Interaction Design and Architecture(s) Journal - IxD&A, N.42, 2019, pp. 11 - 28

Experience matters: Bridging the gap between experience- and functionality-driven design in technology-enhanced learning

Björn Rohles[1], Vincent Koenig[1], Antoine Fischbach[2], Franck Amadieu[3]

[1] Cognitive Science and Assessment Institute, University of Luxembourg, 11 Porte des Sciences, L-4366 Esch-sur-Alzette

[2] Luxembourg Centre for Educational Testing, University of Luxembourg, 11 Porte des Sciences, L-4366 Esch-sur-Alzette

[3] Laboratoire Cognition, Langues, Langage, Ergonomie, Université Toulouse Jean Jaurès, 5 Allées A. Machado, F-31058 Toulouse

{bjorn.rohles}@uni.lu

Abstract. With the growing importance of digital technologies in learning and assessment, it is important to consider user experience (UX) to ensure that tools provide useful functionalities for learning without overwhelming users, to motivate users and ensure that they have positive learning experiences, and to allow users to realize their potential with the help of technology. Building on a case study of concept mapping for technology-enhanced learning, we combined experience-driven and functionality-driven approaches in co-design sessions in four school classes (67 students). We investigated the anticipated experiences that students imagined as well as the functionalities and characteristics they expected. We found that combining experience-driven and functionality-driven approaches is a valuable method for improving technology-enhanced learning.

Keywords: Co-Design, Concept Maps, User Experience, Experience-Driven Design

1 Introduction

Education today faces tremendous challenges posed by societal, economic, ecological, and technological change. Learning and assessment are increasingly mediated and shaped by digital technology. Technology in education is at the core of technology-enhanced learning (TEL), in which technology is used to meet pedagogical needs. The success of this attempt depends on whether humans understand how to use technology for learning purposes. For example, a tool for technology-enhanced learning could potentially offer beneficial functionalities, but these might overwhelm the human user if they impose too much cognitive load that would be ineffective for learning [1, 2]. Furthermore, if a tool for technology-enhanced learning does not provide positive experiences such as enjoyment, learners' motivation to continue learning might be affected [3]. Accordingly, every aspect that shapes learning success has to be considered when designing tools for technology-enhanced learning.

One field that is concerned with investigating how technology shapes human experience is human-computer interaction (HCI). HCI investigates how humans and technology interact in reference to clearly defined sets of needs that have been identified. HCI has a long tradition in integrating users in the design and development process (e.g., in usability evaluation, user-centered design, or co-design) [4]. User experience (UX) has recently emerged as a key trend in HCI research [5, 6].

This paper describes a co-design case study in the field of technology-enhanced learning involving a concept mapping tool. As concept mapping is an effective learning method [7], it is crucial to design a tool that can effectively support learners in concept mapping. Employing the concepts of usability and user experience, the current study was aimed at combining functionality-driven and experience-driven approaches in co-design sessions to obtain a complete picture of what learners expect from a concept mapping tool. The paper involves empirical data collected from four classes of students. We found that the combination of a functionality-driven and an experience-driven co-design approach can help researchers reveal important aspects that need to be considered in designing tools for technology-enhanced learning.

2 State of the Art

2.1 Usability, User Experience, and Co-design

With the rise of digital technologies in every facet of life, including the emergence of technology-enhanced learning, the importance of HCI has grown in recent decades. Research on HCI has long focused on investigating what technology does (the “what” of technology or “do-goals”) along with how humans interact with it (the “how” of technology or “motor goals”) [8]. Likewise, creating technology involves identifying which functionalities it should include and measuring how successful it is in providing these functionalities. Usually, one of the success factors is usability, defined as the effectiveness, efficiency, and satisfaction of achieving a goal [9].

Usability and its associated criteria are well-suited for the design and evaluation of concrete functionalities that users rely on while interacting with a given technology. Usability has thus been the most dominant concept in the designing of technology for many years and has contributed to shaping an approach that provides considerable attention to concrete functionalities. Whereas functionality-driven design and usability remain important, the perspective of HCI has expanded in recent years, moving to a “third wave of HCI” [10] or “third paradigm of HCI” [11] with a stronger emphasis on user experience (UX) [6]. UX describes the human experience with technology from a holistic viewpoint and includes usability [9]. Besides the so-called pragmatic aspects (“do-goals” or the “what” question of experience), UX is equally concerned with hedonic aspects (“be-goals” or the “why” question of experience) [12] that go beyond the instrumental [13]. Whereas interest in the hedonic aspects of UX has grown rapidly [14], Mekler & Hoernbæk recently investigated eudaimonic experiences (striving toward the best) as another dimension [15]. For example, in a fictional online course about data science, pragmatic aspects might be comprised of the lessons, exercises, and search functionalities. Hedonic aspects might be comprised of motivational messages, virtual certificates, or making the exercises enjoyable. Eudaimonic aspects might be comprised of elements referring to the overarching goal of building a career as a data scientist (e.g., by aligning different courses with a suggested learning path).

All of these UX dimensions are highly relevant to technology-enhanced learning. Regarding the so-called pragmatic aspects, the focus is on a tool’s functionalities and characteristics for technology-enhanced learning. Thus, functionality-driven design is about specifying what a product should do. Regarding the hedonic (e.g., motivation, positive learning experiences) and eudaimonic aspects (e.g., realizing one’s potential, achieving happiness or one's ideals), however, the investigation has to move beyond this functionality-driven approach. Experience-driven design is about understanding the abovementioned "why" question of design to discover which experiences a tool should provide [16]. Furthermore, experience-driven design investigates UX at different points in time [17], that is, anticipated UX (before using the tool), momentary UX (while using the tool), episodic UX (after using the tool), and cumulative UX (over time). All of these are equally important from the perspective of humans using technology. Thus, an approach that integrates functionality-driven (pragmatic) aspects with experience-driven (hedonic and eudaimonic) aspects is promising.

The role of the human as a reference point for the design of adequate experiences is essential across all stages of the design process: They can act as informants, designers, testers, and users [18]. User-centered design emerged as a key methodology in HCI research and typically concentrates on "humans as subjects" [19]. Humans are greatly involved throughout the process but mostly as subjects in observations and interviews. However, research in HCI has long investigated the other roles that humans can play as well. Accordingly, it has a long tradition in co-design [19], where humans suggest design ideas in addition to providing insights and testing prototypes.

