Master Thesis

Mobile Learning (M-Learning) - Concept and Development of an App for the Alpine Cartographic Field School

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Statement of Authorship

Herewith I declare that I am the sole author of the thesis named

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which has been submitted to the study commission of geosciences today.

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

Dresden, 05/11/2018   Signature

Acknowledgments

Abstract

The new era of digital technology that started with mobile devices allows making use of their portability (McQuiggan et al., 2015) to extend learning experiences in education. Using mobile devices allows changing the learning experience from traditional to a collective experience of spatial, temporal and context-related learning (Kukulska-Hulme et al., 2009). The latter is done by focusing on learning content related to a given location on that exact location through the location-based mobile learning (LBML) (Sailer et al., 2015). This thesis tried to expand current research in LBML by developing a sustainable method of specialized LBML. This research aimed to design a well-structured lecture on understanding techniques of relief representation on maps for cartography students as a proto-type for en-hancing cartographic teaching at universities. The practical outcome was tested with the prospective target group – International Cartography Master students participating in the Alpine Cartographic Field School that took place in Dachstein Alps, Austria. Reviewing relevant literature and case studies has led to conclusion that the suitable pedagogical and design approaches (conceptual and of users' interface) are: (1) collaborative learning that implements constructivist method of learning and elements of situated learning; (2) gamification of learning followed by discussion as a wrap-up; and (3) user-centered design with reasonable accent on its aesthetics. This concept has been implemented as a quiz-based Android OS mobile application – *mCartoLearn* – and the conducted usability testing resulted in useful conclusions on its usefulness in the context of university teaching. Thus, the scientific innovation of this thesis is extending cartographic lecturing at universities from indoor-based traditional and e-learning into outdoor-based m-learning.

Keywords: Location-based mobile learning; M-learning; Context-related learning; Collaborative learning; Quiz-based learning; Learning-by-doing; Cartographic teaching

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Abbreviations

ACFS	Alpine Cartographic Field School
API	Application Programming Interface
AR	Augmented Reality
GIS	Geoinformation Systems
KML	Keyhole Markup Language
LBML	Location-Based Mobile Learning
M-Learning	Mobile Learning
OS	Operating System
POI	Point of Interest
SDK	Software Development Kit
UI	User Interface
UX	User Experience

1   Introduction

This thesis tries to expand the current research in mobile learning where the learning utilizes mobile devices. More precisely, the aim is in developing a new method of mobile environmental learning, meaning that the research focuses on location-based mobile learning. Let us start with an overview of the background of mobile learning and its development since today.

1.1   Background

McQuiggan et al. (2015) gave a simplified historical overview of the educational technology's development: Digital technology (comprehending computers, laptops, netbooks) was experimentally introduced in the educational system already in the 1950s starting with the first computers. It has always been a promising education-revolutionizing tool, but despite it, has not managed to change the teaching concepts thoroughly since today. Students have had broader access to computers in schools since the 1980s, but the study curriculum has always focused on explaining how computers work, programming and games, and not using them to support the teaching for making learning more natural and more interesting to the students. Furthermore, by using computers in education ensured that students could adapt their learning pace to themselves, but in general, that has been the only benefit of it as computers have not managed to customize the learning process itself to individual's needs. In other words, the teaching was still the same for every student. The new era of digital technology in education started in 2010 with first tablets on the market: Their characteristics, like user's input by touchscreen, intuitive user interface, and access to the Wi-Fi, initiated the era of mobile (i.e., portable) technology. The authors have also recognized the importance of answering questions on computers and tablets such as *"Have they changed education in the same, fundamental way?"* and *"Are they being used to enhance instruction and change the way we learn for the better, or as just another tool in the same old pedagogy?"* Trying to answer these questions, they have realized that the impact of computers and tablets in education was not as significant as it was in other sectors (e.g., industry), our works, homes, and everyday lives. The revolution and a new era in the education system are finally expected with the development of mobile learning as it allows being flexible about the place where learning will take place and the content and, at the same time, students gain relevant skills in

handling the new technology and understanding its benefits. Let us follow the authors' enthusiasm and define now what mobile learning is. (McQuiggan et al. 2015)

1.1.1   Mobile Learning

In general, there are two main approaches in understanding mobile learning (m-learning): one argues that it is primarily related to the learner's mobility allowing him or her to learn anytime and anywhere while the other argues that it primarily refers to the portability of the physical device (McQuiggan et al. 2015). This thesis understands m-learning according to the first approach – like learning that relates to the learner's mobility.

McQuiggan et al. (2015) understand m-learning as *"the experience and opportunity"* – or in other words the benefits – that the modern technology offers to the educational system. They do not consider it the characteristic of mobile devices themselves, but primarily the

> *"anywhere, anytime learning enabled by instant, on-demand access to a personalized world filled with the tools and resources we prefer for creating our own knowledge, satisfying our curiosities, collaborating with others, and cultivating experiences otherwise unattainable."*

It allows merging formal and informal learning in a modern joint system. In other words, m-learning assumes its creativeness and benefits primarily when used in the right way. The main characteristic of mobile devices which enable this way of learning is their portability which means that they are of small physical size (which makes them easy to carry) and can connect to the Internet (so that the learner accesses the learning material on demand at any place). Because of these characteristics, the authors consider tablets, smartphones, and small personal media players as mobile devices exclusively. (McQuiggan et al. 2015)

The same approach had also Sharples et al. (2009)when they defined m-learning as

> *"the processes (both personal and public) of coming to know through exploration and conversation across multiple contexts among people and interactive technologies."*

Furthermore, Kukulska-Hulme et al. (2009) argue that mobile technology is only one part of the digital technology used in education. When using it together with desktop computers, the system allows interactivity and joining experiences of spatial, temporal and context-related learning. The authors also argue that using mobile technology in

education with a proper pedagogical approach is becoming the focus in its future research.

The main characteristic of mobile devices, as already mentioned – their portability (McQuiggan et al. 2015) – allows designing the learning process by directly connecting (i.e., placing) it to locations which are didactically crucial for the learning; thus, bringing us to a more specific type of m-learning – Location-Based Mobile Learning – so let us take a closer look at it in the next section.

Location-Based Mobile Learning

While m-learning generally understands learning as learning about anything at any place (McQuiggan et al. 2015), its further distinction introduces the Location-Based Mobile Learning (LBML). LBML is context-related learning which implies learning something related to a given place (context) on that exact location which means it is the on-the-spot method of learning. The term LBML was nicely summarized by Sailer et al. (2015) expressing it as m-learning subtype where the learning is carried out on the exact location of the contextualized content. In their analysis, they focused primarily on the teacher in charge and recognized the challenges related to implementing an LBML system in teaching and designing LBML management systems. Patten et al. (2006) wrote that among their classification of handheld devices' applications, collaborative applications are most beneficial (among location-aware) for the learning process. Except introducing the gamification of learning, those also support contextual or constructionist pedagogical approach at the same time; thus, the authors argue that for getting best learning results, it is wise to combine elements of collaborative, contextual, constructionist and constructivist pedagogical principles instead of basing the learning only on one of those.

1.1.2   Related work

Until now, there has already been relevant research on m-learning carried out. For example, Sailer et al. (2015) have designed *OMLETH,* a prototype implementation of LBML platform for teaching purposes at the Eidgenössische Technische Hochschule (ETH) Zürich, Switzerland. There, they have mainly also focused on teacher's experience, and not only on context and user. As shown in Fig. 1.1, *OMLETH* also allows the interaction between teachers and students. The cycle starts when the teacher creates site-based exercises, i.e., learning modules, in the system's editor mode according to the curriculum. After publishing created exercises, they are available to students on the

server. Students access exercises via their mobile devices at a real-world site: Once they are in the neighborhood of the exact location, they locate by pressing the self-localization button. Upon successful self-localization, the push service automatically triggers the exercise if the student is inside the designed learning area (polygon). Students can see the learning content on their mobile devices through a web-based application: Therefore, the user's interface is a scalable web map. When students resolve all tasks, the system stores their results on the server and the teachers can use them for evaluation. Teachers can also analyze learners' movement history (path), and their speed of solving tasks as well – which are both beneficial for improving lectures. While students are solving tasks, there is also the chat function available for real-time communication between teachers and students. Examples of activities that students have to do are consuming context information by text or photo, solving tasks by text input, multiple choice, voice or video recording, distance estimation, or activities that involve interaction with, learning from, and comparison of current and historical maps, explain. (Sailer et al. 2015)
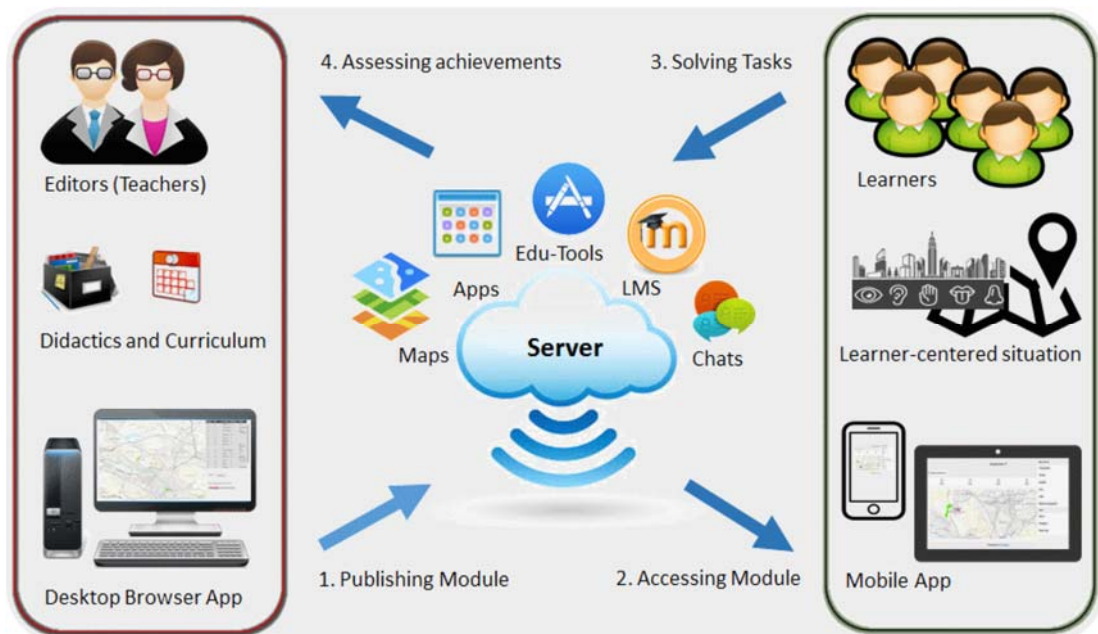
Fig. 1.1 *OMLETH* (Sailer et al., 2015)

Another study, by Melero et al. (2015), focused on users' experience and explored learners' satisfaction when working in groups and sharing a mobile device. For this purpose, a game-based learning system named *QuesTInSitu: The Game* was created as a location-based game for an indoor learning activity as a part of art classes for secondary school

students. Students have to visit a museum where they answer questions about exhibited art pieces. In order to answer a question, they first have to find the painting related to it inside the museum. The research focused on answering what the ideal group size (i.e., the number of learners per group) for game-based learning is. The authors also analyzed differences in performances between students who had exclusive right to interact with smartphones and the ones who did not interact with them at all. Results have shown that different group sizes, and interacting or not interacting with the smartphone, were both important factors on how much attention students made and how much they participated in resolving these group-based m-learning activities. In total, all analyzed groups had the same performance, but students from smaller groups expressed higher satisfaction in participating in the project and smaller distraction in resolving the tasks. Also, students who were holding the smartphone and responsible for interacting with the system expressed higher satisfaction with participating in the experiment. (Melero et al. 2015)

Now, having an understanding of m-learning's basics (and LBML's as well) and seeing related research examples, makes it a right moment to introduce the motivation of the thesis research, its objectives and aimed scientific novelty.

1.2   Research Identification

The research goal of this thesis is to develop a location-based mobile learning system for on-the-spot learning of relief representation on maps methods. Thus, it aims at designing a practical and purposeful application which meets the thesis' idea of an outdoor lecture, and requirements of a pedagogically well-structured lecture at the same time. Let us now analyze these two general characteristics and draw the research objectives and questions out.

