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

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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

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

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

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

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”).

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.

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

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

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