo SCOPUS and Science Direct 20,210,924, 20,220,322 databases using the keywords *visualization* AND *education science* yielded between 180,660 hits and 225,302 hits. This volume gives us a clue that the chosen focus on this research and development work is highly relevant. Surprisingly few texts focussed on general pedagogy, education or general didactics, and not on the development of a digital teaching tool for higher education, so the present description of previous research is only a cross-section of such research we have found relevant to the research question.

Overall, researchers seem to agree that visualizations facilitate learning for many students because they create motivation and generate focus (Jägerskog, 2020). The relationship between visual representations and learning improvements, such as study results and retention, is not self-evident because they simplify a complex reality (Sandahl, 2015) and should be considered an integrative part of the whole content/text. Although visualizations seem to be useful, it is not obvious that they are interpreted and understood correctly; therefore, more research is necessary on how visualizations affect understanding and learning (Donohoe & Costello, 2020). Anyhow, many studies focus on how students understand the representations, but few concern comparisons between various visual representations, according to Jägerskog (2020). In addition, different levels or perspectives on and within visualization are presented by Biljon & Osei-Bryson (2020), who show how visualizations can strengthen understanding but also support discovery and the transference of knowledge. These researchers believe that knowledge visualizations, especially, have a communicative power.

A review of several abstracts showed that many of the texts concerned school subjects, such as mathematics, science, art and geography, as well as subject disciplines, such as biology (cf. Fushova & Korenova, 2019), chemistry, computer science (cf. Dolgolopovas et al., 2020) and medicine (cf. Levett-Jones et al., 2012). Firat and Laramee (2018) confirmed these topics when they classified pedagogical visualization research papers, and the science subjects were dominant. Other researchers, such as Wong et al., (2021), examined interactions between and in student groups via visualizations.

Specifically, regarding design studies, Dahl et al., (2001) showed at the beginning of the century that visualizations are important in concept designs for both the designer and the user. They connect memory to imagination and affect the process and the outcomes. The researchers concluded, *"*Combination with imagination-based visualization led to designs that were significantly more appealing to the costumer" (Dahl et al. 2021, p. 27).

A student perspective on using and improving technology-enhanced learning (TEL) in higher education is described by Kennedy & Dunn (2018), who concluded that students require more consistent and frequent use of TEL in lectures and outside academia. Kennedy & Dunn (2018) recommended that TEL should be used consistently across learning modules and course-wide content. Suarez et al., (2018) exemplify a novel strategy based on technological watch (TW) to identify the state-of-the-art techniques of software development projects.

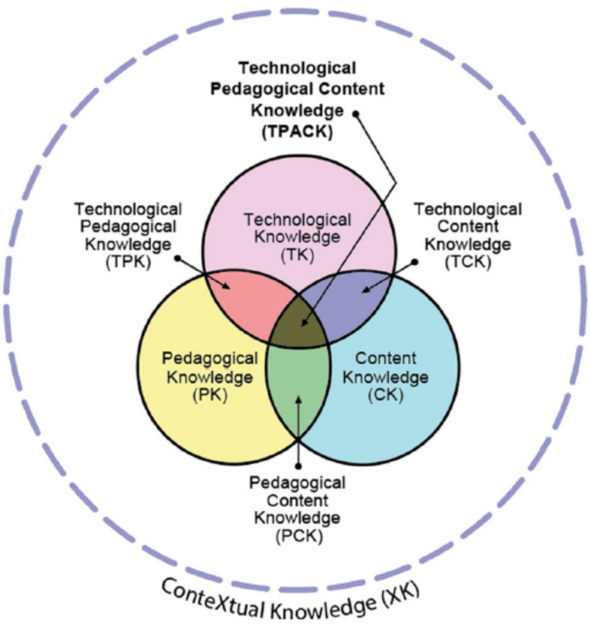
Although pedagogy and education in general are not so prominent in previous studies, Firat and Laramee (2018) claimed that "graphic design and visualization are becoming fundamental components of education. The use of advanced visual design in pedagogy is growing and evolving rapidly*"* (p. 92).

3 Theoretical frameworks

In this study, we framed the results using the TPACK framework explains what aspects of knowledge may be operational when teachers integrate technologies for teaching and learning (see Fig. 1). This framework, which focuses on technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), offers a productive approach for teachers in implementing educational technology. It is useful in analysing teachers' reasoning, knowledge, educational designs, practical use of digital technologies and, in this study, the use of technologies for visual learning support and visualization.

It is not enough to add technology to teaching activities. To achieve positive effects for learning, the teacher needs knowledge of how technology can contribute pedagogically, technological pedagogical knowledge (TPK), how the subject can be treated with technical aids, technological content knowledge (TCK) and how they can present the subject pedagogically, pedagogical content knowledge, (PCK). These considerations overlap in a Venn diagram (see Fig. 1). Three key concepts in the use of the model are the affordances and constraints of technology, the fact that a certain technology can enable and support a certain activity and that it can counteract others. The larger, dotted circle in Fig. 1 represents the context in which learning and teaching take place. The framework is useful in analysing teachers' reasoning, knowledge, educational designs, practical use of digital technologies and, in this study, the use of technologies for visualisation. Research on the context (in this model) has been limited and has not provided enough practice-based evidence (Kelly, 2010; Foulger et al., 2021) showed the important implications associated with context and technology in higher education.