1.2.1   Motivation

This thesis tries to expand the current research in m-learning, and LBML, by developing a sustainable method of specialized environmental m-learning. The research aim is to design a well-structured lecture on a comprehensive relief representation understanding for cartography students. Since mobile technology is nowadays widely available, it can be practically considered necessary to take advantage of it and offer the students a modernized learning method. The main research inspiration was the idea that lots of students, if not even the most, are ready to rely on mobile devices more than on analog

sources and for this reason, they could benefit from a new context-related learning approach (i.e., LBML). Furthermore, the idea was to design it for use on hiking trails and other outdoor locations interesting in historical, geographical, and morphological ways. For example, countryside valleys, hills, mountains, and even volcanoes, national parks, and similar places could be adequate locations for lecturing relief representation. The reason for it may be a faster learning process with students having various real-world examples in front of them which would, therefore, make more sense compared to traditional classroom teaching. Thus, within this master thesis, an educational lesson utilizing mobile technology for information presentation and communication (to students) will be designed, implemented, and tested. The practical outcome targets cartography students taking part in the Alpine Cartographic Field School (ACFS) module at the beginning of the third semester of the Erasmus Mundus Plus International Cartography Master program. After giving the topic background and research motivation in this section, the following one identifies the research by defining research objectives, questions, and aimed innovation.

1.2.2   Research Objectives and Questions

To the result of before mentioned research identification being purposeful for targeted users' group (i.e., cartography students), this research focuses on developing an LBML application for the environmental context of ACFS module – Dachstein Alps in Austria. As an addition to the existing field school manual of the ACFS, the application should take advantage of interactive possibilities of mobile devices and give students an experience of learning and interacting on engaging real-world locations. The resulting product should allow students to adapt their learning pace to their own needs and wishes. Therefore, the research indirectly focuses on making the learning self-paced as well. In addition to that, this research does not aim at developing concepts for individualizing m-learning, even though before mentioned that the future development of mobile devices' usage in education should also go in that direction. This research should derive a generic prototype for the relief representations' understanding.

The stated research objectives are the basis for deriving research question – And answering those questions represents the main research workflow towards the end-result. Research questions are as follows:

1. *Which pedagogical approach is suitable for a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum?*

2. *Which is the suitable conceptual design of a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum?*

3. *Which user interface design of the location-based mobile learning lecture on the methods of relief representation on maps is efficient and motivating for cartography students for learning?*

Defining the research objectives and questions outline the research innovation aimed at – This research aims at finding a new, or improving an existing, way of context-related environmental learning by using mobile devices. It will do so by combining the learning process with location-related observations by the on-the-spot method of learning. Of course, as in any research and its implementation, some difficulties might be, and it is generally advisable to try to identify some of those in the early stage of the research. Thus, the next section gives an overview of those.

1.2.3   Risks and Contingencies

There are always realistic chances that some of the research ideas related to the conceptual design will encounter some logical or practical issues during implementation, or testing. Thus, this section gives a certain focus on possible contingencies which may arise. The risks which could come up in the research implementation, or testing are:

1. *Encountering the weakness, or the lack, or the GSM, mobile data connection and GPS signals in countryside areas which are poorly covered by those and where the exercises will take place – for example in valleys, hills, mountains, glaciers, and similar.*

Two hypothetical situations can arise as results of the weakness, or lack, of the GSM, mobile data connection and GPS signals in countryside areas which are poorly covered by those and where the exercises will take place. The first hypothetical situation is uncertainty that the users can precisely define that they have found the right location, i.e., the one where they have to solve location-related tasks. If students are not on the right location, they might not answer some of the asked questions correctly as those will be related to the context (i.e., sight) of the spot. A possible solution to overcome these two situations could be focusing on selecting only open-area locations with higher chances of strong signals and visual recognition – for example, meadows and ridges instead of woods and valleys. In these cases, even if the accurate self-positioning would not be

possible due to lack of precise GPS location, users could still position themselves approximately using low-precision network self-positioning or, in cases when also the mobile provider network signal is not available, by using visual location recognition and common sense. The second hypothetical situation is running the mobile device application in case of lack of the mobile data connection if the implementation is web-based instead of stand-alone. Considering the internet may not be guaranteed already gives a hint of not being sensible to utilize web technology for implementing the conceptual design: It would be logical to consider the implementation as a stand-alone or hybrid application for mobile devices.

2.   *Selecting the most suitable developing environment for making the location-based mobile learning system available to the most, or even to all students considering different operating system characteristics of their mobile devices. Furthermore, depending on that selection, follows the question of competence in the developing environment (i.e., programming language) to be used.*

After considering if the implementation of the conceptual design should be as a standalone or hybrid application for mobile devices, the question of making it available to most, or even to all students considering different operating system characteristics of their mobile devices arises. For that, it is necessary to select the appropriate developing environment which leads to the question of having enough competences of programming in the selected developing environment follows. As in general the primary goal is not implementing the thesis research for all possible operating systems (OS) of mobile devices (e.g., Android, iOS, Windows, and others) but to make a good conceptual design, it means that developing only for Android OS using, for example, Android Studio, is acceptable.

3.   *Encountering bad weather conditions during usability testing*

The targeted users' group for testing the developed application are International Cartography Master students (as mentioned before in 1.2.1 Motivation) who participate in the ACFS taking place in the area of Dachstein Alps in Austria. The field school takes place in October every year, lasts ten days, and consists of excursions to different locations every day; thus, there is a risk of encountering unfavorable weather conditions. It is questionable if the itinerary can be rescheduled on-the-spot in that case since the excur-

sions are carefully planned, and the weather in the mountainous areas is fairly unpredictable even on a daily basis.

4.   Providing content for the implementation through the mobile application

The research aims at designing and developing a location-based mobile learning system, which per se means that it will probably have to use many examples that relate to the environment related to that locations. Thus, the risk that may occur is the availability of enough relevant content, i.e., maps of different kinds – e.g., topographic and thematic maps of Dachstein Alps, Austria in different scales.

After defining the research objectives and questions, and considering contingencies, it is now time to define the methodology, i.e., the way to achieve the research objectives, answer research questions and overcome the contingencies. Thus, the following section deals with the latter.

1.2.4   Adopted Methodology

The research bases on several phases whose purpose is to answer research questions and meet research goals. The methods for addressing research goals and questions represent research phases and are as follows:

1.   Literature review

The literature review aims at answering research questions by studying the theoretical background of related problems and is the method of gaining knowledge for bringing conclusions on which the conceptual design will base. Also, literature study will give knowledge about the potential and challenges related to mobile and LBML which aims, as before discussed, on context-dependent learning by using personal electronic devices, such as smartphones and tablets.

2.   Conceptual design of the location-based mobile learning system

The conceptual design of the location-based mobile learning system will base on the knowledge and conclusions resulting from the literature review, and its leading requirement is meeting the university module curriculum requirements (i.e., standards). In other words, this phase defines learning goals and brings together the pedagogical, technical and innovational requirements of the new m-learning lecture.

3. *Physical implementation*

This phase includes the physical implementation of the conceptual design of phase two, i.e., developing a concrete product in the form of a mobile device application.

4. *Usability testing*

After completing previous phases, the usability and effectiveness of the product need to be tested and based on it, conclusions on the research made.

2 Literature Review

As earlier mentioned, the purpose of the literature review is leading to conclusions on which the conceptual design will base. Thus, this chapter shows the results of the literature review and answers the three research questions.

2.1 Pedagogical Approaches to Teaching and Learning

The first research question is *Which pedagogical approach is suitable for a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum?* which means the pedagogical background of teaching and learning methods first has to be reviewed to make conclusions that answer the research question.

Learning is a complex process characterized by various aspects. How successful will it be, depends on student's motivation, cognitive capabilities, (support of the) environment, teacher' professional (i.e., subject-specific) and pedagogical skills, and other factors. Because of that, it is important for a teacher to understand well the process of learning and continuously improve the teaching methodology adapting it to students' motivation, wishes, capabilities, and performance. (Forsyth 2016)

Psychological approach teaches us that the learning process consists of several learning subprocesses which Forsyth (2016) described as:

a) Cognitive processes

Learning is driven by cognitive processes which analyze (i.e., process, work-through) the information we receive. All new information compares to the existing knowledge in the same moment it is received. Therefore, the more we know (of a topic), the easier and faster it is for our brain to deepen our knowledge by understanding new facts and linking them to the previous knowledge (to what we already know). The learning process is also affected with our current state of mind: This means that if we heavily focus on personal, or other problems (i.e., non-related to the topic), it will take us longer to learn because of the high cognitive load. The same also happens if we receive too much information in a short period – our cognitive load is again too high. In other words, when our cognitive load is suitable for the situation, we learn easier. However, what is *suitable cognitive load* if we consider that different people process the information with different speed/velocity: some faster, and some slower? For college students, the system (i.e., university, teachers) considers they have similar cognitive capabilities and theoretical

background. Therefore, the appropriate here means that for the average student, the cognitive load should be neither too big – as it could demotivate the student for learning; nor too small – as it could make the lecture boring.

b)   Motivational processes

As previously already implied, the environment also influences the learning process. It may create positive emotions which could motivate students to do their best, or can even demotivate them from performing well. As the learning is considered to be an emotional process, other than only of previously mentioned personal situations, emotions that lead the learning process may be the result of talent, performance and social support as well. On the one hand, if we perform well, understand the lecture easily, get support from peers, teachers, or family, we will be positively motivated and want to get even better. On the other hand, if we do not perform well, have to earn money for living, have health, love, or family problems, we might not be strongly motivated to become the best student in the class.

c)   Personal processes

Personal processes in learning are all those individual differences that define how successful will students be, and how will they succeed. For example, individuals may learn better by reading texts or understanding charts, tables, and images; learn slowly or quickly, and thoroughly or incompletely; be willing to try cheating to perform better; work or learn better in a group, or alone; prefer memorizing definitions, or solving practical tasks, and similar.

d)   Interpersonal processes

Except for personal, interpersonal processes are also important in learning which means that socializing and communication with classmates and teachers influences the learning process. Thus, presence in the classroom is beneficial for learning: It leads to discussions, collaboration, and socializing, which all have a significant influence on shaping one's learning process.

e)   Evidence-based practices

It is generally not easy for a teacher to obtain maximal students' performances. On the one hand, it is beneficial that the teacher considers teaching in a way he finds the most useful for himself – In that case, students may benefit from teacher's big personal experience. On the other hand, it is also important to structure the lecture according to

proven and tested, teaching methods: This is not trivial because, as previously mentioned, it is important to consider the cognitive load and the depth of student's background. In that way, the delivery of the course gets neither too easy (which can make it boring), nor overdemanding (which can make it demotivating).

Learning at universities requires from the students the in-depth learning, i.e., high learning skills which combine all before mentioned learning subprocesses. In other words, it is not enough to only read a paper, and notice listed bullet points and definitions – It is necessary to understand the paper in a way that the main ideas, principles, and methods can be perceived and extracted, even if not explicitly stated. Students should also be able to discuss the paper, perceive its meaning in the profession, link it to their previous knowledge and solve tasks related to it. Furthermore, they are also expected to have a background of the topic, and high skills in writing, communicating, using digital technologies, working in teams, and understanding cultural differences in order to succeed in their studies. All these characteristics enable analytical thinking, requesting further explanations, understanding concepts, and bringing conclusions. One of the leading educational purposes is not only providing information to students, but also to achieve a thorough understanding and to perceive the information *"clearly, logically, critically, and profoundly."* The purpose of all these is to make students able to apply the knowledge, i.e., to solve a problem in the real world – on a project, at work, and similar. (Forsyth 2016)

2.1.1   New Learning Approaches

There are three main methods of learning: *individual, collaborative* and *situated learning.* Individual learning is a traditional way of education always emphasized in the past. Today, institutions and teachers are trying to encourage students to learn in different ways – For example, mostly by emphasizing social collaboration and context-related tasks, and often offering the learners the latest technology. Collaborative and situated learning methods have developed as a result of experimenting with learning by social collaboration and solving context-related tasks. (Ryu and Parsons 2009)

Now, let us see how Ryu and Parsons (2009) define the differences between the three learning methods:

a) *Individual learning* employs the *constructivist* method of learning where an individual builds-up his previous knowledge based on new information and experiences. Thus, the new knowledge is built-up on the previous one. A modern version of

individual learning is game-based learning which often gives learners a higher motivation to involve themselves as it makes the learning process more fun.

b) *Collaborative (student-to-student) learning* is proven to be equally effective as traditional (teacher-to-student) learning, and moreover, to bring students more pleasure in learning. A benefit of collaborative m-learning in comparison to the individual is giving diversity in learning as students are not focused only on interacting with their device anymore, but also on interaction with peers. Of course, as already stated, collaborative lectures should be well-designed so that students get positively motivated to learn from each other, and come to right conclusions.

c) *Situated learning* is context-related learning which makes situated m-learning learning with a mobile device application that is aware of its location and can adapt the content accordingly. For example, in developed and well-digitized cities, mobile applications could get the context from data collected by numerous sensors placed in the current real-world location (i.e., of the user) and adapt the content to it.