Based on the idea that everybody is creative [20], co-design has a wide range of advantages for the user-centered design of technology-enhanced learning tools. It democratizes design [21] because it allows participants to take an active role in dealing with today's educational challenges, fitting well into an "era of participation" [21] with ever-increasing demands for 21st-century skills [22]. Thus, co-design provides an excellent opportunity to match the functionalities of technology-enhanced learning tools with learners' real interests. Therefore, in this case study, we investigated a co-design approach that invited participants to create their ideal tool for technology-enhanced learning and to explain why it might help them with learning and assessment.

2.2 Concept Mapping in Technology-Enhanced Learning

We selected the design of a concept mapping tool to use in a case study in which we combined an experience-driven and a functionality-driven co-design approach in technology-enhanced learning. Concept maps are visual representations of knowledge [23] that make the relations between various parts of a topic or process explicit. They use concepts inside shapes (nodes) with labeled links that can be directed or non-directed. A pair of concepts form a proposition that specifies their semantic relation. Thus, concept maps are node-link diagrams [7] that are similar to other types of visual representations used in education (e.g., mind maps or knowledge maps). They are used for many purposes in learning and assessment [24, 25] (e.g., unrestricted concept mapping, providing key terms for concepts and labeled links, or leaving blanks in a concept map that students should fill in). Many studies have explored the learning benefits of concept maps [7, 26]. They differ from well-known mind maps [27] by explicitly showing the relations between connected concepts with the help of link labels [28], making them a more structured approach for the visualization of knowledge [29].

Concept mapping is a compelling case for technology-enhanced learning for several reasons. First, concept mapping is a promising approach for the learning of 21st-century skills because of its potential to promote meaningful learning [30], critical thinking in complex systems [31], sustainability [32], and interdisciplinarity [33]. Second, technology-enhanced concept mapping offers several advantages over paper-and-pencil-based concept mapping, particularly because of its greater flexibility in adding multimodal attributes such as color, images, or fonts to a concept map [34], easier correction of errors [35], and availability of a variety of scoring methods [24]. Third, regarding summative assessments [36], concept mapping allows for a variety of tasks, such as identifying errors in concept maps [37], creating maps around a focus question [38], or investigating the effects of collaborative concept mapping on individual learning [39]. Finally, regarding formative assessment [36], concept mapping is a promising method for investigating knowledge construction over time [40].

Furthermore, co-design has the potential to advance the method and the tools involved in concept mapping. For example, research has found that students who self-generated concept maps during learning performed worse than students who used concept maps that were provided to them, potentially caused by the higher cognitive load imposed by the poor usability of a demanding tool [41]. Usability is a crucial factor in concept mapping as students using a usability-optimized tool outperformed students using a baseline version [42]. However, usability has rarely been considered in concept mapping research [43]. Thus, we collected evidence of what learners expect from a concept mapping tool to provide a solid foundation for a user-friendly design.

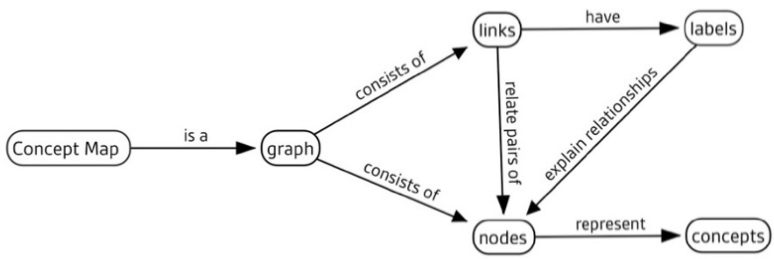

Fig. 1. Example concept map [43].

3 Research Questions

We conducted a case study of a concept mapping tool in which we combined experience-driven and functionality-driven approaches in technology-enhanced learning. The first research question concentrated on students' anticipated experiences. Their anticipated experiences included hedonic and eudaimonic aspects (e.g., basic needs that the tool should address, hopes for advantages that it might afford, motivations for using it, contextual factors such as the hardware supporting the tool, and the emotional aspects accompanying its use). These aspects provided the foundation of what users expected to experience. Afterward, the second research question concentrated on the pragmatic functionalities and characteristics that students expected from a concept mapping tool to realize their anticipated experiences. We defined anything that the tool was supposed to do (e.g., saving) as "functionality" and any general attribute of the tool (e.g., an aesthetic design) as a "characteristic."

1. *Research Question 1*: Which anticipated experiences do students communicate in their co-design artifacts (hedonic and eudaimonic aspects, the "why" question)?
2. *Research Question 2*: Which functionalities and characteristics do students envision for a concept mapping tool (pragmatic aspects, the "what" question)?

After answering these research questions, we relate the anticipated experiences to the functionalities and characteristics in the discussion section, pointing to the areas that require further investigation in research and design. Accordingly, this study contributes to bridging the gap between the functionality-driven and experience-driven design of technology-enhanced learning tools.

4 Methodology

4.1 Participants

Four classes with 67 students from Luxembourg participated in the co-design sessions. All classes had a similar age range, but they came from three different socioeconomic settings. Table 1 presents the descriptive details of the classes.

Table 1. Classes participating in the co-design study

Session	School	Participants
I	Private Catholic secondary school	22 (ages 18-19)
II	Private Catholic secondary school	11 (ages 17-18)
III	Technical secondary school	15 (ages 17-19)
IV	Classical secondary school	19 (ages 17-18)

4.2 Materials & Setting

The co-design sessions took place in 90-min lessons during regular school hours. We chose regular classrooms to facilitate student participation and to purposefully observe the actual context where the tool will be used [4]. However, this decision implied that the environment of the study was less controlled in comparison with our lab facilities. Accordingly, some adjustments to our settings were necessary regarding ethics, background knowledge, and co-design approach. The research project obtained ethical approval from the University of Luxembourg's Ethics Review Panel (ERP 18-031). Both the APA Ethical Principles & Code of Conduct and the UXPA Code of Conduct were consulted in planning the study. All the materials and instructions were pretested in two additional classes that did not participate in the study.

Regarding ethics, the challenge consisted of safeguarding the strict requirements of (informed) consent in a setting where students were required to be present in class. We thus first collected written informed consent from the students (and their parents when the students were minors) who wanted to participate. Afterward, we distributed the answer sheets independently and explicitly pointed out that students were free not to return them if they did not want to participate. Furthermore, collecting informed consent and answer sheets independently ensured the anonymity of the data, making it impossible to connect the answer sheets to the participants' names.