Fig. 1 TPACK framework as of 2019 (Mishra, 2019, p. 77)



4 Method

4.1 Design science research

Our aim in this study is to build and evaluate an interactive learning tool based on visual support and visualizations of structured knowledge, which is why we employed DSR, which typically involves the creation of an artefact and/or design theory as a means to improve the current state of practice and existing research knowledge (Baskerville et al., 2018). We also aimed to answer questions about the artefact in its environment (Johannesson & Perjons, 2014). DSR starts with a practical problem, an undesirable state, an existing gap between the current and desirable states or a needed change or improvement. It consists of an overarching model with two activities, build and evaluate. These activities are performed iteratively before the final artefact is produced (Hevner et al., 2004). The iteration implies that the building and evaluation processes contains several steps (see Fig. 2), which are repeated until the final design for the artefact has been achieved (Johannesson & Perjons, 2014). The first three blocks require building, and the last two require evaluation. We have chosen such an iterative research approach that is used in design science, which, according to Oates (2006), is called design and creation.

Design science research can be described as a waterfall method with separate research designs/methods for each step (Johannesson & Perjons, 2014). In Fig. 2, we illustrate this DSR framework with research designs for MethodViz. The chosen framework consists of the five steps: Explicate problem, Requirements, Design & development, Demonstrate, and Evaluate. We explicitly added iterations of the development. The blue boxes are the main activities, and the white boxes are the strategies for building the learning tool and collecting empirical data.

4.2 Assessments

In the iterative evaluations, we used diagnostic assessment (focus group including teachers and experts), formative assessment (interviews with illustrator, web design-

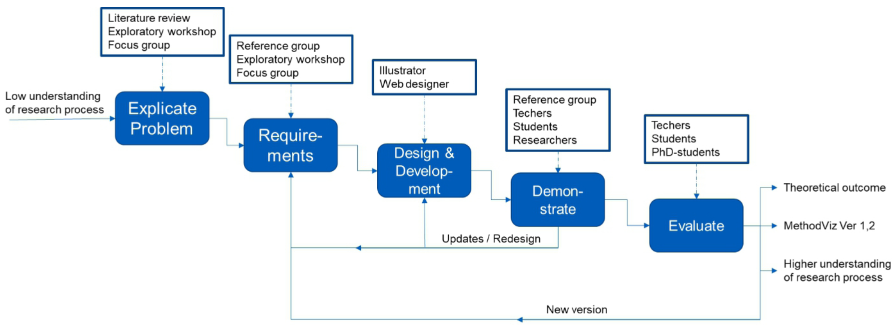


Fig. 2 Summary of the DSR process employed when designing and developing MethodViz

Table 1 Research activities, empirical data and informant, and compilation of empirical data

Activities	Empirical data & informants	Compilation of empirical datad data
Literature review of academic literature During two months, research assistants examined the most used research literature at the university.	**8,000 text pages in 50 books**	**Report** Boström & Sjöström, 2021
Two exploratory workshops The workshops aimed to enhance stronger relations of reciprocity between researchers and educators/teachers in the emerging field. These were carried out in the first and second stages of the research process	**Research team, Experts** Two protocols from the workshops. Text and process-pictures.	**Prototype** Prototype of learning tools in the form of PowerPoint images.
Three focus group discussions Through focus group discussions, the aim was to gain an in-depth understanding of the issues. Two focus group discussions were carried out in the first stage, and a third on the second stage of the research process.	**Research team** Notes from all researchers in workshops, 18 pages A4-text	**Field notes** Summary of the notes to about four pages of cohesive text.
Reference group discussions and written feedback The reference group participated in two meetings, during the second and fourth steps in the process, but they also gave written comments on four occasions. The written feedback was given when prototypes had been developed and we wanted answers to specific questions.	**Reference group** Oral comments were recorded to 10 pages text, written feedback consisted of 10 pages text.	**Field notes, summary of written feedback** Summary of the discussions and notes to about four pages of cohesive text.
Illustrator and web designer, instructions and interviews. From the second stage until the evaluation, the web designer and the illustrator were involved in discussions about the design. When the work was completed, they were both interviewed with semi-structured questions.	**Illustrator and web designs** Eight meetings with the web designer and the illustrator. Conversations and instructions. Individual interviews with semi-structured questions.	**Summary of discussions and interviews** Summary of the discussions to about four pages of cohesive text. Interviews analysed with content analysis.
Researchers-discussions Throughout the process, the researchers discussed the development of the learning tool at monthly meetings.	**Four researchers** Notes and protocols for two years, 20 meetings.	**Summary of feedback** Summary of the discussions to about ten pages of cohesive text.
Students, web survey, group discussions Five student groups (in total 150 students), three during design &development phase and two during evaluations phase, evaluated the learning tool via an online survey comprising eight questions and an oral evaluation in groups.	**Five student groups** Notes on the oral group evaluations. Summary from web-survey.	**Summary of feedback** Summary of the oral evaluations to about four pages. Web-surveys, overview and summary, ten pages text.
Teachers in classes – feedback Five teachers, three during design &development phase and two during evaluations phase, evaluated the learning tool via an oral evaluation	**Five teachers** Notes on the oral individual evaluations.	**Summary of feedback** Summary of the oral evaluations to about four pages
PhD students - web survey, group discussions		**Summary of feedback**
50 project meetings Meeting once or twice a month. Discussions about the whole process.	**Project leaders** Notes on the project meetings	**Notes** Summary of the notes for two and a half years, about 25 pages.