As already been mentioned (see 1.1.1 Mobile Learning) the modern approach to learning leans mainly on collaboration, i.e., collaborative learning. Thus, let us now go into more details on the characteristics of collaborative learning.

2.1.2   Collaborative Learning: Getting to Collaboration

Dillenbourg (1999) understand collaborative learning as learning where new knowledge results from group task solving and cooperation – not from merely task sharing. In other words, the process of collaborative learning should include brainstorming and creative discussion, rather than merely splitting tasks or sharing (re)sources – as this would not qualify the learning as collaborative learning. The benefit of learning in a group involving activities like mutual *explanations, agreements, disagreements,* and *regulations* which result in clarifying, task solving and absorbing new information, i.e., *new knowledge.* Precisely this is the purpose of collaborative learning – motivating students to work together in order to trigger and emphasize learning mechanisms for increasing the chances for successful learning. The authors differentiate four main conditions for triggering good collaboration (i.e., group work, interaction):

1. *Initial conditions* – Setting up initial conditions is not an easy task. Generally, different tasks and topics require different conditions for triggering a constructive collaboration. There are many arrangements to be carried out, like optimal group size, type of groups (e.g., heterogeneous or homogeneous groups by sex, viewpoints, theoretical background, and similar), tasks for triggering the collaboration, usage of devices in case of using additional devices like computers or mobile devices, and other.

2. *Collaboration contract* – Two handy methods for triggering interaction between group members include: (1) Defining a scenario and assigning roles to students, and (2) Allocating different visual aid or source to each team member. These methods usually manage to inspire students to cooperate in finding the solution.

3. *Interaction rules in the medium* – The teacher should instruct students how to behave in the discussion, for example by expressing their agreement or disagreement, and backing-up their point of standing by giving arguments and ideas for improving the solution.

4. *Supervising the interactions* – The teacher should be involved only by monitoring and assisting in case of problems. The teacher's role is not guiding the interaction or providing correct answers, but assuring a constructive collaboration.

Other than here mentioned, collaborative learning wraps other different aspects of learning like working in groups from two to any number of people, lasting from short (e.g., 20 min) to long (e.g., a year or more) terms, type of content, and way of interaction in learning. These are all to for considering when creating a collaborative lesson. (Dillenbourg 1999)

The authors also argue that even though sometimes not all students might have the same background knowledge depth, but it is essential that they share the same goals. That is why setting-up common goals for students is an essential step in creating a stimulating collaborative environment where learners work together on finding the solution instead of splitting the work onto subtasks among themselves – They ought to study the materials, and solve tasks together, and that is the crucial difference between cooperation and collaboration. The authors nicely define that

> *"a situation is termed 'collaborative' if peers are more or less at the same level, can perform the same actions, have a common goal and work together."*

The authors also say that *interactivity, synchronicity,* and *negotiability* are essential characteristics of collaborative interaction. Firstly, as before mentioned, interactivity means that the work is done together, and not by splitting it in the group. Secondly, the synchronicity means that frames for real-time interactions have to be defined. For example, if students should communicate electronically, which delay in delivering and answering to messages can be considered as a real-time (i.e., synchronous), and which as a non-real-time (i.e., asynchronous) communication? Lastly, the negotiability means that the peers have similar academic or professional rank and base the discussion on arguments, not on their titles or statuses. For example, an interaction between boss and employee, or teacher and student, is less negotiable than an interaction between employees or students only. Other than the three mentioned, another important feature of collaborative interactions are *misunderstandings* since they often lead to discussions that are beneficial for learning. To wrap up, the path to successful collaborative learning is based on *suitable cognitive load and putting different opinions together in real-time* for triggering explanations, conflicts (as differences in opinions often lead to solution questioning and re-thinking) and solving real-world tasks. (Dillenbourg 1999)

Now, after reviewing relevant literature, let us proceed with concluding the answer to the first research question.

2.1.3   Conclusion

Let us first remind of the first research question: *Which pedagogical approach is most suitable for achieving the planned location-based mobile learning lecture for cartography study curriculum?* After consulting the literature, and researching modern approaches to that topic, the conclusions which will be the base for designing the mobile learning lecture are as follows:

− Considering the three main methods of learning (individual, collaborative, and situated) a highly automated situated m-learning system in the research application environment would not be possible as there are no required sensors installed on the mountains, for example. That means that various data sources for modifying the application's content would not be available on-the-spot. Therefore, this research will focus on designing a collaborative m-learning utilizing the constructivist method, but it will make use of some aspects of situated learning approach, like planning the context. In other words, the

examples and tasks will relate to real-world locations, but the application will not actively and dynamically utilize the context – a route the content will be pre-designed.

‒ Collaborative lectures should be well-designed so that students get positively motivated to learn from each other, and come to right conclusions through mutual explanation, agreement and disagreement, misunderstanding, and regulation (Dillenbourg 1999).

‒ Portable technology is nowadays being offered to students as a learning tool attempting to provide experiences different from using desktop computers and laptops via e-learning systems. As the content designed for e-learning systems is not appropriate for mobile devices – as it does not make use of benefits of the portable technology – it is crucial to design the content according to the used technology. (Ryu and Parsons 2009) In other words, the purpose of it is to assure that students can apply the knowledge in the future. (Forsyth 2016)

In simple words, the most suitable pedagogical approach for designing the aimed location-based mobile learning lecture for cartography study curriculum is *collaborative learning implementing the constructivist method of learning and elements of situated learning.* Let us now proceed to the second research question.

2.2   Practical Approach to Designing Mobile Learning Experiences

The first research question *Which is the suitable design of a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum*? means the location-based learning mobile learning literature has to be reviewed to make conclusions that answer the research question. Thus, this chapter aims to answer how to define and design a location-based mobile learning lecture on relief representation on maps for cartography students.

2.2.1   Learning Perspectives

In contrast to Patten et al. (2006), who saw the content and the function of m-learning as the most important in designing mobile learning systems, Ryu and Parsons (2009) focused on the experience of m-learning (i.e., the experience of learning with newest mobile technology) as the vital aspect of it. M-learning system should consider two main perspectives, technical and learning perspective, linked with the individual, collaborative

and situated learning activities (see 2.1.1 New Learning Approaches) into a learning space. When designing the system, it is necessary thinking also of technical perspective to avoid the misbehavior, or possible failure, of the system. (Ryu and Parsons 2009))

Technical perspective

Technical perspective's principal characteristics are (1) mobility; (2) user profiles; (3) user interface; (4) multimedia facilities; (5) communication support; and (6) spatial-temporal dimension. (1) Mobility means that the system should guarantee the mobility of the user, or the portability of the device, depending on the understanding of mobility (see 1.1.1 Mobile Learning). (2) Type of users, their needs, and preferred ways of communication and learning should be regarded as well by creating user profiles: For example, some users might be keen on using SMS or chat services, while others e-mails. Type of mobile learner is essential for content customization, but as previously mentioned, this thesis focuses on temporal, not contextual flexibility. Thus, as mentioned in 2.1.3 Conclusion, m-learning lecture will not be able to "learn" about the learner (e.g., his learning habits, style, and efficiency), but the context-related content will be pre-designed. (3) The user interface should be intuitive and react fast to the user's input without overloading the system operating capabilities. (4) Learning should be supported with relevant multimedia. M-learning should consider different media types for enhancing users' learning experience and helping them understand the content: For example, it could employ images, animations, videos, augmentation, and similar. (5) Possibility for communication between students and teachers might also increase the learning success or speed it up. (6) The spatial-temporal dimension is related to the context by a priori describing it, and known in this research as all learning activities will depend on the outdoor locations of Dachstein Alps in Austria (spatial dimension), and it will take place during one of the 10-days Alpine Cartographic Field School excursion (temporal dimension). (Ryu and Parsons 2009)

Learning perspective

Mobile learning should not only merely put together the learning and the technology, but it should also link them in a qualitatively providing meaningful learning experiences like (1) exposition; (2) exploration; (3) elaboration; and (4) exploitation – All important pedagogical aspects of learning. (1) Expositional learning means exposing the learner to a predefined content. In m-learning it means that the content should be delivered in

multiple portions of less information, rather than as a whole at once. The main idea is that user can access a task multiple times since m-learning often takes place as a secondary activity between two primary ones. Therefore, the user might not always complete tasks at once and might want to repeat the learning. (2) M-learning should also be exploratory by offering the user the freedom, or creativeness, in reaching the goal, whether guided on this path or not. The explorational character makes m-learning also more exciting and enjoyable. (3) M-learning should include collaborative activities which trigger students' socializing closer through communication and problem-solving: This way, they are developing elaborative skills by explanation, argumentation, and discussion (as discussed in 2.1.2 Collaborative Learning: Getting to Collaboration). (4) M-learning should also include learning from mistakes – which is the exploitation component of m-learning. (Ryu and Parsons 2009)

Fig. 2.2 shows a schematic overview of technical and learning perspectives of mobile learning as the learning space of the mobile learning system. It would be now logical to continue with reviewing successful implementations of the mobile learning: Thus, the following section is dealing with that.
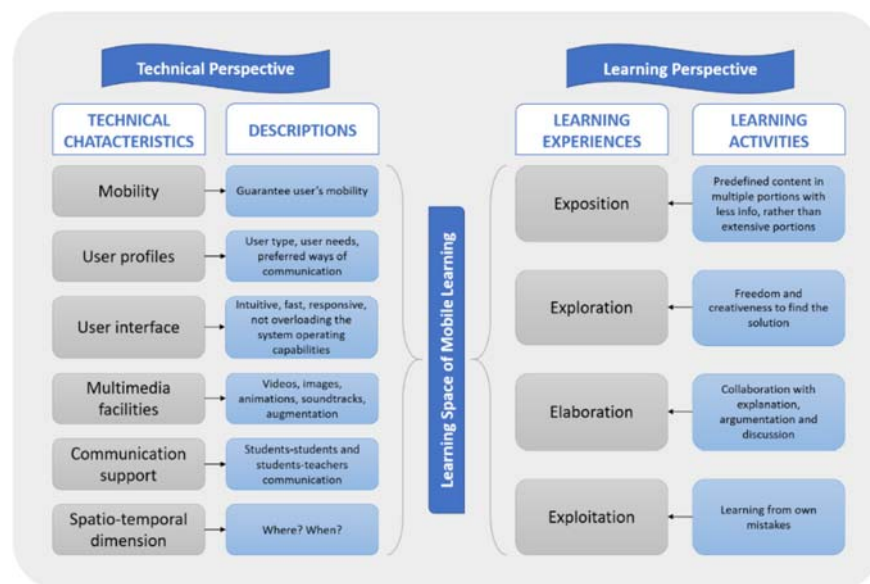

Fig. 2.2 Learning space of a mobile learning system

2.2.2 Case Studies: Learning Getting Game-Based

This section reviews several practical m-learning implementations which leads to useful insights for the thesis research by understanding the applied principle of m-learning lectures.

The first example is the *AMULETS* project in the period from 2006 to 2009 where Spikol et al. (2009) explored how does the new mobile technology help the learning process. They created three different indoor and outdoor collaborative m-learning systems and performed usability testing with elementary school children and teachers. Their results have shown that while users highly enjoyed using the technology and receiving additional information on the topic, they ranked the collaboration experience higher and more useful. Also, the authors have discovered that different groups came to different conclusions [Author's comment: Knowledge], thus recommended having a discussion session at the end of the lecture. The research conclusion was that contextual learning by utilizing portable technology, and game-based characteristics was a successful learning method which both the teachers and children recognized as a useful experience, which emphasizes the importance of putting additional attention on stimulating a productive collaboration and discussion within groups.