Regarding background knowledge, we made sure that every student had sufficient knowledge about the topic from the co-design session (concept mapping). First, we introduced the students to concept mapping by explaining its characteristics. Specifically, we compared concept maps with mind maps because students were already familiar with mind mapping. We explained the differences between concept maps and mind maps and provided them with three examples of concept maps. Students were allowed to ask questions. We used a fill-in-the-blank concept map about their ideal concept mapping tool (see fig. 2). This template allowed students to experience concept mapping even if they had no previous experience with the method. The template prompted them to select a hardware device (e.g., a computer or tablet), provide reasons for their choices, and explain why concept mapping could help them in learning or knowledge assessment. This template allowed us to collect data about their anticipated experiences (Research Question 1, the "why" question) because it asked the participants to imagine the experience of using a concept mapping tool while at the same time explaining the reasons behind the experiences they identified as valuable.

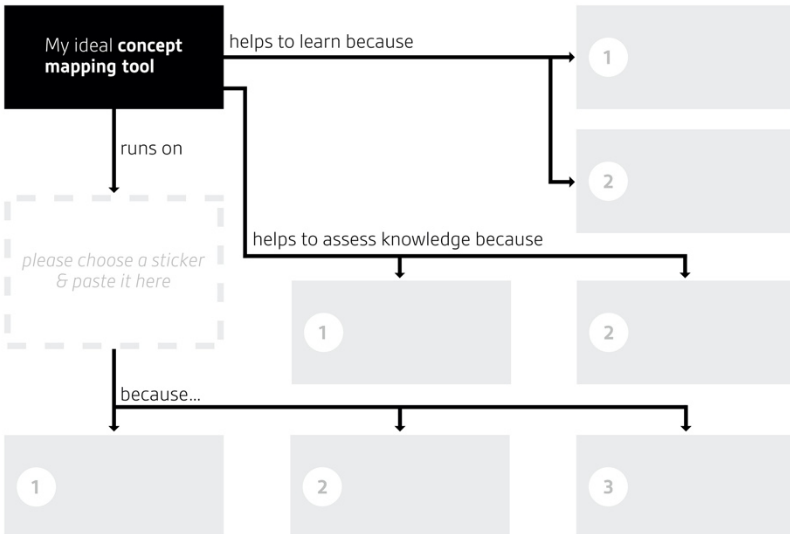

Fig. 2. Fill-in-the-blank mapping template.

Regarding the co-design approach, we carefully devised the approach that was best suited for collecting the students' design ideas. Building on their anticipated experiences regarding the concept mapping tool, students were invited to form groups after a short break to co-design their ideal tool. The groups were told they should think about which functionalities and characteristics (Research Question 2, the "what" question) would be necessary for the experiences they anticipated they would have, but they were also free to include other ideas they considered important. The co-design activity was a 3-12-3 brainstorming [44]: First, students were invited to discuss in groups of 2 to 4 students what an ideal concept mapping tool should look like for 3 min.[1] Second, they should choose one of their ideas and sketch a possible solution.[2] The researcher stressed that every form of representation that they considered appropriate for conveying their ideas was allowed. The co-design phase lasted for 12 min. Table 2 provides an overview of the co-design artifacts the students created

[1] The instructions were: "Please discuss what your ideal tool for learning with concept maps should look like: Which functionalities should it have, what should it look like, which other characteristics would be important for you?"

[2] The instructions were: "Select one of your ideas and create a sketch of it (e.g., of the interface, a person or group interacting with the tool, a certain functionality or what it does)."

during this phase. Finally, each group presented their ideas by showing and explaining their sketches to the class. Students from the other groups were invited to ask questions and discuss their ideas either publicly or by commenting on the answer sheets. Each group had 3 min to present their ideas. Overall, the co-design session lasted for roughly 30 to 35 min with an additional 10 min for debriefing. During the presentations, the researcher took notes on his observations to facilitate the analysis.

4.3 Analysis

Table 2. Co-design artifacts created in the collaborative sessions

Group	Artifact	Description
I-1	App icon & first app screen	Concept mapping app “Easy learning” with personal login
I-2	Text in bullet points	Multifunctional app (e.g., course plan, chatting, scanner, calculator, concept map)
I-3	Several drawings of features and interactions	Concept mapping tool with different interaction styles (voice, pen, icons)
I-4	Entire user interface	Software with graphical user interface and pop-ups
I-5	Elements of user interface & text	Multifunctional tool (e.g., course plan, chatting, broadcasts of courses, concept map, books)
II-1	Drawings & texts describing features	Various options for the designing of concept maps, access control, multiple languages
II-2	Entire user interface with example concept map	Software with graphical user interface & concept map with different design options (shapes, border styles, font sizes)
II-3	Example concept map & text	Concept map with different design options (colors, shapes, font styles)
II-4	Concept map of tool features & aspects	Various aspects of a concept mapping tool (options, user interface, design)
II-5	Device (tablet) & text	Tablet app with voice recognition and personalization options
II-6	Entire user interface, individual screens & text	User interface on desktop & smartphone screen with personalization options
III-1	Entire user interface, example map & text	Software with graphical user interface & concept map
III-2	Fragments of user interface & text	Multifunctional tool (e.g., calculator, dictionary, periodic system, concept maps)
III-3	Several drawings of features and elements of user interface	Multifunctional tool with external sources integrated into concept maps, export functions
IV-1	Several successive app screens	Step-by-step drawings of smartphone app with motivational features
IV-2	Elements of user interface, drawings of devices & example map	Multifunctional pen (microphone, fingerprint sensor) to digitize analog maps while drawing, several toolbars, example map with different design options
IV-3	Elements of user interface & text in bullets	Multifunctional social network for students with concept map navigation
IV-4	Elements of user interface & text	Concept mapping tool with design options & integration of search engine results
IV-5	Entire user interface, device & text	Learning tool dealing with problems in chemistry with a concept map
IV-6	Entire user interface & text in bullets	User interface on smartphone with personalization options and design features

After the classroom sessions, the answer sheets were collected, digitized, and analyzed in the MaxQDA software for qualitative data analysis. We followed a qualitative content analysis approach and performed a summarizing content analysis [45] regarding students' anticipated experiences (Research Question 1) and the functionalities and characteristics they expected (Research Question 2). We went through every artifact and inductively placed the anticipated experiences and functionalities and characteristics into categories. When appropriate, we subsumed them under existing categories. We reconsidered and verified the categorization system after the first two classes, applied it to the remaining classes, and verified it a second time, making sure that we did not miss any aspect. As outlined in the preceding section, we designed the "fill in the blank" concept maps to point our participants toward anticipated experiences and the co-design artifacts to point them toward functionalities and characteristics. However, participants sometimes mentioned functionalities or characteristics in their fill-in-the-blank concept maps and vice versa. Thus, we coded both the fill-in-the-blank concept maps and the co-design artifacts for both research questions.