ers, experts, students and teachers) and summative assessment (students and teachers). We selected these assessment strategies in accordance with Shneiderman and Plaisant's (2006) recommendations for evaluation of visualization tools. We analysed data from evaluations through a hybrid content analysis in an iterative process (Fereday & Muir-Cochrane, 2006) to assure quality development of the artefact. We thus applied the content analysis in the hybrid workflow (cf. Braun & Clarke, 2019).

The table 1 below illustrates various activities to collect the empirical data and the form of compilation of the empirical data.

5 Analysis & results

In this chapter, we report the analysis and results for each activity based on the empirical data.

5.1 Explicate problem

The activity phase is about investigating and analyzing the practical problem and formulating the problem of significance, not only for local practice but also for general interest. The problem in this study was obvious concerning previous evaluations in higher education concerning scientific approaches in writing a thesis and conducting a review of scientific literature. We have more students today than before, but varying experiences of academic studies. To meet this diversity of students, different forms of knowledge representation are needed. If the teaching is based primarily on textbooks that include mostly written text and teachers' lectures, it will disadvantage many students whose learning strategies are not primarily visual or auditory (Boström & Löfquist, 2012).

Complementary learning tools for books are thus needed. The problem is both democratic and pedagogical. The empirical data we used in this activity was the literature review (Boström & Sjöström, 2021), but we also used one exploratory workshop and focus group discussions. In this stage, we discussed in detail which pedagogical knowledge (PK) and content knowledge (CK) would be included in the learning tool and how the technological knowledge (TK) would support the content. This activity resulted in an overview of a tentative prototype of the research process.

The decisive step in this activity was the exploratory workshop. The researchers stayed as objective as possible to capture and describe the problem and arrive at the best possible overview. Diagnostic assessment of the problem was addressed in workshops and focus groups.

5.2 Define requirements

Requirements should describe the expected performance and limitations set on the solution or the external constraints on the solution "outline" as a creative process. The problem is transformed into demands of the artefact. Defined requirements in this activity phase include functionality, structure, and environmental aspects. In this stage detailed discussions were mainly about the technological knowledge (TC) in combination with (TPC). The empirical data used in this activity was first input from the references group and the adjustments to the prototype. Then a second exploratory workshop was conducted, followed by focus group discussions with the research team. These discussions focused mostly on the core based on the TPACK model. The ability of different technical solutions to fulfil the requirements was discussed in order to assure a successful outcome. At the end of this activity, we reached a consensus on the artefact's structure and content. In this step, diagnostic assessment was also addressed in focus groups. Figure 3 is an illustration of the results of the requirements. The hierarchical learning structure in several layers, which imply a successive refinement of learning, is illustrated.

More precisely, our intention concerning basic learning, was to get the structure of the whole research process to be synchronized and logical and get the illustrations to be as clear as possible. In this step, it was discussed how the illustrations would depict CK as well as possible. Furthermore, we had a requirement that pop-ups should be displayed with an overview description of the content. Finally, we had a requirement that students' learning should be deepened through theoretical descriptions of the process, combined with interactive personal questioning. These requirements were constantly discussed and re-evaluated with the web –programmer. At this stage, the core of the TPACK-model was incorporated.