The second example is an m-learning system named *PLASPS* created by Yin et al. (2009) to help students understand how sorting algorithms work. The *PLASPS* consists of three parts: initial process, system-driven, and learner-driven learning. The system employs a scaffolding principle or learning which combines two learning techniques. In the first step, students receive instructions, theory input, and instructions for cases of mistaking. In the second step, students learn by doing, i.e., based on right answers, mistakes (i.e., discovery learning), and discussion with peers (since the system does not indicate what, or where, the mistake was). The system's architecture consists of: (1) server module; (2) teacher module, and (3) student module. (1) The server module consists of a central database, schedule, GPS, and sorting managers, and keeps track of history log. (2) The teacher module consists of the teacher(s) who is responsible for defining the task on the server module. The teacher defines groups' sizes, chooses a sorting algorithm that is going to be the learning task, and stores these settings on the server. The module is connected to the server module by a wired Internet connection. (3) The student module consists of students who receive instructions via their mobile devices, solve the task, and upload the result to the server, and have a discussion of the experience. The student module has two interfaces – user and help interface – and is connected to the server module by a wireless Internet connection. (Yin et al. 2009)

Now, pure theoretical input can satisfy learning for traditional school exams but does not necessarily lead to a full understanding of the content and being able to apply the knowledge for problem-solving in the real world (e.g., at work). Skills like teamwork, independence, and responsibility are necessary to take part in a modern world. Thus, new ways of learning are mainly replacing traditional constructivist methods of learning. A new approach – pervasive games as a way of learning – could motivate students to compete in finding a solution. When a game also includes tasks like describing the problem and solution, it could lead to better understanding of the topic, and developing analytical thinking. Thus, the third example of applied m-learning is learning by pervasive gaming – the Digital Economy game created by Kittl et al. (2009) which shows that students achieved had better learning results than students in previous case studies: The differences were noticed in various aspects – emotions, flow experience, and information assimilation, processing, and storage. (Kittl et al. 2009)

The fourth, and last example of applied m-learning is the *Light Aircraft Pilot* application, developed by Owen (2009) as a part of the EU m-learning *COLLAGE* program. It shows that it is possible to engage learners by multiple-choice question quiz. The learner pretends to be a pilot on the plane and has to bring the same decisions as a real pilot in a plane would in order to keep the aircraft flying. A wrong decision could cause plane crashing, and this gives the learner the motivation approach seriously to answering questions, and think of consequences. Quiz authors have concluded that questions should be formulated to represent real-world situations (i.e., problems) giving at the same time opportunity for analytical reasoning, and learning by doing – not by memorizing theory content. (Owen 2009)

In the last two examples, the authors have shown that having fun and playing game can be additional dimensions in designing learning experiences. As employing game-based learning gets bigger and bigger attention in teaching, the Institute of Play (2018) designed seven principles for *game-like learning:*

1. *Everyone participates* – The game should allow all students to contribute in solution finding, depending on his or her experience, or background:
2. *Mistakes are considered iterations* – Mistaking is not considered failing, but getting experienced;
3. *Learning is fun as playing a game* – Learning experience is fun and engaging;

4. *Doing is learning* – Doing is an opportunity to think analytically;

5. *Real-time feedback is provided* – Learner can track their progress in the moment of learning;

6. *Learning is full of challenges* – The solution is not reached effortless – it is not served on the plate;

7. *Everything is linked* – Learners share their experiences, knowledge, and learn from each other.

Now, having these seven recommendations, let us take a look at are they implemented in a commercial mobile application for m-learning – Babbel by Lesson Nine GmbH (2018)– an application for learning languages using mobile devices. On the one hand, it is not designed for collaborative learning, or competing in learning – in other words, for group learning – but, on the other hand, some of the previously listed recommendations for game-like learning (2 to 6) are nicely visible (see Tab. 2.1). For example, mistakes are iterations, and user learns by doing: This is visible from Question screens 2 and 3 where the user first makes a mistake since no explanation helps to find the solution – User should discover it on his own which makes learning a challenge. These screens also depict that user receives the feedback on the correct or false answer in real-time (i.e., right upon selecting the answer), and the user can proceed to the next question only after answering correctly. At the same time, learning is also fun – after selecting the correct answer, the user sees a photo depicting the answer, also aiming at helping to remember the answer for the future. On the Performance Feedback screen is visible that the system keeps track of all correct and false answers; thus, the user gets feedback on his performance at the end of the lesson. Now, after reviewing relevant literature, case studies, and a commercial mobile learning example, let us proceed with concluding the answer to the second research question.

2.2.3   Conclusion

As before, let us first remind of the first research question: *Which is the suitable conceptual design of a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum?* After consulting the literature, and researching modern approaches to that topic, the conclusions which will be the base for designing the mobile learning lecture are as follows:

1. Question Screen	2. Question Screen
This is the Question screen that shows a question, multiple-choice and feedback on the current progress (i.e., the user is answering third of four questions).	This is the Question screen that gives real-time feedback that the selected answer is not correct.
3. Question Screen	4. Performance Feedback Screen
This is the Question screen that gives real-time feedback that the selected answer is correct.	This is the Score Feedback screen that notifies users of their score of the just completed lesson.

Tab. 2.1   *Babbel's* screens (Lesson Nine GmbH, 2018)

– Mobile learning conceptual design should provide meaningful learning experiences like exposition, exploration, elaboration, exploitation;

- Mobile learning conceptual design should motivate students to have fun while learning by collaboration and using mobile devices, and compete in finding solutions; thus, it should be game-based, for example as multiple-choice question quiz with scoring system, and try to follow the Institute of Play's (2018) seven principles for game-like learning as much as sensible;

- All students should come to the same knowledge; thus, it is recommended having a discussion session at the end of the lecture.

In simple words again, the most suitable concept for designing the aimed location-based mobile learning lecture for cartography study curriculum is *game-based mobile learning lecture closing with a public discussion*. Let us now proceed to the third, and last research question.

2.3   User Interface Design

The third research question is *Which user interface design of the location-based mobile learning lecture on the methods of relief representation on maps is efficient and motivating for cartography students for learning?* which means this chapter aims to answer how to structure the user's interface to be efficient and motivating for learning, and at the same time to meet the requirements of answers to the first two research questions.

To answering the research question, let us first start with an analysis of the existing augmented reality (AR) geographical applications conducted by Wang et al. (2017). The authors ran the analysis to get to conclusions useful for their research objective of developing the *GeoFARA* (Geography Fieldwork Augmented Reality Application). Their results have shown that (1) the AR view consists of real-time scenes as seen through the camera and context-related information as an additional interactive layer; (2) map views display either static or digital [Author's comment: Interactive] maps – either as base maps or satellite image layers; and (3) all types of multimedia can be integrated – texts, images, sound records, animations, and videos. Based on these results, the authors also argue that the application needs a user-centered design. (Wang et al. 2017)

To designing a user-oriented interface, the ISO 9241-210:2010 standard describes steps in developing a product. The first step in the design process is defining the context of the product's use. The following steps are designing the product which best meets user requirements, evaluating the product with users, and improving it in critical aspects based on the evaluation results. Finally, once the product has satisfying results upon

iterated evaluations, it is considered as use-ready and can be released. By following this lifecycle in developing the *GeoFARA* application, the authors have first defined the learning context and researched user requirements for an AR system through a field-work with a group of geography students. The students were taken to the fieldwork in Dongshan (Suzhou), China to learn about the spatial structure of the town and influence of human activities on the environment. Questionnaires, interviews, and observations investigated user requirements. Prior learning activities, students filled a questionnaire which has shown the user profile: age, gender, the field of study, background on the topics and AR, familiarity with mobile technology, and others. Students' were observed during learning activities, and after completing the work, part of students and teachers interviewed. (Wang et al. 2016)

2.3.1   User-Centered Design

Let us now take a closer look on user-centered design; Garrett (2010) sees it as a product design process which focuses on the user's experience in using the product. It is about how easy or intuitive it is for the user to reach the goal [Author's comment: To do a task] using a specific product, for example, software or digital device. Product developers often focus on making the product multifunctional and thus making it very complicated for the user to understand how the product works and follow handling steps. Also, the user design is often understood only as an aesthetical of functional design – For example, making the product either very stylish, either functioning correctly. Both of those approaches are important; thus, both should be considered at the same time. In other words, the aesthetical design should make the product is visibly attractive, and functional design capable of doing the task. Both of these designs have a direct impact on user experience; thus, it is essential to consider the user experience design as well. User experience design should answer how easy or practical is the product for using: is it easy to find the functions, are they comfortable and intuitive to be used, and similar. For example, it should show if the buttons are too small for fingers, too close to each other, too hard to find them; is it easy to pan and zoom the map, possible to scroll on the page; are the menus too complicated, and similar. (Garrett 2010)

Regarding web technology [Author's comment: Software, applications, websites], it should be designed for easy understanding and using it with no need for manuals,

instructions, training, or extensive customer support. Users should be able to use the product from the first moment; otherwise they might feel stupid for not understanding how it works; thus, the usage should be sufficient. The authors nicely define user-centered design as *"The practice of creating engaging, efficient user experiences […]"* Its main characteristic is that it considers users in every step of product design. In other words, it is the designer who designs the user experience – the users themselves are not responsible for the experience. (Garrett 2010)

2.3.1.1   User Experience

The conceptual framework of user experience consists of five elementary planes: surface, skeleton, structure, scope and strategy plane. Firstly, the *surface plane* defines what the user sees at first, a basic understanding of the product. Secondly, the *skeleton plane* consists of the product's functionalities and their arrangement to be easily accessible. It defines how to present the information, and interface and navigation design which show the user how to interact with the system, and navigate through it. Thirdly, the *structure plane* defines the arrangement of product's elements, and how can the user access them – i.e., defines if the product's navigation is horizontal or vertical structure. It includes interaction design (how the system responds to the user's actions) and information architecture (how are the information organized). Fourthly, the *scope plane* defines how product's features and functions fit together by answering the question *What are we going to make?* It also defines the product's functionalities and content requirements – For example, the scope could define if the user can save settings like user detail for future use. Content requirements do not need to apply to the product as a whole: some might apply only to specific features. Lastly, the *strategy plane* defines how can user and producer both meet their goals. It should answer *Why is this product being made?* For example, the provider wants to sell goods because users want to buy those goods; or a lecturer is keen on teaching a particular topic because students show interest in it. Thus, the strategy defines both users' needs and product objectives. (Garrett 2010)

Now, the five elementary planes were presented in the order users experience it; they see first its surface and last its strategy. However, from the producer's side, the user experience is built from bottom to top, meaning from strategy to surface: By considering each step in this order – from invisible to visible – the result will be a well-

connected user experience architecture where each plane is dependent on the plane below. The author further divides further these five planes into two parts: *functionalities* and *information*. Functionalities considering tasks which user can do with the product, while information considers the information that the user can reach by using the product, and how to navigate them. (Garrett 2010)
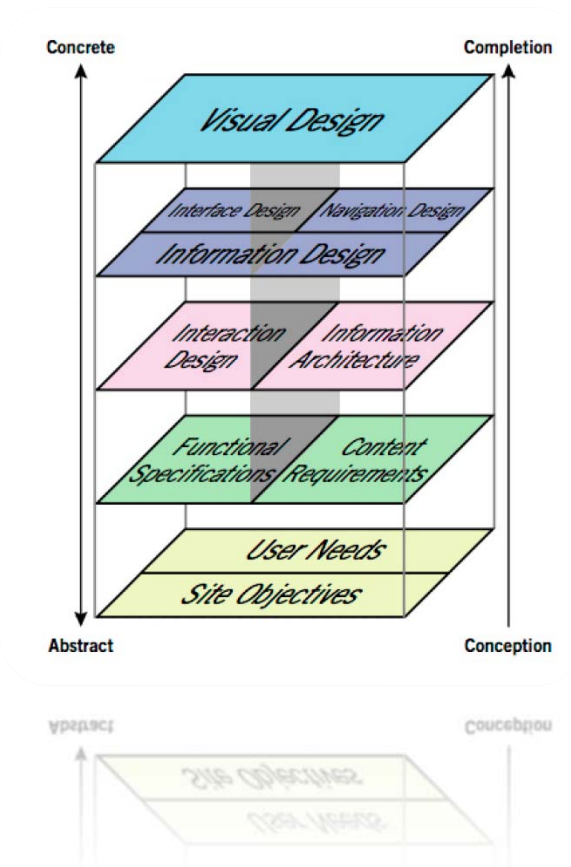

Fig. 2.3 Elements of user experience for conceptual design (Garrett, 2010)

Furthermore, Fig. 2.3 by Garrett (2010) schematically shows the product's planes, and nicely wraps-up the importance of combining both aesthetical of functional designs as explained earlier: Defining product's five planes is followed by visual design to bring the product to completion and concrete. The same was also implied by Sonderegger and Sauer (2010) who conducted a study on the influence of design aesthetics on user performance and perceived usability. For their study, they have designed two prototypes of a mobile phone: one that can generally be considered appealing, and one unappealing. Their focus in designing these two prototypes was on devices' color, texture, symmetry, and clarity, while functional-wise they were identical. School students were asked to evaluate the prototypes before and after using them, and the results have

shown that they rated appealing phone's usability higher than unappealing one, both before and after using them. Furthermore, the device's aesthetics had a great impact on students' motivation for using it, which is the reason why students' performance was higher when using the appealing mobile phone than not-appealing. (Sonderegger and Sauer 2010)

Now, after reviewing relevant literature and a case study, let us proceed with drawing conclusions to the answer to the third research question.