5 Results

In the following, we first present the anticipated experiences that participants reported (i.e., the "why," Research Question 1); in a second step, we report the ideas about functionalities and characteristics the participants imagined (i.e., the "what," Research Question 2). In the tables, we distinguish between the fill-in-the-blank activity (method M1) and co-design studio groups (method M2). A total of 67 students participated in the study, with a total of 67 fill-in-the-blank concept maps. The students then broke into a total of 19 groups (of 3 to 4 students on average), which each provided one co-design artifact. The numbers in the tables specify how many of the fill-in-the-blanks or co-design artifacts mentioned the result. Examples of verbatim responses were translated from German by the first author.

5.1 The Why: Anticipated Experiences with a Concept Mapping Tool

Participants' anticipated experiences covered which hardware device they preferred for a concept mapping tool and the learning and assessment aspects afforded by concept mapping. These were mainly derived from the fill-in-the-blank concept maps (M1), although some additional points were found in the co-design artifacts as well (M2).

Preferred devices for a concept mapping tool. Regarding the preferred devices for the tool, no clear trend was found: There were 28 votes for computers (41.8%), 34 for tablets (50.7%), and some additional votes for both platforms (2 votes; 3%), paper (2 votes; 3%), or smartphones (1 vote; 1.5%). Reasons for computers were efficiency ("it is faster to type on or to select something"; "the screen is bigger"), versatility ("you can format the tool more easily"), precision ("mice and keyboards are more precise than the screen on a tablet"), or ease of use ("I can deal with it better"; "I have been using it since I was young"). Reasons for tablets were portability ("it is handy"; "I can take it with me anywhere and learn anytime"; "I have everything in one place instead of having 1,000 sheets of paper"), touch screen ("it is more precise because you can draw with a pen"; "I can easily make the image bigger or smaller"), and ease of use ("it is more practical because it has a touch screen"; "it is easy to use"; "it is easier to work with than a mouse and keyboard"). Based on preferences for both devices, the concept mapping tool should be optimized for both computers and tablets with their respective input modalities.

Anticipated experiences regarding learning and assessment advantages afforded by concept mapping. Participants anticipated a variety of experiences (see Table 3), particularly regarding structuring complexity, learning how to learn with the help of concept mapping, and assessing knowledge.

Table 3. Anticipated experiences with a concept mapping tool in fill-in-the-blank concept maps (M1) and co-design artifacts (M2) (number of times mentioned in the artifacts)

Category	Functionalities or characteristics	M1	M2
1) Structuring complexity	Structure, orderliness, good overview, clear arrangement	40	3
	Collect and summarize topics or ideas	2	
	Greater efficiency in communicating knowledge in collaboration	2	
	Compare maps with others	2	
	Discover new aspects or connections through mapping	1	
2) Learning how to learn (efficiency)	More efficient learning	17	1
	Appropriateness for different subjects	5	2
	Crossing borders between subjects and topics	3	
	Fun while learning	2	
3) Learning how to learn (sustainability)	Advantages of visual aspects of concept maps	18	
	Learning benefits from mastering the method of concept mapping	8	
	Learning benefits from creativity	2	
4) Assessment	Greater efficiency in communicating knowledge in tests	5	
	Opportunity to judge how people use what they know	1	
	Specify importance of concepts and links in maps (weighted concept map)		1

Structuring complexity was found to be a very prominent anticipated experience for students with respect to concept mapping (i.e., Category 1 in Table 3). Accordingly, many of the fill-in-the-blank answers (M1) expressed the desire to get a better overview for oneself (“it gives me a better overview”; “everything at one glance”; “it is more orderly”) or to be able to communicate knowledge more efficiently in collaboration (“you can more easily share and compare concept maps”).

Learning how to learn with the help of concept maps was another prominent anticipated experience, particularly in two areas: the efficiency of learning and the sustainability of it (i.e., Categories 2 and 3 in Table 3). First, regarding the efficiency of learning, participants expressed that concept mapping might make learning faster and easier (“it reduces the material to the essential and you only have to learn the most relevant aspects”) or more enjoyable (“other than a text, it is visually more attractive”; “it is fun to create a concept map, and therefore it is fun to learn”). In addition, participants expressed that concept mapping might be a learning approach appropriate for different subjects, potentially even demonstrating relations between subjects (“you can easily summarize the different subjects”). Second, regarding the sustainability of learning, students expressed that the visual nature of concept maps might help them retain knowledge (“I can remember things better visually”). The reasons they communicated were either that the method might be a useful alternative to other learning methods (“it is something new, and it might connect school and learning better”; “it is individual, a personal learning method”) or that the spatial arrangement might add another modality to learning (“the visual nature makes it easier to remember words because you remember where they were located”).

Regarding the assessment of knowledge (i.e., Category 4 in Table 3), participants expressed that concept maps can help them identify whether they know something or not ("it becomes immediately clear whether you have understood something"). However, many participants left the assessment blanks unanswered, provided very general answers ("it is explicit"; "it is logical"), or expressed doubts ("assessment is limited because it is hard to connect topics"). These results indicate that even though students consider concept maps to be a valuable assessment method, they also need substantial guidance on how to use them.

5.2 The What: Functionalities and Characteristics of Concept Mapping

Four categories were extracted to organize ideas about functionalities and characteristics (see Table 4): ideas concerning the user interface, freedom and creativity, collaboration inside the typical school setting, and assessment of knowledge. Whereas most ideas for functionalities and characteristics were expressed in the co-design artifacts (M2), some were found in the fill-in-the-blank activities as well.

Easy-to-use and aesthetic user interface optimized for input modalities. Several of the ideas communicated in the co-design artifacts concentrated on the characteristics of the user interface (i.e., Category 1 in Table 4). First, the user interface was expected to be clear, simple, and user-friendly. However, qualities of the user interface also included hedonic aspects such as an aesthetic and stimulating design, a nice app icon, and motivational messages to support the learning process.