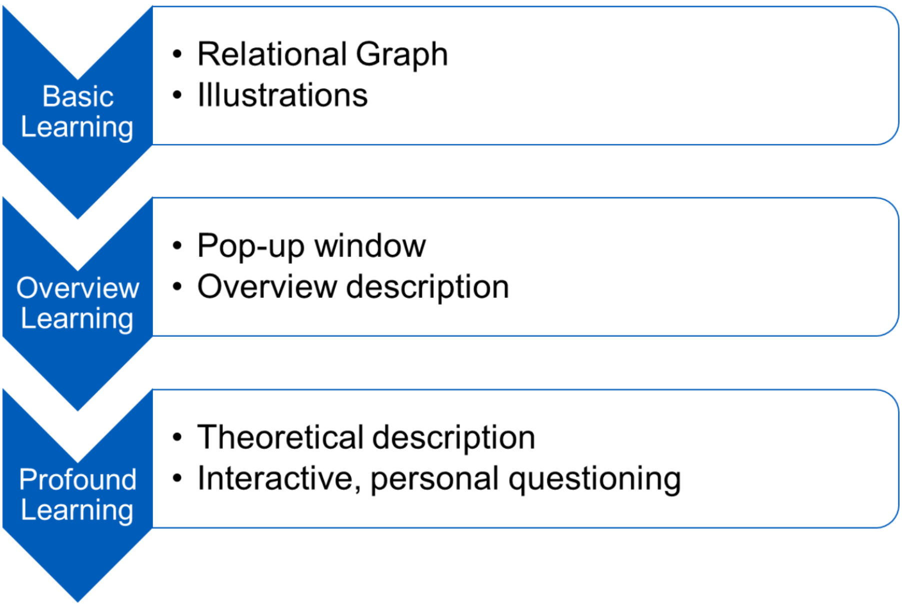


Fig. 3 Design of a hierarchical learning structure in several layers

5.3 Design & Development

In this activity, the artefact that addresses the problem was created. For this learning tool (the artefact), we used a programmer and an illustrator to meet the defined requirements in the creation of the artefact. In this situation, the discussions were mostly about the combination of technical and pedagogical issues (TPK). The programmer proceeded from a visual description of the whole artefact and the researchers' explanations and then implemented the technical requirements. The illustrator was commissioned to create a complete picture of the process and a pictogram for the important steps in the process. Together with the research team, the execution was discussed several times.

In interviews with these key staff members, the following strategies emerged. *The illustrator* emphasised that her starting point for the pictograms was that they would reinforce the text that was communicated. The text and pictogram should communicate the same content in the best possible way. The pictograms would also support and strengthen students' retention. The illustrator made proposals for each pictogram based on what she believed they communicated and signalled. The pictograms were discussed with the research group, and some adjustments were made. The illustrator also designed the overall picture of the learning tool. The first consideration was that the page would be aesthetically pleasing, and that colours and shapes would complement each other but in some cases be distinctive. For example, the illustrator used squares for factors that came from outside the research process, for example the pictogram such as from society, and ovals represent aspects that eventually affected the process.

The programmer emphasised that a complex image formed the basis of the website. The MethodViz software is full-stack application created using an object-oriented PHP architecture. It employs a virtual Windows-server with an Apache webserver and a MySQL database-server. Libraries used include a Bootstrap (CSS library), jQueary for certain JavaScript functionality, and TinyMSC to make neat interaction boxes in the subviews.

The graphic layout had to be iterative, and the progression should be visible. An important problem for him to solve was making the graphic image interactive but also scalable. He solved that problem by building a coordinate system in which the whole image was split into smaller pieces and each smaller image was entered into the coordinate system. The working process was based on conversations with the research team and the illustrator. The conversations shared a common thread in which everyone focused the overall project and then broke everything down into smaller parts regarding content, functionality, and priority. A strength of the work was that we had a clear goal, a clear sketch, and well-formulated goals, which specifically facilitated the programmer´s work. Areas for improvement were more of a technical nature, namely, to create interfaces for editing website content and delimitation of what should be included in the responsive website. The first version of the website focused on layout and lightweight functionality for desktops but also included basic layout for mobile tools. Collaboration with the illustrator was also an important part of the creation process. For example, it was important to understand that different computers have different resolutions, which will display images differently. Changes can also occur in texts when they are translated to different languages. The key to a successful collaboration is to work together to find the best possible solution and be open to feedback.

Text information entered by the user is stored in a database, in which each user has an item for each textbox in the tool. The text is kept between user access sessions and can also be downloaded into a word document for further processing. The database for MethodViz was designed to keep information about its users and their respective interaction inputs. First there is a table defining the users, which stores a unique user ID, e-mail address, password, first and last name, timestamp for creation, and whether the user is admin or not. For the rest, the database follows the hierarchical structure such that each module (e.g. *Current knowledge*, *Problem area*, etc.) has its own table. Modules requiring several interaction inputs have a table for each individual input. The tables have a unique ID, user input text, a timestamp for creation and last update, and a project ID. The latter links to an individual project belonging to a user and is defined by a separate table that contains project ID, user ID, project name, and timestamp for creation and last update. The project table enables a user to use MethodViz for several different research projects.

In this step, a combination of formative, diagnostic and summative assessments were carried out. The purpose of the formative assessments was to create improvements in the artefact's development and design. We used interviews, discussions and simple surveys.

5.4 Demonstrate

The fourth activity in the DSR design is to demonstrate the artefact in real-life settings. It is also called "proof-of-concept" because the artefact's feasibility will be proved. In this activity, the reference group, students, teachers, and researchers, tested and gave feedback regarding the learning tool, using formative assessments. In this step, all aspects were thoroughly examined by the TPACK model. Several adjustments and improvements were made based on the feedback. For example, a marking was needed to indicate where they would start in the research process. No major changes were made to the original artefact except that the research process became an oval instead of a circle because further steps of the research process were added.