2.3.2   Conclusion

As before, let us first remind of the first research question: *Which user interface design of the location-based mobile learning lecture on the methods of relief representation on maps is efficient and motivating for cartography students for learning?* After consulting the literature, and researching modern approaches to that topic, the conclusions which will be the base for designing the mobile learning lecture are as follows:

– The product's conceptual design should follow the five planes structure to consider user experience;

– Product's aesthetics has a high impact on students' motivation for using it; thus, the m-learning application has to focus on its aesthetics in a reasonable amount;

– The context of product's use will specify a persona and scenario;

– The route should be displayed on a map interface by either static or interactive map – either as base maps or satellite image layers.

In simple words again, the most suitable user interface design needs to base on *five elementary planes of user experience* and utilize an *appealing aesthetical design* to provide students motivation for learning and satisfying user experience.

After reviewing the literature related to the research questions on mobile learning lecture design, let us now proceed to the conceptual design that will lead to the physical implementation of it.

3   Results

After answering the research questions in the previous chapter (2 Literature Review), it is time to develop a research concept based on those answers. After the conceptual design, the next step is implementing it, and upon that, testing it with users. Thus, this chapter deals with the latter. Let us start with the conceptual design.

3.1   Conceptual Design

At first, in order to define the concept of the aimed m-learning lecture, it is necessary to define the outcomes of the learning. Then, based on those, the learning space can be structured as suggested by Garrett (2010), followed by considering the user experience and belonging data architecture. As the learning space is an extensive structure, it will be defined through the first two subchapters (3.1.1 M-Learning Outcomes and Learning Space and 3.1.2 Elements of User Experience) instead of at once. At last, the persona and scenario follow logically before proceeding to the implementation, and usability testing.

3.1.1   M-Learning Outcomes and Learning Space

The outcomes of the m-learning session represent its *strategy plane* and should be considered from two main perspectives: *learning* and *technical perspective*. While the learning perspective defines learning goals, the technical perspective defines optimal technical performance and user interface (UI) design. When both of these aspects are optimized, they should guarantee a smooth and satisfying user experience (UX). Also, learning and technical perspectives define the content requirements for the scope plane.

Learning perspective

Considering the research objective – designing a lecture on comprehensive relief representation understanding for cartography students utilizing mobile devices – the outcomes of the learning experiences arise of it as follows (and as inspired by Lázaro Torres et al. (2017)):

1. A better understanding of the relief representation methods after solving the quiz;
2. Improving map-reading skills – orientation, navigation and terrain perception – by meeting the first goal;

3. Encouraging collaborative situated learning with analytical reasoning and discussion based on doing;

4. Ability to apply new cartographic knowledge to other study assignments and in everyday life.

These objectives can be further thought-of as the *scope plane's* content requirements as the mobile application's content should support reaching the following objectives: Upon completing the lectures, students can:

1. Understand isolines, calculate a point elevation, and elevation difference between two points using information provided on a map by isolines;

2. Understand the importance of light source position and contour lines information for the terrain shading technique;

3. Understand the terrain structure that the hachuring technique shows – for example, the differences in representing rocks, debris, and scree on the surface, and indicating the direction of mass movement.

4. Understand the relation of elevation ranges and colors used in the elevation tints technique;

5. Virtually perceive the terrain (e.g., terrain profile, or steepness), and recognize different terrain structures on a map (e.g., valleys, hills, peaks, ridges, cliffs, rocks, and others) based on understanding cartographical techniques from the first two points;

6. Draw or mark the direction of prominent terrain characteristics (e.g., valley bottoms, ridges) onto a map;

7. Navigate and orientate themselves along the route using a provided map, and GPS and compass sensors embedded in the mobile device.

Technical perspective

The technical perspective should assure that the implementation of the learning perspectives enables:

1. Successful completion of the lecture;

2. Good system performance;

3. Intuitive UI which does not need thorough handling instructions;

4. Engaging (i.e., exciting and motivating) UI design.

It should also make sure that the *structure plane* includes easy navigation, intuitive interaction and good (visual) content organization for the user. The structure plan itself will thus base on three main application interfaces: *map, quiz,* and *instructions interface.* How those relate to each other is explained in the following subchapter 3.1.2 Elements of User Experience in section (2) Content architecture.

Based on technical and learning perspectives, a learning space as shown in Fig. 3.4 follows the Ryu and Parsons' (2009) suggestion. It shows how technical specifications relate to the learning context and learning activities to learning objectives. Together, they form the designed collaborative situated mobile learning system, i.e., its learning space.
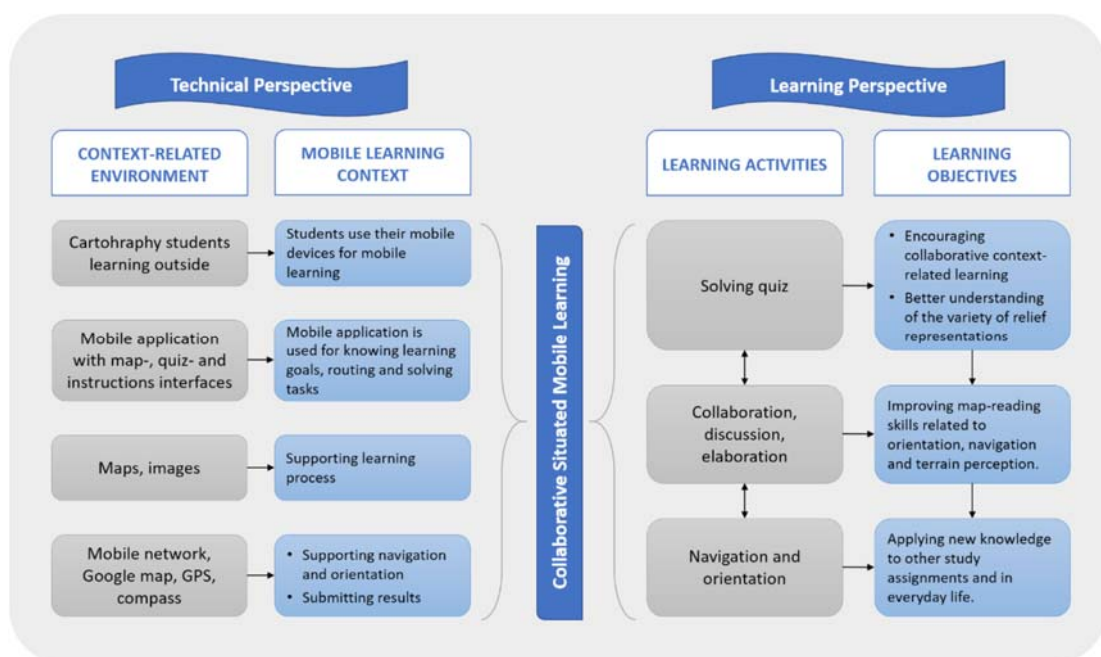
Fig. 3.4 Learning space of the conceptual design

3.1.2   Elements of User Experience

The conceptual design of the m-learning system design was inspired by Wang et al. (2017) and divided into four main features: (1) mobile application functionalities; (2) user interface(s); (3) content (i.e., data) architecture; and (4) hardware and software specifications. Each of them will be explained now into more details.

Mobile application functionalities

As one of the main purposes of the m-learning is to offer a good user learning experience, the functionalities of the mobile application need to follow accordingly. These are the possibilities of user's interaction with the system, meaning what should

the mobile application be able to do, and what should the user be able to do. In this purpose, the planned minimum of application functionalities was:

- Giving the option to save students' details, for example, a group number and participants' names;

- Displaying a navigational route map so students can navigate and orientate themselves in the environment to find locations where individual lessons should take place;

- Symbolizing locations where students should stop and learn by solving the quiz and context-related tasks;

- Reloading the default route display in case of losing orientation on the map, or unintended panning to areas far from the route;

- Displaying quiz-based questions, context-related tasks, examples, and comprehension questions

- Providing feedback on right or wrong answers, and points scored;

- Providing playing instructions, clarifications, lecture purpose, workflow, and similar;

- Allowing the user to restart the whole lecture, or to leave a lesson while solving it;

- Unlocking the access to reviewing answers and submit functions after completing all lectures;

- Reviewing answers to comprehension questions to allow the possibility to discuss further and analyze the answers, and edit them if wanted;

- Providing feedback on the overall core;

- Submitting the results – the overall score and the answers – to get evaluated by the teachers.

As previously defined in this chapter (see 3.1.1 M-Learning Outcomes and Learning Space), the strategy and scope planes are mainly set by learning and technical objectives. Following the Garrett's (2010) data architecture, the application's architecture differentiated into the *user interfaces,* and *content architecture* defines the structure plane. Let us then now review those in the following sections.

(1) User interfaces

The mobile application will consist of three main interfaces that will present the content:

1. *Map interface* – for navigation and orientation;
2. *Quiz interface* – for learning;
3. *Instructions interface* – for understanding the learning goals, application functionalities, and students' tasks.

Firstly, map interface gives an interactive route overview with self-positioning functionality. The reason for it is that to start with context-related learning, students first have to reach the targeted location on the route; they first have to find the way there by using a map. Secondly, even though the map interface should motivate students to practice their navigating and orientating skills independently (of others who already know the way – e.g., teachers), the targeted learning is being done in the quiz interface. Its purpose is to stimulate students to jointly collaborate on and discuss the tasks to answer the single-, and multi-choice questions correctly, and open questions precisely: This means that the quiz interface conveys the learning content on relief representations on maps to students. For this reason, it could also be thought of as a *learning interface.* Lastly, the instructions interface should provide information for understanding the learning goals, what are students' tasks, and the learning flow of the lecture. The relations between these three interfaces, i.e., the mobile application architecture, are explained in the following section.

(2) Content architecture

As mentioned in the latter section, the application consists of three main interfaces that present the content: map, quiz, and instructions interface. The interface architecture scheme in Fig. 3.5 shows their relation to each other. The scheme shows the default interface upon opening the application – is the map interface. From it, the user can access the quiz interface and the instructions interface. Therefore, the *structure plane* (i.e., data access) begins at the map interface having a vertical hierarchy; the quiz, and instructions interfaces are children of the map interface (which is parent interface). At the same time, the instructions interface child can also be accessed directly from the other child – quiz interface – allowing with this user's higher flexibility, and quicker access to the lecture goals and playing instructions overview.
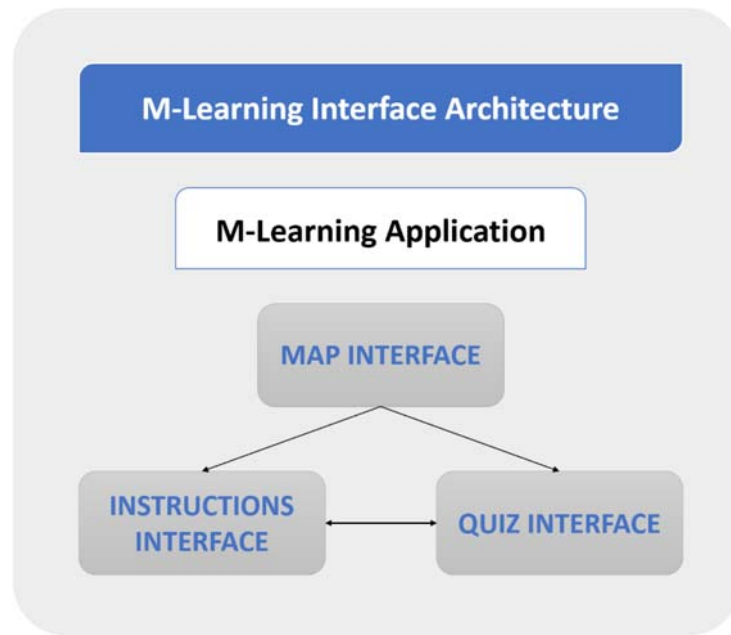
Fig. 3.5 M-learning interface architecture

The second scheme in Fig. 3.6 is quiz architecture scheme that shows a parallel architecture of the quiz interface meaning that each question can only be accessed after correctly answering the previous one, and consequently, the last comprehension question can only be reached if all previous questions and tasks were successfully solved. In other words, it is not possible to skip questions and tasks, and only completing all lessons enables the reviewing and submitting the answers and results' functionalities. At the same time, this scheme also gives the insight on the information presented as the part of the skeleton plane by showing that the information is presented sequentially inside the quiz.