Second, the user interface ideas mentioned a range of specific functionalities such as help and search functionalities, localization of the user interface, and personalization (e.g., by selecting tools for the toolbar or by changing the color scheme; see fig. 3).

Third, the user interface ideas showed an awareness of differences between specific input modalities. In particular, ideas included the strong wish to draw concept maps by hand or with a pen on tablets ("it is more precise than a computer if you draw with a pen"; "you can develop your own creativity by drawing with your hand"; see fig. 3), multitouch gestures on tablets ("it is easier to make a picture bigger or smaller"), or dragging and dropping elements from another window into the concept map.

Freedom and creativity that help learning with concept maps. A variety of ideas focused on specific functionalities aimed at aiding learning, mainly concerning aspects of freedom and creativity (i.e., Category 2 in Table 4). Twelve co-design artifacts showed options for creativity in choosing fonts, colors, line styles and thicknesses, or a variety of shapes. In addition, ideas included the opportunity to enrich concept maps by adding other media (images, videos, audio files) or to integrate external sources into the maps. Furthermore, aspects of freedom could be seen in ideas such as the ability to run offline or to open several maps at the same time for comparison and in an interface that would allow students to start maps on their own, without the teacher granting access. Finally, several ideas focused on language functionalities (e.g., auto-translation or dictionaries). These ideas would allow students to create their maps in any language they preferred, a finding that reflects the multilingual situation in the country of study.

Table 4. Functionalities and characteristics of a concept mapping tool in fill-in-the-blank concept maps (M1) and co-design artifacts (M2) (number of times mentioned in the artifacts)

Category	Functionalities or characteristics	M1	M2
1) User interface	Clear, simple, intuitive user interface	7	7
	Drawing with hand or pen on a tablet	5	6
	Personalization of user interface		8
	Simple, useful search function	1	3
	Provide help functionalities	1	3
	Personalization of map background		2
	Interface localization		2
	Drag & drop		2
	Aesthetic app icon		2
	Aesthetic design	1	
	Motivational messages		1
2) Freedom & creativity	Multiple design options for maps	2	24
	Integrating external data sources	7	4
	Language functions (auto-correction, dictionary)	2	6
	Learn wherever you are	4	
	Have all learning materials in one place	3	
	Functionality of judging the trustworthiness of external sources	2	
	Undo & redo		2
	Offline mode	1	
	Open & compare several maps at the same time		1
	Create maps independently of teacher		1
	Opportunity to nest maps (submaps)		1
	Provide templates that set relevant options		1
	Grid or guiding lines to position elements		1
	Legend to explain the meaning of design options		1
	Specify importance of concepts and links in maps (weighted concept map)		1
	Auto-save		1
3) Collaborative school settings	Share maps with others	2	4
	Individual accounts		6
	Export & print functionalities		4
	All-in-one application integrating concept maps with other tools		3
	Rights management		2
	Chat or comment function		2
	Public cloud with maps		1
	Synchronous collaboration in one document		1
	Track changes by person		1
4) Assessment	Self-assessment	5	
	Learn from mistakes & knowledge gaps	2	2
	Features to practice before tests	1	1

Whereas this study was not aimed at systematically investigating the roles that freedom and creativity play in concept mapping, the results still offer some evidence on how participants imagine they would use creative options. Four of the student groups deliberately used a concept map to communicate their ideas (cf. fig. 3). These concept maps use creative options in a meaningful way to distinguish between different categories of concepts or between broader concepts and examples. In addition, one co-design artifact explicitly included a functionality where students could create a legend that explained the meaning of their design choices.

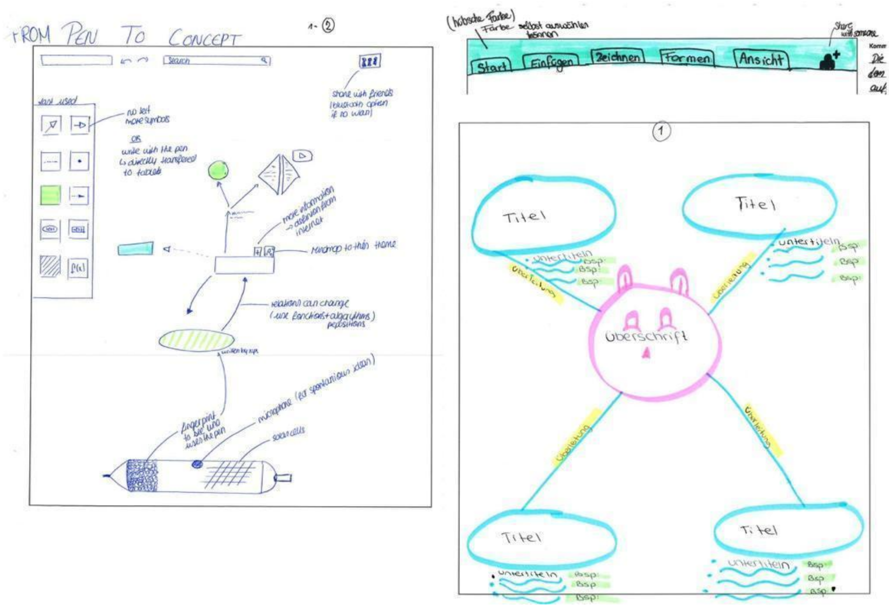

Fig. 3. Pen drawing with adaptable toolbar (left, from Session IV), personalization of user interface colors (top right, from Session II), meaningful use of design options to distinguish content (bottom right, from Session II)

However, besides the variety of creative options, participants also suggested functionalities that would deliberately limit or guide their freedom in creating concept maps. Among these was the use of templates that limit the options for meaningful choices, grid lines to automatically position concepts, or the nesting of maps into submaps that can be revealed if needed. In addition, safety functionalities such as undo/redo or the auto-saving of maps were mentioned frequently.

Concept maps in collaborative school settings. Another set of ideas pointed to the collaborative school setting where the concept mapping tool will be used (i.e., Category 3 in Table 4). Accordingly, the co-design artifacts included chat or comment functionalities, individual accounts for every student (including rights management and the tracking of changes when students collaborate on concept maps), and different ways of sharing concept maps (e.g., via social media, links, public cloud, printing, or exporting the map in various formats). Three groups combined the concept mapping tool with other functionalities such as calculators or the periodic system.