As images are directly processed by our long-term memory, we have introduced two kinds of visualizations in the learning tool. Firstly, we have described the interrelations between the steps of the research process with a relational graph. These interrelations can be seen as a linear process with several feedback loops. Our choice was, however, a circular format in order to emphasise the cycle of research being an accumulation of new knowledge to existing knowledge, which then is the basis for future research. The many possible feedback loops within the research process were omitted because the visual impression with be unnecessary complex and not supporting an easy access and learning of the process' main parts. In the present version, feedbacks were left to be described in texts and to be emphasised by a teacher. Secondly, we have introduced pictograms to each step of the research process. The pictograms have been designed to give a straightforward association with the process step, and been placed both in the relational graph of the research process, as well as on the sub-pages describing each step in detail. The aim was to create a direct link with the students' long-term memory and so facilitate the learning.

In this activity, approximately 200 students and 20 teachers and researches were involved. We needed such a large number of testers because the testing was combined with the evaluation step to assess the artefact's usability with respect to learning research methods. The testing was firstly introduced by demonstrating the functionality of the learning tool. Then the test persons were given access to the tool to use it as desired, only using instructions in form of a short overview as part of the learning tool. The assessment for the Demonstrate step consisted of a number of open questions for suggested improvements. The results led to new requirements, such as including the oval format as the process was adapted with further steps.

5.5 Evaluate

The last activity was to evaluate the artefact and determine whether it fulfilled the requirements and could solve the practical problem. The project leader carried out a first evaluation checking the functionality with respect to the requirements. Test persons followed the procedure presented in Sect. 5.4. Approximately 200 undergraduate students, 10 PhD students and 10 teachers evaluated the learning tool via either a web survey or discussions. The web survey considered all aspects based on the TPACK model. We used summative tests to assess the learning tool's final functionality and usability with respect to learning research methods via web surveys. This learning resource has in its various prototypes been evaluated above all with quantitative data but also descriptive statistics. Through conversations, interviews and web surveys, students, experts and teachers continuously have given us feedback on the learning resource. The qualitative data has been analyzed with thematic content analysis. Thus, we have been able to take part in their personal perceptions of the learning tool. The quantitative data has given us indications of whether the various parts of the learning tool have worked at group level for the students. For example, they estimated how they understood the texts or tasks in the form of five-point Lickert scale and open comments. We have seen how different parts of the tool have functioned.

An overwhelming majority believed that this learning tool was long overdue and much needed in academic studies. The overall conclusion in our summary of the evaluations was that the artefact would contribute to a different way of understanding the research process.

5.6 In summary

As the researchers who developed this learning tool, we can first and foremost state that this research process has taken time. In a process that combines creative thinking and the scientific method, it is important to keep the structure of the work together and to document all activities thoroughly. The DSR model in Fig. 2 is a fundamental formalisation of the design and development process. It gives the process structure and elucidates the relationship between an appropriate research strategy and its outcomes. Figure 4 shows the main page of the learning tool. The design process and the identified hierarchical structure (see Fig. 4) led to a relational graph of the research

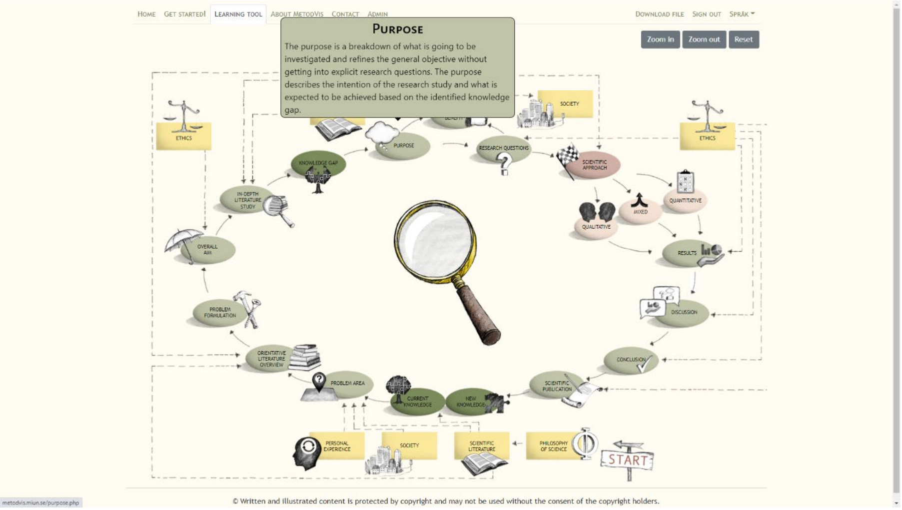


Fig. 4 The front page of the learning tool

process with representative illustrations, where refined knowledge is gained through (1) pop-up windows containing familiarizing descriptions of the step and (2) a profound description in a sub-page. We have chosen the general picture more circular (oval) and not rectilinear because we see the research process as holistic. Then we have chosen a shorter summary of each aspect, which the students get if they hover over words. Then we have each aspect summarized on about one page (left). That text is more formal. On the right side is an exercise assignment that is written more personally to the student.