To sum it up, the connection between mobile application interfaces is hierarchical with the map interface as the parent one. The quiz interface is organized in a half-parallel architecture, meaning that the access to the lessons is parallel – they can be accessed unrelated to each other, at any time – but the questions within a single lesson are accessed sequentially – one after another. Furthermore, reviewing and submitting the answers and overall score can be accessed only after completing all lessons; which makes the access to those functionalities sequential, even though being displayed on the quiz interface by parallel-looking access.
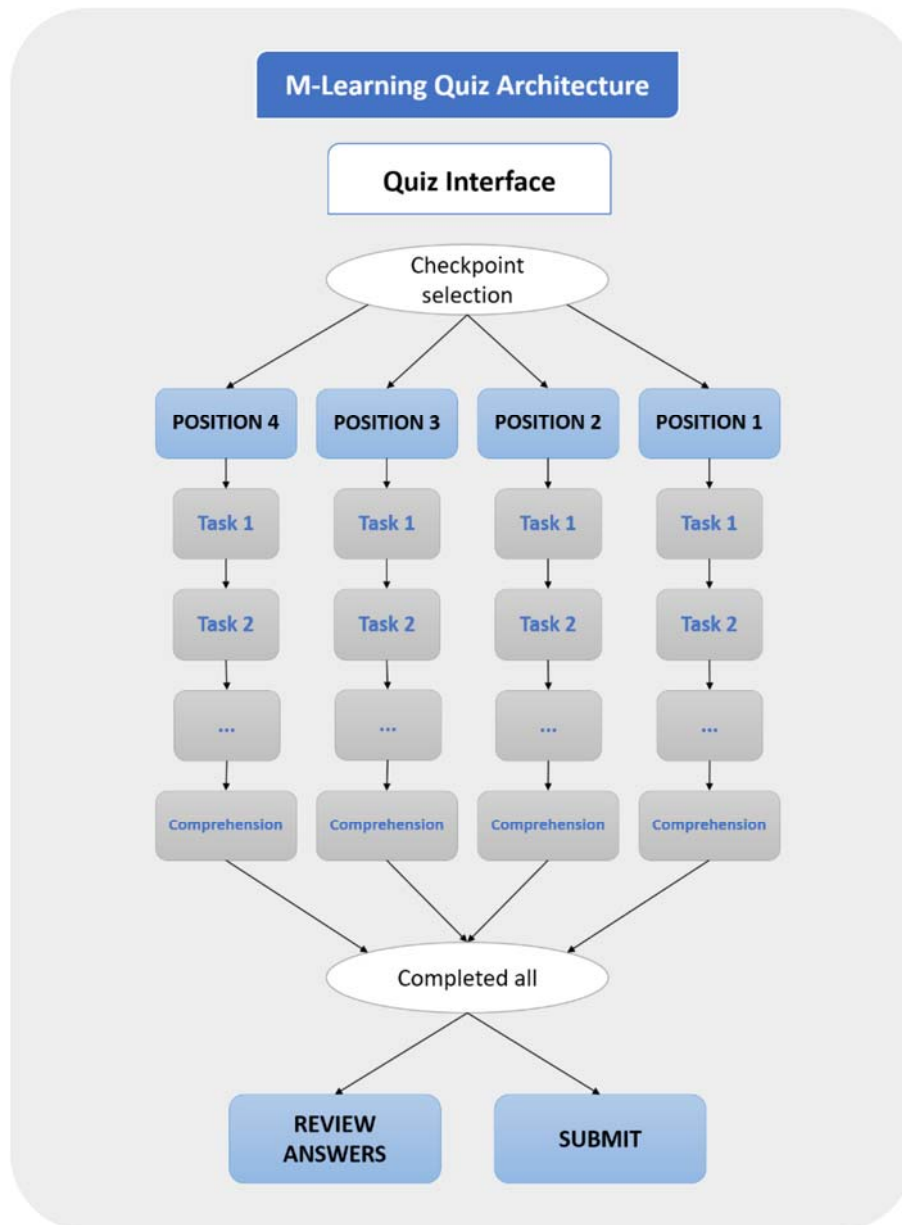
Fig. 3.6 M-learning quiz architecture

(3) Hardware and software specifications

The first technical requirement of the m-leaning lecture is using a mobile device with a reasonable-sized screen in order to clearly see the content and efficiently interact with user interfaces. Thus, a tablet, or smartphone of screen size 4 inch or larger, is needed since the mobile application has complex interfaces with maps, multiple-choice questions from two to six possible answers, and open questions. Using a small-screen mobile device, for example, smartwatch, is not sufficient and would most probably not even allow successful interaction with the quiz interface, and completing the tasks, even though it could be rather easy to navigate the route (to learning locations). The second

technical requirement for a successful m-learning lecture that follows previously designed concept is that the mobile device has GPS and compass sensors for navigation and mobile data connection for loading the map; The latter may even be done in advance, e.g., by Wi-Fi, before going out to the field). The reason for these two technical requirements is the fact that the m-learning does not assume a need for additional hardcopy materials, for example, a printed map, to compensate the screen size or navigational capabilities.

Furthermore, while these two requirements were related to the device's hardware specifications, the third requirement is related to the device's software specifications. Therefore, the third, and last requirement of the mobile device is utilizing an operating system (OS) which supports smooth user experience in displaying and using the embedded interactive map and solving the quiz. In this purpose, a minimum OS version like Android 5.0 (API level 15 – Jelly Bean), iOS 5, or equivalent, is recommended.

3.1.3   Persona and Scenario

Essential elements for defining the scope of the product are defining the persona and scenario. They give a clear insight to the user type and situations in which the product is going to be used; Also, they answer an essential question for defining the product's surface plane: *"What are we going to make?"* Out of it, two leading sub-questions evolve: *"Who will be using the product?"* and *"In which situations is the product going to be used?"* (Garrett 2010) For this reason, the persona and scenario need to be created with attention. To fit the persona well into the research context, she was created considering general student statistics for International Cartography Master's intake 2016, and the Alpine Cartographic Field School (ACFS) questionnaire on students' learning experiences of the excursion for the same intake, as well.

Persona

Her name is Anna (25), and she is enrolled in the third semester of the International Cartography Master of the Erasmus Mundus Plus joint program of four partner universities – Technical University of Munich, Vienna University of Technology, Dresden's University of Technology, and University of Twente. Her bachelor's study was in GIS and Remote Sensing; she is familiar with using topographical maps for navigation but does not have a deep understanding on the represented relief on those – she cannot name cartographic methods used, or produce a map like that. Therefore,

Anna wants to get familiarized with different relief representation methods used on a topographic map because as by her experience as a map user, she is skilled only in reading toponyms and identifying different vegetation areas on the map. She sees the map only as a whole, and cannot differentiate the constitute layers of relief elements. For this purpose, Anna thinks it would be good to introduce exercises related to this topic to the ACFS; for example, reading contour lines could be one of them. Moreover, Anna would have nothing against if some lectures utilize electronic devices; for example, mobile devices. For Anna's overview, see Fig. 3.7.

Anna

,,I need to learn and apply skills of cartography more. I want to improve my understanding between cartography and relief.''

Anna has often used topographical maps, but she is frustrated that she is only able to get a basic understanding of the terrain out of them. She believes that she needs a deeper map understanding as a cartographer.

Age: 25
Occupation: Student
Studies: M.Sc. in Cartography
Semester: 3rd
Previous studies: GIS and Remote Sensing

Technical profile: Familliar with maps and digital technology. Owns a large-screen Android smartphone with fast processor and Internet (Samsung Galaxy A5 (2017)).
Maps use: For orientation and navigation. Easily understands map legend.

Fig. 3.7 Persona

Scenario

Every third semester of the International Cartography Master organized by the Technical University of Munich, Vienna University of Technology, Dresden's University of Technology, and the University of Twente, enrolled students participate in a module organized as a field school – Alpine Cartographic Field School (ACFS). It takes place in the area of Dachstein Alps in Austria and students are accommodated in Ramsau am Dachstein, a place convenient for daily excursions because of its proximity to the locations that the students visit. The field school lasts ten days, of which seven days is for field excursions, two days for traveling there and back from Dresden by cars and one day for resting. By defining where and when, the spatial-temporal dimension of the

m-learning learning space is also finally defined; thus, the learning space is now complete.

One of the daily excursions is the excursion to Dachstein Südwandhütte where students start close to the Neustadtalm (beneath the Dachstein glacier), and their task is to find the way to Dachstein Südwandhütte, located beneath the Dachstein glacier as well, by themselves as an exercise for practicing orientation and navigation in space. After reaching the destination, they have free time for lunch and rest. On their way back to the starting point (Neustadtalm), students conduct the m-learning lecture on relief representation methods on maps. During this lecture, they follow the designed route and stop at marked locations. On these locations, they use their mobile device, where they have preinstalled the m-learning application, and solve the tasks related to the lesson designed that location.

As Anna is taking part in the ACFS (see Fig. 3.7), she also participates on the excursion. She had installed the application on her smartphone the evening before and charged the smartphone during the rest at the Dachstein Südwandhütte. At the beginning of the m-learning lecture, lecturers divide students into groups. Anna joins with two other students, and they decide to use her smartphone for conducting the lecture, as she has a big screen, and has almost fully charged her battery.

When the group starts the mobile application, it decides to navigate along the route by using the self-positioning functionality of the mobile application. Therefore, Anna turns on the mobile data connection and Location option on her smartphone to get the device's precise position. The group starts walking the route marked on the route map in the mobile application. Every once in a while, they check their position when they have doubts about the right direction. When they reach each location marked on the route map, they solve the quiz lesson designed for that location using Anna's smartphone. In the group, there is also a student who is experienced in cartography and geography more than Anna and the third peer. This student's study background is very valuable in tasks solving as the group aims to gain a high score in the quiz. The questions that they have to answer, and tasks that they have to solve, are based on analytical reasoning, and discussion and collaboration within the group; This way Anna learns and gets experience in cartographic topics. When the group reaches the Neustadtalm again and solves the last lecture, they review and submit their answers for

later evaluation by the teachers, and wait for all the groups to get together at the Neustadtalm again. Then, they further discuss the answers all together and bring conclusions on best answers. This way, Anna doublechecks what she has learned, and strengthens her previous answers on the lessons.

3.1.4   M-Learning Phases

Based on the user scenario, three logical m-learning phases can be defined; These phases represent the flow of the lecture and should be communicated to students by teachers as the following steps:

Phase I: Before excursion

 – *Step 1:* Students owning an Android OS mobile device (smartphone, tablet) should download and install the application prior to the field trip;

Phase II: During excursion

 – *Step 2:* Teachers bringing students to the beginning of the route if it is not easily reachable from the accommodation (e.g., they need to be driven there); otherwise students find the start location by themselves;

 – *Step 3:* Forming groups by assuring each group has one Android OS mobile device for using it. After starting the application, students should read the *Instructions* – They get enough time to get familiarized with their tasks and learning goals, for example about 10 minutes. If further clarifications are needed, students discuss them with lecturers;

 – *Step 4:* Students orientating by reading the map, finding the route and predefined locations, and solving the quiz. They should collaborate, think critically and learn from each other. The next meeting point for all groups is the end point of the route;

 – *Step 5:* Upon reaching the route end, each group reviews their answers to comprehension questions. Once they are satisfied with the edits they have eventually made, they submit their results using the submitting functionality which sends the overall group score and answers to comprehension questions to lecturers;

Phase III: After excursion

- *Step 6:* All groups meet, and their task now is finding the best answers to each comprehension question by sharing individual answers and discussing them. After it, every student should be familiarized with cartographic methods for relief representation on maps and able to make his or her definition on it, recognize it on a map, and use the knowledge in the future;

- *Step 7:* Students filling the questionnaire on the m-learning experience (if applicable);

- *Step 8:* Teachers evaluating each group's performance based on submitted results, and grade students.

After defining the m-learning phases, it is now sensible to define the final concept of the mobile application as well. Thus, the following section describes the latter.

3.1.5   Mobile Application Concept

Steps 3 to 5 in the m-learning's phase (see the previous section) II are the basis for the application concept. Therefore, it might be useful to take a look at those steps schematically: The scheme depicted in Fig. 3.8 shows the steps of using the m-learning application. The flow of the application use reflects the already defined scenario. In short, firstly, after starting the application, in first two steps students read the instructions and familiarize with their tasks, and also have the option to save group details, like group number, and peers in the group. Secondly, in the third step, students move to the map interface where the route is displayed. The purpose of this step is to help students with navigation, way-finding and route following – This also represents a way of learning to orientate in the environment and is the secondary source of knowledge generation within the application. Thirdly, in the fifth step, students use the quiz interface for learning on relief representation methods on maps – which is the primary information source. The knowledge is generated by collaboration, analytical reasoning, discussion and learning by doing (i.e., mistaking). Lastly, when students complete all the lessons within the application, in the sixth step, they submit their results to teachers for the evaluation.