Assessment of knowledge with concept maps. Finally, a range of ideas about functionalities focused on the assessment of knowledge (i.e., Category 4 in Table 4), for both formative and summative assessment [36]. Regarding formative assessment, participants investigated how the tool could provide feedback about learning progress to allow for self-monitoring [46]. Ideas included an interface suggesting areas for improvement ("when you write a concept map, it could show you how to make it better") or for specifying errors that participants made ("it shows me my errors"). Regarding summative assessment, ideas about functionalities tended to concentrate on preparing for exams ("additional, teacher-made exercises to prepare for tests").

6 Discussion

Investigating the fill-in-the-blank concept maps and the co-design artifacts provided insights into anticipated experiences and the functionalities and characteristics students expected from a concept mapping tool. Two aspects were particularly important for the generalizability of our results beyond this case study: the methods chosen and the relations between the experience-driven and the functionality-driven investigations.

6.1 Triangulation of Methods

First, the triangulation of methods is noteworthy. The study used a combination of individual fill-in-the-blank concept maps and collaborative co-design sessions, which revealed different, yet complementary results. Unsurprisingly for a learning tool, most of students' anticipated experiences in the fill-in-the-blank concept map concentrated on aspects of effective learning and the assessment of knowledge (the "why" question). Frequent topics were being able to better structure knowledge visually and more efficient learning. The co-design artifacts, on the other hand, much more prominently communicated functionalities such as creative options, hedonic features of personalization and self-expression, and collaborative features (the "what" question). Neither method was able to reveal the entirety of the results without the other.

Accordingly, the evidence suggests that combining experience-driven and functionality-driven methods of data collection is a valuable approach for obtaining more nuanced and complete specifications of tools for technology-enhanced learning. For example, it is striking that the fill-in-the-blank concept maps emphasize aspects of competence, whereas the co-design artifacts emphasize aspects of creativity and self-expression. A possible explanation for this finding might be that the fill-in-the-blank concept map asked for an ideal concept mapping tool regarding aspects of learning, assessment, and technology. These questions could have primed participants to focus on aspects of competence. However, the co-design sessions equally asked participants to imagine their ideal concept mapping tool for learning. An alternative explanation might thus be that participants moved one step further when asked to actively imagine their ideal tool in their co-design artifacts: They included functionalities and characteristics that could realize their anticipated experiences (e.g., creative options to structure knowledge) while at the same time considering functionalities and characteristics that went beyond the building of competence (e.g., options for collaboration or for adjusting the user interface to their own preferences). Likewise, the fill-in-the-blank concept maps revealed anticipated experiences that participants did not cover in their co-design artifacts (e.g., for formative assessment), potentially because they did not know how.

Although these individual results are limited to our specific case, the methodological idea of combining experience-driven and functionality-driven approaches applies to the co-design of other tools for technology-enhanced learning. It helps acquire a complete picture of what users expect from a tool for technology-enhanced learning.

6.2 Relations between Anticipated Experiences and Functionalities

Second, the study revealed a range of potential conflicts to consider when designing the concept mapping tool. The central aspects informed by the users were the structural organization of knowledge, efficient learning, and creativity. However, how these aspects are related is not entirely clear. In the example concept maps that students created in their co-design artifacts, they tended to use creativity functionalities in a meaningful way to structure knowledge (e.g., by specifying subtopics and categories of concepts). This observation raises interesting questions: Do these functionalities enhance learning with concept maps because they make the relations clear? How should these functionalities be included in concept map assessments, which tend to rely on the written content and the structural connections of maps [24]? However, it might also be the case that the creative feature hinders learning because students spend too much time on stylistic aspects [47], thus reducing the efficiency of learning. For example, adding multimedia elements to concept maps has a positive effect on the time spent with concept mapping and the coherence of the created maps, but it does not positively affect learning outcomes [48]. Thus, investigating how creativity functionalities and learning outcomes are related might help advance the method of concept mapping.

Furthermore, our findings raise important questions about balancing the aspects of usability and user experience in the design of the concept mapping tool. For example, fig. 4 shows the interface of one of our tool prototypes. It offers a limited selection of design options (e.g., six colors that cannot be adapted by participants) and automatically calculates the closest path between connected concepts. Whereas this tool has already been extensively tested and optimized for usability and pragmatic aspects [42], the limited choices for its design options might interfere with students' need for creativity and the building of their individual knowledge structures as communicated by participants in this co-design study. Accordingly, it might be worthwhile to reconsider these design decisions in experience-based studies.

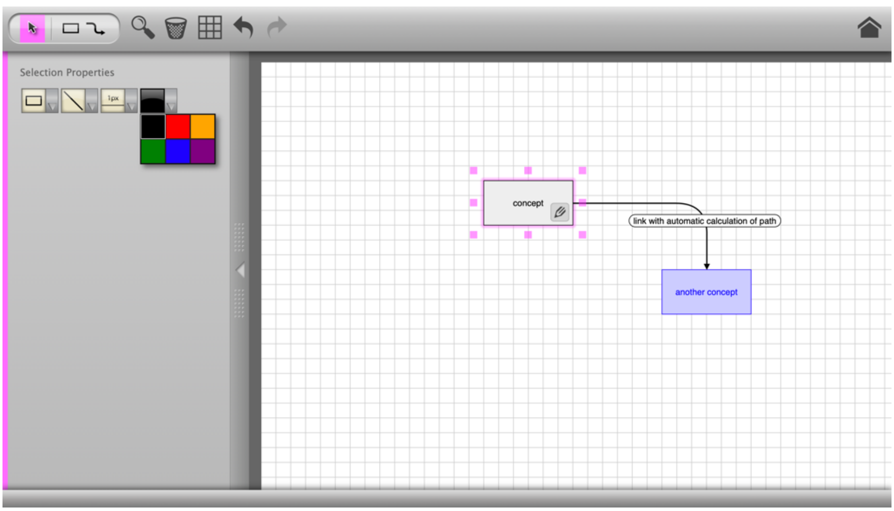

Fig. 4. Prototype with limited design options

Another interesting question was posed by the observation that users anticipate the functionality of adjusting the user interface to personal preferences and a user-friendly, simplified interface at the same time. How should the design of the concept mapping tool balance these potentially opposing aspects? Should one be considered more important in designing technology-enhanced learning tools? These are difficult decisions for any designer to make, and only further research will be able to provide answers. However, knowing which areas to explore is a critical step in the design process. The methodological approach of this co-design case study in technology-enhanced learning has proven valuable in determining these research directions.