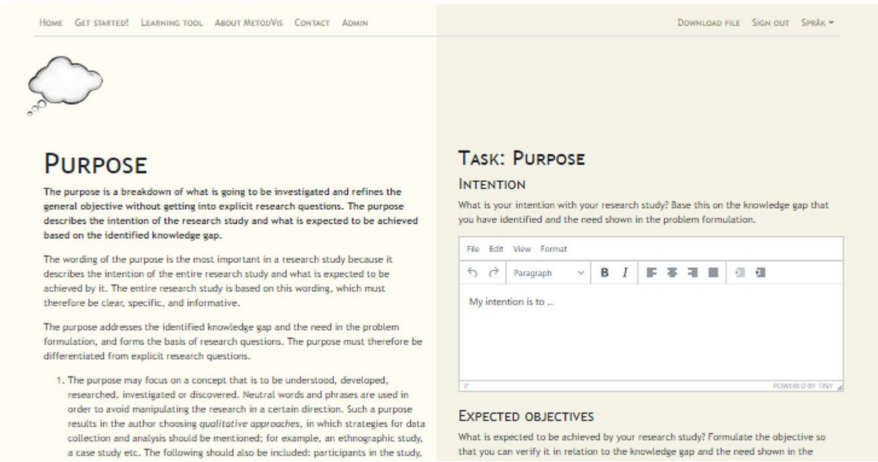


Fig. 5 Example of a sub-page

Students start at the box philosophy of science where there is a short text about its contents followed by some questions to answer. The students save their answers in a database. And then they continue to the next yellow box, scientific literature to get an insight into the specific content. To each step there is also a pictogram illustrating the core of the content. The students continue through the oval and at some stages they might go back and complement their notes, for example the boxes ethics or society. At the end they will have the most important aspects of their chosen content to be able to write the thesis in a logical way.

The sub-page contains a theoretical description of the research step on the left and questions for interaction and relation to the student's own research on the right (Fig. 5).

5.7 Methodological considerations

All research designs have their strengths and weaknesses. Our research strategy in this study has been a kind of action research. Our intention was to produce an artefact (learning tool) that addresses a practical problem in a real-word setting. We, the research team, including the illustrator and the programmers, all participated in the changes. The key activities can be described as cyclical processes. They major concerns in this strategy are weak generalizability and lack of impartiality (Johannessen & Pajons, 2014). The scientific paradigm is often a pragmatic worldview, which naturally leads to weak generalizability. To maintain the scientific approach, we included a reference group with researchers from various disciplines with expertise in various scientific traditions. With these experts' help, we were able to manage the risk of impartiality. We are also well aware that the results cannot be generalised but that they can inspire other researchers with similar problems.

6 Conclusions

In this section, we will conclude the research process and finally reflect on the selected frameworks.

6.1 From the research idea to the artefact

The stated problem that formed the basis of this research project was the students' difficulties in understanding the scientific process when they write a thesis as well as the lack of learning tools available in the field. Previous studies have shown a great interest in interactive learning tools in higher education (Kennedy & Dunn, 2018; Suarez et al., 2018) as well as the need for visualizations in education (Firat & Laramee, 2018). The project's overall purpose was therefore to design and evaluate an interactive learning tool to facilitate, strengthen and improve the learning of the core of research, namely scientific methods. To answer the research question, which was how to design and evaluate an interactive visualization-based learning tool for scientific methods that could be used independently of time and space, we used a DSR method (cf. Johannesson & Perjons, 2014), with activities are performed iteratively before producing the final artefact (Hevner et al., 2004).

First, a learning tool about scientific methods was produced that offers students alternative forms of representations of the subject's content. We designed and evaluated an interactive visualization-based learning tool for scientific methods. Each activity in the development process was clearly documented to develop and improve the artefact in accordance with the recommendations made in the DSR (cf. Baskerville et al., 2018; Johannesson & Perjons, 2014; Oates, 2006). Using various iterative evaluations, including diagnostic, formative and summative assessment, important updates and redesigns were implemented. With clear instructions for and discussions with the programmer and the illustrator, we established the technical solutions, layout and visual components.

Second, from a pedagogical perspective, this is a unique educational tool offering students an overview of the totality of the research process, where connections and order between the process's steps and boundary conditions, such as philosophy of science, theory, society and the researcher themselves, are presented. We therefore created an educational tool for higher education requested by, among others, Bell & Hoston 2021.