Now, this scheme was only a general overview of the functionalities that the app should offer – It means that a detailed scheme before the implementation should also be designed. For that reason, the scheme depicted on the Fig. 3.9 shows the detailed concep-

tual design of the mobile learning application. When the students run the app for the first time, first they see a welcome screen (1) [Author's comment: If it is not the first time, they see the route map screen, which is the default screen, as defined in Fig. 3.5 in chapter 3.1.2 Elements of User Experience, *(1) User interfaces*]. Shortly after, they get to see the screen where they can enter and save details about the group (2): group number, self-given team name, and the participant peers. Before students save the details and proceed to the route map screen (4), they have the option to access the instructions screen (3) with instructions on the goal of the lecture and description of their task (this is also accessible from the route map and quiz screens). When they proceed to the route map screen (4), the system automatically saves group details in an internal database. After the students access the route map for the first time, they see a dialog asking if they want to allow the application access to the device location. If students answer affirmatively, the application shows the option to self-locate on the map.
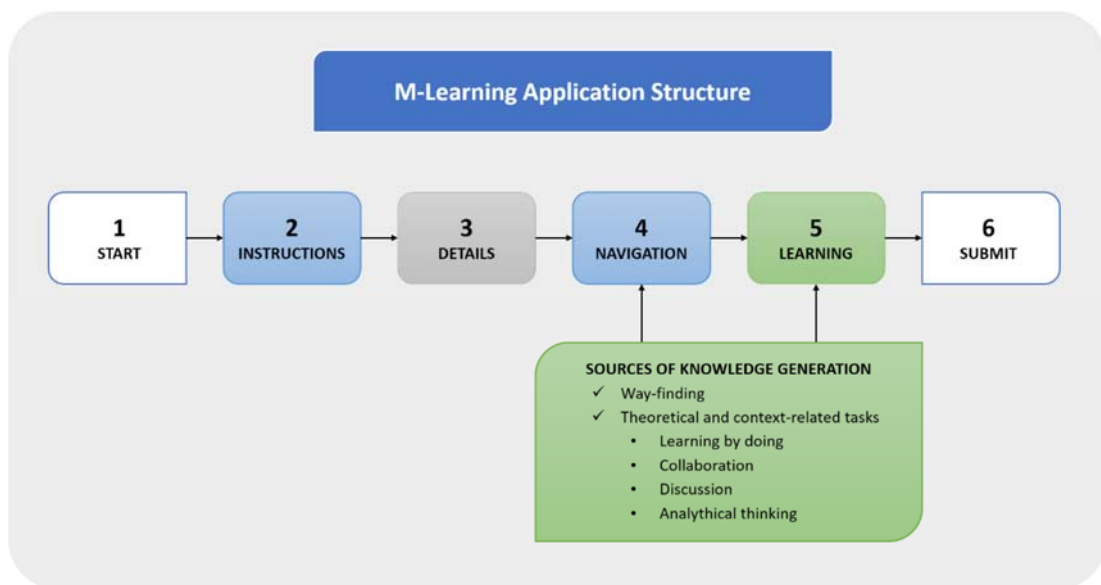
Fig. 3.8 M-learning application structure

The next step is exploring the route map and orientating in the real-world accordingly. From the route map screen, students can access the quiz screen (5), instructions screen (3), or go back to group details screen (2) if they want to edit those. There is also the option to reload the route map view which brings the map camera to the starting position and zoom level and displays the complete route again on the screen. After reaching one of the marked locations on the route, students proceed to the quiz screen (5). This view contains the following: buttons of each cartographic lesson (6); button to

access the answers to the comprehension questions at the end of each lesson (7); button to submit results for evaluation (8); display of the current points' score after solving lessons; button to replay the quiz (e.g., if students want to play the quiz again after completing it once); and, as already mentioned, button to access the instructions.
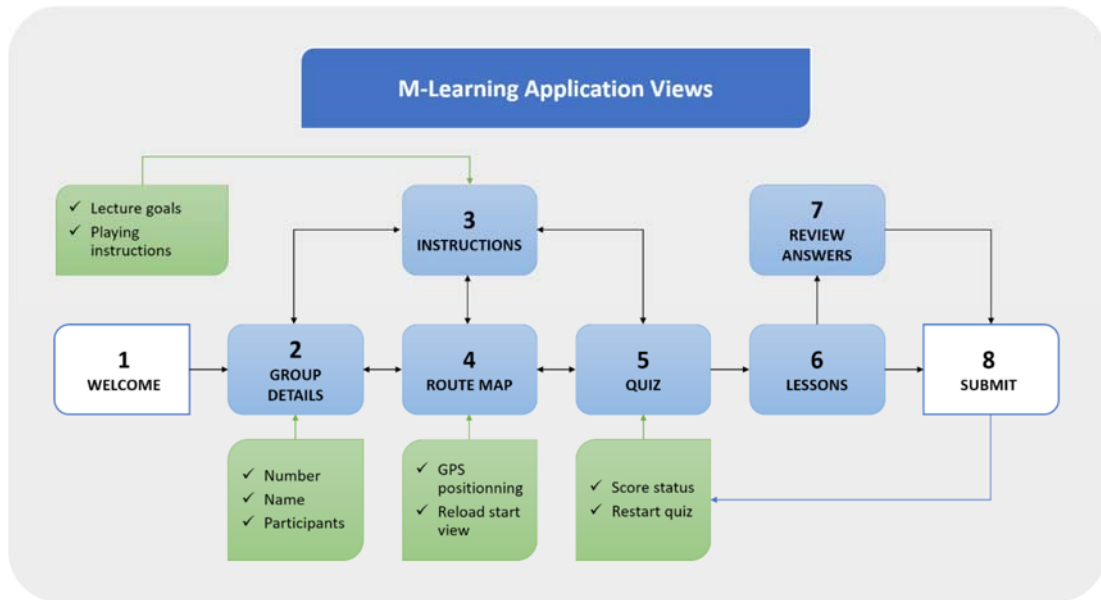
Fig. 3.9 M-learning application screens

Learning

As already mentioned in this subchapter, the primary knowledge generation is related to the quiz interface. Thus, it is sensible to give more detailed attention to its design. The structure of the quiz interface was described earlier in chapter 3.1.2 Elements of User Experience, *(2) Content architecture* (see Fig. 3.6). The scheme shows that each lesson consists of a series of questions and context-related tasks, and a comprehension question at the end for a wrap-up of the topic. Each question screen follows a defined design standard and consists of the question, a hint for finding the solution (e.g., to check the example by clicking the toolbar button, or to pay attention to specific features in the real-world), and a selection of possible answers. The number of answers to choose from varies from question to question. If a graphic example is relevant for the question, the toolbar contains a button for displaying it. Besides that, on each question screen, the toolbar also gives the possibility to leave the lesson and return to quiz screen. If *Leave* option is selected, the score in the current lesson is not held, i.e., the lesson has to be restarted from the beginning next time.

Moving to the next question is possible only after selecting all correct (and none false) answers. The answer check is done upon the clicking the *Done* button on the question screen. If the answer is correct and it is the first try in answering, students get +2 points; If the answer is correct and it is the second try in answering, students get +1 point; And, if the answer is correct, but students took more than two tries to find the correct answer, they get +0 points. When students answer incorrectly, a dialog on the screen gives notification that the answer is not correct and that they should try further to find a correct answer. Each question screen also displays the current score in the lesson in progress. When students answer all questions, the comprehension (wrap-up) question screen displays. Depending on the lesson, it asks students to type an answer or to select an answer from a multiple-choice answers' list. Also, the comprehension question screen does not allow to finalize the lesson until the question is answered assuring this way that students try to make their resume of the lesson. This answer is not graded with points but submitted for the evaluation at the end of the m-learning lecture. Upon answering the comprehension question, students get two notifications: first saying they have completed the lesson, and that the last answer is accessible for reviewing in the review answers screen, and the second giving feedback on how many points they scored in the just completed lesson. After completing the lesson, the user has to reset the quiz to repeat it.

Upon completing all lessons, the functionalities of the *Review answers* and *Submit* buttons finally get enabled. Pressing the *Review answers* button leads to the answers' overview where students can read and edit them if they want to make corrections. The purpose of the *Submit* button is to submit students' quiz results and answers to the comprehension questions to the teacher who will evaluate their performance. It does it by compiling an e-mail without leading to a new screen, but by opening a dialog asking to input sender's e-mail address. Then, it gets the targeted information from the database (group number, students' names, overall score, and answers to comprehension questions), and compiles and sends the e-mail to a predefined teacher's e-mail address. If there is no internet connection available, it notifies the user to turn on the mobile data connection or connect to the Wi-Fi. After all these steps have been done, the last logical step for students is to restart the quiz using the *Reset* button if, or when, they want to repeat the m-learning lecture – for example for practicing what they have learned. This functionality clears the database, which results in *Review answers* and *Submit* buttons being

disabled again, while simultaneously the access to the lessons is enabled, and the new displayed score is zero.

Now, after defining the lecturing and application concept, the next logical step is to proceed to the implementation of those. Therefore, the next chapter describes the physical implementation and includes defining lecture topics, theory content, route, programming the mobile application, and testing the result.

3.2   Implementation

The implementation followed several logical phases: (1) defining the topics for the quiz and creating content for those (e.g., questions, examples); (2) designing the hiking route; (3) programming the application; (4) testing the product; and (5) analyzing usability testing's results. This chapter discusses these implementation phases.

3.2.1   Defining Content

The topics for the concept's implementation are defined to match the mobile application's purpose. Since the purpose of the mobile application is learning relief representation methods on maps, the topics of the lecture are the four methods of representing relief on maps: (1) Contour lines and elevations; (2) Elevation tints; (3) Hachuring; and (4) Shading.

The primary requirement for the quiz content is being context-related in reasonable amounts to provide students the opportunity to understand better the specialties of the relief representation methods on maps. In other words, the content is designed to be a logical mixture of questions (theory-related) and tasks (context-related) for the targeted user group – cartography students which need a professional understanding of the topic. Thus, the content should support reaching the particular cartography-related m-learning objectives as listed in 3.1.1 M-Learning Outcomes and Learning Space. It means that each quiz lesson (i.e., topic) should contain questions that reflect the theoretical background on the topic, context-related tasks to support understanding of the topic, and a wrap-up question to check the students' understanding of the topic after answering all questions and solving tasks. The questions may always be modified and adjusted to a new route, i.e., for different contexts, by the teachers.

Let us take a look at the elevation tints topic and several questions' examples that reflect the questions and tasks style. Question 3 asks students to observe the environment

around them and to think how would they represent it on the map by using elevation tints technique (see Tab. 3.2). After they have learned that elevation tints use colors to represent relief on maps in Question 1, and in what way is vegetation represented on maps in Question 2, they are asked in Question 3 to consider how could they represent the terrain around them with colors by thinking how many colors would they use to do it. After students conclude that first four answers are not relevant because they are related to vegetation, in Question 4, students have to conclude that elevation tints – just like its name implies – are used to represent elevation ranges, and not vegetation, on the map. Thus, it is logical to ask them in the following question – Question 5 – to consider what does the colors' number in this technique relate to so they could conclude that it relates to the number (i.e., size) of the elevations ranges that are being represented by this technique.

Questions and tasks are complex and designed to require observing the environment (context), analytical thinking and discussing for finding and understanding the correct answer.

Tab. 3.2   Questions' examples: Elevation tints

These examples were given for a better understanding of the learning concept and the way the content is being taught and communicated to students. After defining the topics and the content for those, the next step was to define a route with locations that give a clear sight to the surrounding terrain so that the tasks may be well related to the context; this is described in the next subchapter.

3.2.2   Defining Route and Checkpoints

The main requirements for the walking, or in this implementation – hiking, route were:

– Finding, and including, locations from which the environment suitable for the topics' tasks that relate to it can be observed for solving tasks;

– Being suitable for students' physical conditions having in mind that not all students might be in a good physical condition – meaning that it should be a low-demanding route walkable in one afternoon;

– Being in the area which is possible to reach during the 10-day ACFS to the Ramsau am Dachstein in the Dachstein Alps in Austria.