6.3 Limitations

Whereas conducting our study in the classrooms facilitated student participation, it also meant we had to respect strict time constraints. Because we could not interfere with regular school lessons, extensions were impossible. Accordingly, we left a substantial amount of buffer time and concentrated on the two data collection methods described in this case study. We made sure we strictly adhered to our instructions on concept mapping to guarantee that students gained sufficient knowledge about the topic. When we had additional time left, we led the students in activities that helped them learn even more about design, or we answered students' general research-related questions. We carefully defined and pretested how much time students could spend on the co-design activities. However, we could not rule out the possibility that students with more concept mapping experience or more time to create co-design artifacts might come up with additional ideas for functionalities and characteristics or anticipated experiences. Thus, we think that replicating the study with experienced students or with variations in the setting would be interesting despite the fact that our particular tool is targeted toward novice students.

It should be noted that communicating an idea about functionality does not necessarily mean that users will actually use it. Furthermore, there might be important functionalities that participants could not think of. In addition, frequently mentioned ideas might turn out to have less impact on user experience than rarely mentioned ones. Finally, anticipated experiences do not necessarily have to align with users' actual experiences when using the tool. For example, it might turn out that other experiences become more important in a real-use situation that students could not have imagined beforehand. However, user experience explicitly included anticipated user experience [17], making this solid ground from which to begin the design work.

Finally, there were fuzzy cases in which the distinction between an anticipated experience and a functionality or characteristic was not clear-cut. We used the definitions given in the research questions section as the basis for our decisions. Accordingly, we defined data relating to hedonic and eudaimonic aspects as "anticipated experiences" (e.g., why participants use a tool and which contextual factors such as emotions, motivations, or the situation in which the tool is used affect their experience). We defined data relating to pragmatic aspects as "functionalities or characteristics" (e.g., what the tool is supposed to do and the general characteristics it should have). However, a subset of our data might fall in between these categories. This is particularly true for the hardware choices where aspects of anticipated experiences (e.g., easier use with a touch screen) are closely related to functionalities (e.g., drawing maps with a pen). However, given that our main argument is that the combination of an experience-driven and a functionality-driven co-design approach is valuable, we do not view these fuzzy cases as a major issue for the validity of our results.

7 Conclusion

Building on a case study of co-design sessions for the design of a concept mapping tool, we investigated the combining of an experience-driven and a functionality-driven co-design approach in technology-enhanced learning. We demonstrated how anticipated experiences reveal answers to the "why" question about the tool, in particular the needs to structure complexity, enhance the efficiency and sustainability of learning, and improve assessment. Afterward, we found evidence for functionalities and characteristics that students expect from a concept mapping tool, in particular, an easy-to-use but aesthetic user interface, creative options, collaborative functionalities, and formative assessment. Finally, we demonstrated how anticipated experiences are related to the functionalities and characteristics of a tool, and we found interesting questions to address in the following design phase.

Whereas this case study investigated the design of a concept mapping tool, it has broader implications for the design of technology-enhanced learning. First, it demonstrated the usefulness of simultaneously investigating anticipated experiences as well as functionalities and characteristics. Both perspectives are necessary for a complete picture of what users expect from a tool for technology-enhanced learning. Second, it revealed a range of ideas beyond pragmatic aspects, in particular, hedonic (e.g., aesthetic design or personalization options) and eudaimonic aspects (e.g., learning how to learn), all of which have the potential to positively affect learning success. In conclusion, combining experience-driven and functionality-driven design approaches has the potential to substantially enhance the quality of tools for technology-enhanced learning.

Acknowledgment This study was funded by the SCRIPT, an institution of the Luxembourgish Government that aims to enhance education.

References

1. Leppink, J., Paas, F., Van der Vleuten, C. P., Van Gog, T., Van Merriënboer, J. J.: Development of an instrument for measuring different types of cognitive load, Behavior Research Methods, 4, pp. 1058--1072 (2013)
2. Sweller, J.: Element Interactivity and Intrinsic, Extraneous, and Germane Cognitive Load, Educational Psychology Review, 2, pp. 123--138 (2010)
3. Wang, L.-Y.-K., Lew, S.-L., Lau, S.-H., Leow, M.-C.: Usability factors predicting continuance of intention to use cloud e-learning application, Heliyon, 6, pp. e01788 (2019)
4. Muller, M., Druin, A.: Participatory Design: The Third Space in HCI, in J. Jacko, The Human-Computer Interaction Handbook, pp. 1125--1154, Lawrence Erlbaum Associates, Hillsdale, NJ, (2012)
5. Krannich, D., Zeisig, A., Wajda, K.: Digital Experience Design, in B. Robben, H. Schelhowe, Be-greifbare Interaktionen. Der allgegenwärtige Computer: Touchscreens, Wearables, Tangibles und Ubiquitous Computing, pp. 167--189, transcript, Bielefeld, (2012)
6. Lallemand, C., Koenig, V.: Lab Testing Beyond Usability: Challenges and Recommendations for Assessing User Experiences, J. Usability Studies, 3, pp. 133--154 (2017)
7. Schroeder, N. L., Nesbit, J. C., Anguiano, C. J., Adesope, O. O.: Studying and Constructing Concept Maps: a Meta-Analysis, Educational Psychology Review, 2, pp. 431--455 (2018)
8. Hassenzahl, M.: Experience Design: Technology for All the Right Reasons, Morgan & Claypool, (2010)
9. Burmester, M., Hassenzahl, M., Koller, F.: Usability ist nicht alles – Wege zu attraktiven Produkten, i-com, pp. 32--40 (2002)
10. Bødker, S.: When second wave HCI meets third wave challenges. In: Proceedings of NordiCHI '06, pp. 1--8. ACM Press (2006)
11. Harrison, S. R., Tatar, D., Sengers, P.: The Three Paradigms of HCI. In: Proceedings of the Alt. Chi. Session at the SIGCHI Conference on Human Factors in Computing Systems, pp. 1--18. (2007)