Third, this is a project that we can call technology-supported learning, which aims to take advantage of and develop the possibilities of digitalization requested by, among others, Kennedy & Dunn (2018). This as an important step in strengthening, developing and supplementing the integrated knowledge environment that is emerging in the borderland between interactions, visual pedagogy and visualizations. Furthermore, this study will contribute to the field of design for learning, where a learning tool is designed and developed at the interface between visual pedagogy, visualization, digitization, and technology with pedagogical frameworks for evaluation of usability, development, and technological improvements.

The result in a longer perspective, whether this artefact will support students' learning and retention, will be an upcoming project. Whether more flexible ways of learning scientific methods will counteract dropouts and increase the throughput of education as well as lead to better quality and more publications is an important research question. Another question is whether this artefact could create positive changes in motivation, learning, commitment and scientific results for students. Another important question is whether this learning tooltool could strengthen and develop digital studies and working environments for students and teachers. We intend for this artefact to serve as a supplement to traditional teaching materials, and we see the possibility that students can use it in their home environment, as well.

6.2 About theoretical framing

We previously framed this study using theoretical framework, the TPACK, gives us an understanding of the individual and the collective competencies that have contributed to this learning tool as well as insights into what future users need to be able to do. With the combined academic competence, we were able to design and develop the learning tool, and we partly learned to understand others' fields of competence. With this synergy effect, we reached the middle of the TPACK model. We can also state that large parts of our conversations and discussions concerned content knowledge and contextual knowledge. We believe that with this study, we have made an important knowledge contribution to contextual knowledge, which Fougler et al. (2021) and Kelly (2010) requested.

6.3 In summary

The DSR methodology we employed in the project entailed the application of several research strategies per step and resulted in a learning tool well-founded in existing research and teachers' and students' expectations. Therefore, it is an effective approach in design for learning. A result of this design process is the use of representative illustrations and visualizations, which have been shown to be useful tools in the learning process. The integrated hierarchical learning structure seems reasonable for the learning process but has not been evaluated in detail and requires further investigation. The theoretical frameworks establish reasonable evolvement and use of technology, and they show the potential for further development. Also, interaction as part of the learning tool involves students in their own contexts and thus relates to student-centred learning and project-based learning, which have both been shown as successful approaches for learning (Kennedy & Dunn, 2018). MethodViz is based on visual communication and uses a relational graph for describing the research process, as well as pictograms to establish connections between text and visual representation, and thereby enhance the remembrance of each part of the research process. Future versions of MethodViz are foreseen to include interactive visualizations to envision details of research methods. What remains is to improve and develop this learning resource, for example with different, specific methodological approaches, and to test it on a larger scale.

Acknowledgements We thank the reference-group, the teachers, students, the programmers and illustrator for good teamwork.

Funding Open access funding provided by Mid Sweden University.

Data Availability 'Not applicable'.

Declarations

Conflict of interest None.

References

Agostinho, S. (2011). The use of a visual learning design representation to support the design process of teaching in higher education. *Australian Journal of Educational Technology*, *27*(6), 961–978

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., & Matti Rossi, M. (2018). Design Science Research Contributions: Finding a Balance between Artifact and Theory,". *Journal of the Association for Information Systems*, *19*(5), 358–376. https://aisel.aisnet.org/jais/vol19/iss5/3

Bell, S., & Hoston, B. (2021). Where is the support? Learning support for multimodal digital writing assignments by writing centres in Canadian higher education. *The Canadian Journal for the Scholarship of Teaching and Learning*, *12*(1), 1–20. https://doi.org/10.5206/cjsotl-rcacea.2021.1.10780

Biljon, J., & Osei-Bryson, K. M. (2020). The communicative power of knowledge visualizations in mobilizing information and communication technology research. *Information and Technology Development*, *26*(4), 637–652

Boström, L., & Löfquist, S. (2012). Students Study Results, A question of Styles, Strategies, or (mis) Matching? *Journal of Studies in Education*, *2*(4), 79–97. https://doi.org/10.5296/jse.v2i4.2410

Boström, L. & Sjöström, M. (2021). Slutrapport 2021 för ALP-projektet MetodVis 1.0. [Final report 2021 for the ALP project MethodViz 1.0.]. Mid Sweden University

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport Exercise and Health*, *11*(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Brocke, J., Hevner, A., & Maedche, A. (2020). Introduction to Design Science Research. In J. Brocke, A. Hevner, & A. Maedche (Eds.), *Design science research. Cases* (pp. 1–13). Springer

Dahl, D., Chattopadhyay, A., & Gorn, G. (2001). The importance of visualization in concept design. *Design Studies*, *22*(1), 5–26. https://doi.org/10.1016/S0142-694X(99)00028-9

Ding, L., Wei, X., & Liu, X. (2016a). Variations in university students' scientific reasoning skills across majors, years, and types of institutions. *Research Science Education*, *46*, 613–632

Ding, L., Wei, X., & Mollohan, K. (2016b). Does higher education improve student scientific reasoning skills? *International Journal of Science and Math Education*, *14*, 619–634