12. Hassenzahl, M.: User experience (UX): towards an experiential perspective on product quality. In: Proceedings of the IHM '08, pp. 11--15. ACM Press (2008)
13. Hassenzahl, M., Tractinsky, N.: User experience – a research agenda, Behaviour & Information Technology, 2, pp. 91--97 (2006)
14. Diefenbach, S., Kolb, N., Hassenzahl, M.: The 'hedonic' in human-computer interaction. In: Proceedings of DIS '14, pp. 305--314. ACM Press (2014)
15. Mekler, E. D., Hornbæk, K.: Momentary Pleasure or Lasting Meaning. In: Proceedings of CHI '16, pp. 4509--4520. ACM Press (2016)
16. Olsson, T., Väänänen-Vainio-Mattila, K., Saari, T., Lucero, A., Arrasvuori, J.: Reflections on experience-driven design. In: Proceedings of DPPI '13, pp. 165--174. ACM Press (2013)
17. Roto, V., Law, E., Vermeeren, A., Hoonhout, J.: User Experience White Paper. Bringing clarity to the concept of user experience. In: Proceedings of the Dagstuhl Seminar on Demarcating User Experience, pp. (2010)
18. Druin, A.: The role of children in the design of new technology, Behaviour & Information Technology, 1, pp. 1--25 (2002)
19. Sanders, E. B.-N., Stappers, P. J.: Co-creation and the new landscapes of design, CoDesign, 1, pp. 5--18 (2008)
20. Jung-Joo, L., Jaatinen, M., Salmi, A., Mattelmäki, T., Smeds, R., Holopainen, M.: Design Choices Framework for Co-creation Projects, International Journal of Design, 2, pp. 15--31 (2018)
21. Smith, R. C., Bossen, C., Kanstrup, A. M.: Participatory design in an era of participation, CoDesign, 2, pp. 65--69 (2017)
22. Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., Rumble, M.: Defining Twenty-First Century Skills, in Assessment and Teaching of 21st Century Skills, pp. 17-66, Springer Netherlands, Dordrecht, (2012)
23. Novak, J. D., Gowin, D. B.: Learning how to learn, Cambridge University Press, Cambridge, (1984)
24. Strautmane, M.: Concept Map-Based Knowledge Assessment Tasks and their Scoring Criteria: An Overview. In: Proceedings of CMC 2012, pp. 80--88. (2012)
25. Cañas, A. J., Novak, J. D., Reiska, P.: Freedom vs. Restriction of Content and Structure During Concept Mapping – Possibilities and Limitations for Construction and Assessment. In: Proceedings of CMC 2012, pp. 247--257. (2012)
26. Nesbit, J. C., Adesope, O. O.: Learning With Concept and Knowledge Maps: A Meta-Analysis, Review of Educational Research, 3, pp. 413--448 (2006)
27. Buzan, T., Buzan, B.: The Mind Map Book: Unlock Your Creativity, Boost Your Memory, Change Your Life, Pearson Education Ltd, (2010)
28. Eppler, M. J.: A Comparison between Concept Maps, Mind Maps, Conceptual Diagrams, and Visual Metaphors as Complementary Tools for Knowledge Construction and Sharing, Information Visualization, 3, pp. 202--210 (2006)
29. Davies, M.: Concept mapping, mind mapping and argument mapping: what are the differences and do they matter, Higher Education, 3, pp. 279--301 (2011)
30. Novak, J. D.: Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations, Routledge, (2010)
31. Brandstädter, K., Harms, U., Großschedl, J.: Assessing System Thinking Through Different Concept-Mapping Practices, International Journal of Science Education, 14, pp. 2147--2170 (2012)
32. Segalàs, J., Ferrer-Balas, D., Mulder, K. F.: What do engineering students learn in sustainability courses? The effect of the pedagogical approach, Journal of Cleaner Production, 3, pp. 275--284 (2010)
33. Reiska, P., Soika, K., Cañas, A. J.: Using concept mapping to measure changes in interdisciplinary learning during high school, Knowledge Management & E-Learning, 1, pp. 1--24 (2018)
34. Kim, P., Olaciregui, C.: The effects of a concept map-based information display in an electronic portfolio system on information processing and retention in a fifth-grade science class covering the Earth's atmosphere, British Journal of Educational Technology, 4, pp. 700--714 (2008)
35. Erdogan, Y.: Paper-based and computer-based concept mappings: The effects on computer achievement, computer anxiety and computer attitude, British Journal of Educational Technology, 5, pp. 821--836 (2009)

36. Dixson, D. D., Worrell, F. C.: Formate and Summative Assessment in the Classroom, Theory Into Practice, 2, pp. 153--159 (2016)
37. Aguiar, J. G. D., Correira, P. R.: Is A Concept Mapping With Errors Useful For Evaluating Learning Outcomes? A Study On Declarative Knowledge and Reading Strategies Using Eye-Tracking. In: Proceedings of CMC 2014, pp. (2014)
38. Cañas, A. J., Novak, J. D.: Re-Examining the Foundations for Effective Use of Concept Maps. In: Proceedings of CMC 2006, pp. 494--502. (2006)
39. Chen, W., Allen, C., Jonassen, D.: Deeper learning in collaborative concept mapping: A mixed methods study of conflict resolution, Computers in Human Behavior, pp. 424--435 (2018)
40. Trumpower, D. L., Sarwar, G. S.: Formative Structural Assessment: Using Concept Maps as Assessment For Learning. In: Proceedings of CMC 2010, pp. 132--135. (2010)
41. Colliot, T., Jamet, É.: Does self-generating a graphic organizer while reading improve students' learning, Computers & Education, pp. 13--22 (2018)
42. Weinerth, K.: How does Usability improve computer-based knowledge assessment?, (2015)
43. Weinerth, K., Koenig, V., Brunner, M., Martin, R.: Concept Maps: A useful and usable tool for computer-based knowledge management? A literature review with a focus on usability, Computers & Education, pp. 201--209 (2014)
44. Gray, D., Brown, S., Macanufo, J.: Gamestorming: a playbook for innovators, rulebreakers, and changemakers, O'Reilly, (2010)
45. Mayring, P.: Einführung in die Qualitative Sozialforschung, Beltz, Weinheim, Germany, (2002)
46. Sadler, D. R.: Formative assessment and the design of instructional systems, Instructional Science, pp. 119--144 (1989)
47. Miller, N. L., Cañas, A. J., Novak, J. D.: Use of Cmaptools Recorder to Explore Acquisition of Skill in Concept Mapping. In: Proceedings of CMC 2008, pp. 674--681. (2008)
48. Sanchiz, M., Lemarié, J., Chevalier, A., Cegarra, J., Paubel, P. V., Salmerón, L., Amadieu, F.: Investigating multimedia effects on concept map building: Impact on map quality, information processing and learning outcome, Education and Information Technologies, pp. 1--23. (2019)