Dolgolopovas, V., Dagiené, V., & Jevsikova, T. (2020). Methodological guidelines for the design and integration of software learning objects for scientific programming education. *Hindawi Scientific programming*, 1–19. DOI:https://doi.org/10.1155/2020/6807515

Donohoe, D., & Costello, E. (2020). Data visualisation literacy in higher education: An exploratory study of understanding of a learning dashboard tool. *International Journal of Emerging Technologies in Learning*, *15*(17), 115–126

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, *5*(1), 80–92. https://doi.org/10.1177/160940690600500107

Fırat, E., & Laramee, R. (2018). Towards a survey of interactive visualization for education. *Computer Graphics & Visual Computing*, 91–101. https://doi.org/10.2312/cgvc.20181211

Foulger, T., Buss, R., & Su, M. (2021). The IT² survey: Contextual knowledge (XK) influences on teacher candidates' intention to integrate technology. *Educational Technology Research and Development*, vol. 69, pp. 2729–2760. https://doi.org/10.1007/s11423-021-10033-4

Fushova, M., & Korenova, L. (2019). Visualization in basic science and engineering education of future primary school teachers in human biology education using augmented reality. *European Journal of Contemporary Education*, *8*(1), 92–102. doi: https://doi.org/10.13187/ejced.2019.1.92

Hevner, A. R. (2007). A three cycle view of design science research. *Scandinavian Journal of Information Systems*, *19*(2), 87–92. 4http://aisel.aisnet.org/sjis/vol19/iss2/4

Häggström, M., & Örtengren, H. (2017). Visuella uttryck som didaktiska verktyg [Visual expressions as didactic tools]. In M. Häggström, & H. Örtengren (Eds.), *Visuell kunskap för multimodalt lärande* (pp. 9–10). Studentlitteratur

Ingerman, Å., Lindberg, V., & Marshall, D. (2009). The learners experience of variation. Follow the students' threads in learning physics in computer simulation sessions. *Instructional Science*, *37*(3), 273–292

Jefferies, D., McNally, S., Roberts, K., Wallace, A., Stunden, S., D'Souza, S., & Glew, P. (2018). The importance of academic literacy for undergraduate nursing students and its relationship to future professional clinical practice: A systematic review. *Nurse Education Today*, *60*, 84–91

Jägerskog, A. S. (2020). *Making possible by making visible. Learning through visual representations in social science* [Unpublished doctoral dissertation]. Stockholm University

Kelly, M. A. (2010). Technology pedagogical content knowledge (TPACK): A content analysis of 2006–2009 print journal articles. *Society for Information Technology & Teacher Education International Conference* (pp. 3880–3888). Association for the Advancement of Computing in Education, San Diego, CA, United States. https://www.learntechlib.org/primary/p/33985/

Kennedy, M., & Dunn, T. J. (2018). Improving the use of technology enhanced learning environments in higher education in the UK: A qualitative visualization of student´s views. *Contemporary Educational Technology*, *9*(1), 76–89

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60–70

Johannesson, P., & Perjons, E. (2014). *An introduction to design science*. Springer

Levett-Jones, T., Gilligan, C., Lapkin, S., & Hoffman, K. (2012). Interprofessional education for the quality use of medicines: Designing authentic multimedia learning tools. *Nurse Education Today*, *32*, 934–938

McWilliams, R., & Allan, Q. (2014). Embedding academic literacy skills: Towards a best practice model. *Journal of University Teaching & Learning Practice*, *11*(3), 120. http://ro.uow.edu.au/jutlp/vol11/iss3/8

Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education*, *35*(2), 77. https://doi.org/10.1080/21532974.2019.1588611

Oates, B. (2006). *Researching Information Systems and Computing*. SAGE

Sandahl, J. (2015). Preparing for citizenship: The value of second order thinking concepts in social science education. *Journal of Social Science Education*, *14*(1), 18–29

Shneiderman, B., & Plaisant, C. (May 2006). Strategies for evaluation visualization tools: Multi-dimensional in-depth long-term case studies. *The 2006 AVI Workshop on Beyond Time and Errors: Novel Evaluation Methods for Information Visualization*. https://doi.org/10.1145/1168149.1168158

Suarez, C., Bucheli, V., Restrepo-Calle, F., & Gonzalez, F. (2018). A Strategy Based on Technological Maps for the Identification of the State-of-the-Art Techniques in Software Development Projects: Virtual Judge Projects as a Case Study. *Advances in Computing*, 338–354. https://doi.org/10.1007/978-3-319-98998-3_27. https://link.springer.com/chapter/

Universitets- och kanslersämbetet (UKÄ (2019). [Swedish Higher Education Authority]. (UKÄ). https://www.uka.se/om-oss/aktuellt/nyheter/2019-04-16

Wong, G., Li, Y. K., & Lai, X. (2021). Visualizing the learning patterns of topic-based social interaction in online discussion forums: An exploratory study. *Education Technology Research development*, *69*, 2813–2843

www.tophat.com/glossary

Author 1&Author 2, (2021).