Fig. 3.10   Surrounding of Ramsau am Dachstein

For this purpose, first a broader area around Ramsau am Dachstein (Austria), and Schladming (Austria) was examined on analog topographical maps in scales 1:50K and 1:25K (see Fig. 3.10 and Fig. 3.11). The areas examination was done in collaboration with course lecturers to have experienced feedback on which routes are applicable, and which not. After considering several areas and routes, the final decision was to set the "playground" in the area beneath the Dachstein Glacier. There were several reasons for that: (1) the terrain structure has open-area locations with clear sight; (2) the environment is rich in different terrain structures like valleys, hills, mountain peaks, cliffs, ridges, and others; (3) the area has several hiking routes possibly applicable for the

m-learning route; (4) the m-learning lecture can be combined that day with the excursion to the Dachstein Südwandhütte taking place in the morning.

Fig. 3.11   Surrounding of Schladming

After deciding on the exact hiking route for the m-learning lecture, the route was digitized using Google Maps' online service and exported into a KML file (see Abbreviations). The KML file allowed accessing the sequence of the route's coordinates and editing them using a text editor – Crimson Editor SVN286M into a structure for implementation in Android Studio. Fig. 3.12 depicts the route on a Google Map terrain view base map. As already mentioned, this route is appropriate to walk it in one afternoon and should take approximately three hours for it. The stop locations (i.e., checkpoints) for context-related tasks are marked on the route as well. Those are:

- *Checkpoint 1:* Elevation tints;
- *Checkpoint 2:* Hachuring;
- *Checkpoint 3:* Shading;
- *Checkpoint 4:* Contour lines and elevations.

Fig. 3.12   M-learning route with checkpoints

Firstly, Checkpoint 1 gives a view of the surrounding terrain from a high point, and since the elevation tints' technique uses colors to represent elevation ranges, the location is appropriate for the topic. Secondly, hachuring is a technique of representing scree, debris, and rocks on the maps, and it, therefore, requires a location to observe those. Thus, Checkpoint 2 was chosen for its location right under the Dachstein Glacier where the terrain characteristics like scree and debris are well visible. Moreover, the whole area is surrounded by mountain rocks, which makes this location suitable for relating it to the rocks' depiction on maps as well. Thirdly, Checkpoint 3 was chosen for the terrain shading technique because it gives a clear sight to the valley, hills, and mountain peaks, which is useful in understanding how terrain shading technique works. Lastly, Checkpoint 4 was chosen for the contour lines and elevations' technique, because it is another location with clear sight to the surrounding terrain structures like valleys, hills, a ridge, and uniform, variable, mild, and steep slopes.

Now, after defining the concept of the m-learning lecture, cartographic content that it will teach, and route and checkpoints, the next step was to proceed with the physical implementation of the mobile application; thus, the latter is described in the following subchapter.

3.2.3   Developing Mobile Application

The conceptual part of the m-learning lecture defines that the basis of the learning process being collaboration within a group, and the quiz being solved on one smartphone within a group (see 3.1.3 Persona and Scenario) to keep the group collaborating. The question for which operating system develop the m-learning application arose from these specifications. The first information which was necessary for the decision was the mobile devices' market share. According to the IDC Corporate USA's (2018) statistics in the moment of research – July 2018 – the Android operating system held almost 85% of the market share, being followed by approximately 15% of the iOS's share while the other operating systems' share was around 0.1%, and were, therefore, ignored. Based on this statistic, the assumption was that a sufficient number of students will own an Android-based mobile device and that the groups of no more than two to three students could be formed. Therefore, the decision was to proceed with mobile application implementation for Android OS.

The programming for Android is being done in Android Studio; a developing environment based on Java programming language and Android's Software Development Kit (SDK). The Android Studio version used for implementation was Android Studio 3.2. The projects' specifications in creating the project were set to support the minimum SDK version 15, which means for the Android 5.0 (API level 15 – Jelly Bean), and compiling SDK version 27, which means for the Android 8.1 (API level 27 – Oreo). Further project settings defined in the *build.gradle (Module: app)* file are shown on the Fig. 3.14.

Fig. 3.13   *mCartoLearn* logo

The mobile application was named *mCartoLearn* which stands for *Mobile Cartographic Learning* and will be referenced this way in the following chapters. The idea for the *mCartoLearn* logo (see Fig. 3.13) came from the mountainous Alpine environment which is the excursion's destination and was designed in Inkscape 0.92.1.

```
1    apply plugin: 'com.android.application'
2
3    android {
4        compileSdkVersion 27
5        defaultConfig {
6            applicationId "com.mzahtila.thesisapp"
7            minSdkVersion 15
8            targetSdkVersion 27
9            versionCode 1
10           versionName "1.0"
11           testInstrumentationRunner "android.support.test.runner.AndroidJUnitRunner"
12           vectorDrawables.useSupportLibrary = true
13       }
14       buildTypes {
15           release {
16               minifyEnabled false
17               proguardFiles getDefaultProguardFile('proguard-android.txt'),
                 'proguard-rules.pro'
18           }
19       }
20       sourceSets { main { res.srcDirs = ['src/main/res', 'src/main/res/drawable/chk1']
         } }
21   }
22
23   dependencies {
24       implementation fileTree(dir: 'libs', include: ['*.jar'])
25       //noinspection GradleCompatible
26       implementation 'com.android.support:appcompat-v7:27.1.1'
27       implementation 'com.android.support.constraint:constraint-layout:1.1.2'
28       implementation 'com.google.android.gms:play-services-maps:15.0.1'
29       testImplementation 'junit:junit:4.12'
30       androidTestImplementation 'com.android.support.test:runner:1.0.2'
31       androidTestImplementation 'com.android.support.test.espresso:espresso-core:3.0.2'
32       implementation 'com.android.support:mediarouter-v7:27.1.1'
33       implementation 'com.android.support:design:27.1.1' // design support Library
34       implementation 'com.github.chrisbanes:PhotoView:2.1.3'
35   }
```
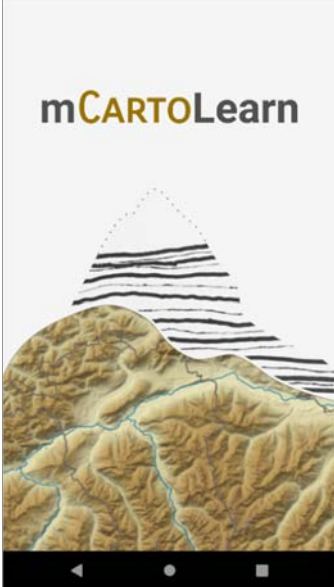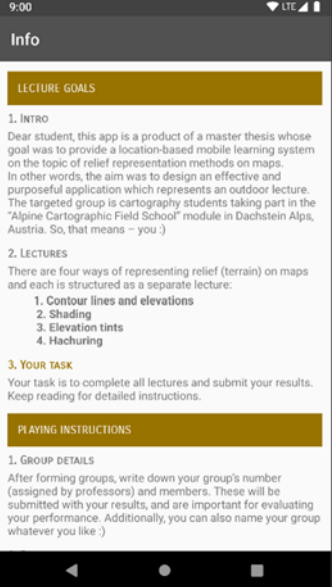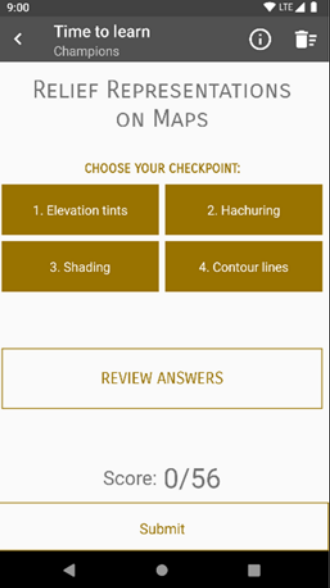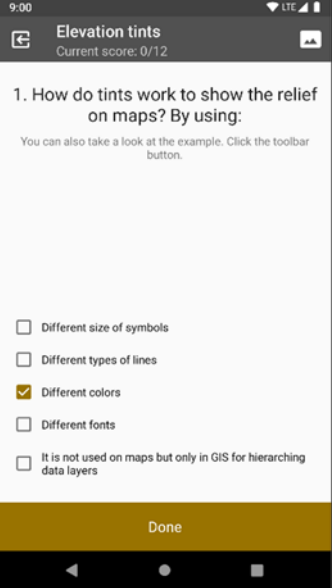
Fig. 3.14   Android project's *build.gradle Module* specifications

3.2.3.1   Mobile Application Screens
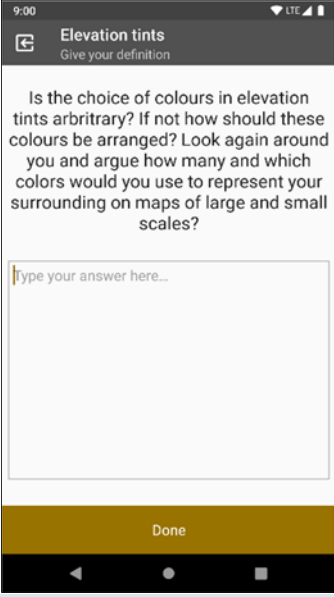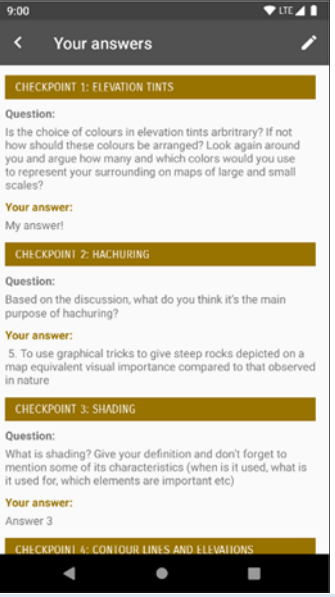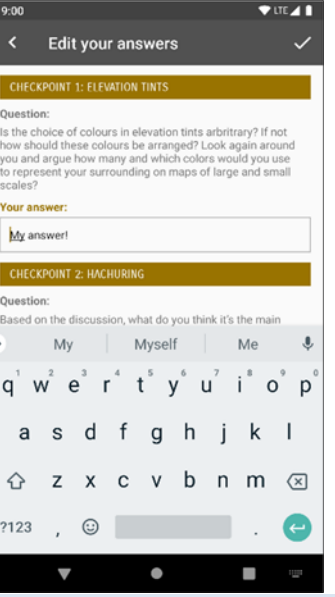
The *mCartoLearn* screens were designed to reflect the mobile application's architecture described in the chapter 3.1.5 Mobile Application Concept, and colors used in the logo design. The resulting application screens, i.e., user views, are depicted and described in the table Tab. 3.3 below. Then, after seeing all the default screens, let us take a further look at their functionalities.

Route Map
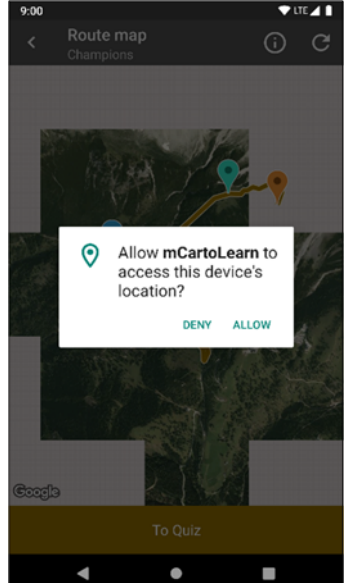
The map interface has several functionalities – depicted and described in the table Tab. 3.4 below. In short, there are three main Route Map screens: (1) asking if the user wants to allow self-positioning on the map; (2) default route camera view displaying complete route on the map; and (3) Detailed Route Map screen which gives information on checkpoints and lessons.

1. Welcome Screen	2. Group Details Screen	3. Instructions Screen
Welcome screen appears when users start the *mCartoLearn* application for the first time.	Group Details screen gives users the option to save group details like group number assigned by teachers, self-chosen group name, and students' names.	Instructions screen gives users information on the lecture goals and playing instructions.

4. Route Map Screen	5. Quiz Screen	6. Question Screen
Route Map screen displays the route with marked checkpoints. (See further explanations in the *Route Map* section of this chapter)	Default Quiz screen when users first start the quiz. (See further explanations in the *Quiz* section of this chapter)	Default Question screen is showing multiple choice answers. (See further explanations in the *Questions* section of this chapter)

7. Comprehension Question Screen	8. View Answers Screen	9. Edit Answers Screen
Comprehension Question screen shows the comprehension question and a box for typing the answer. (See further explanations in the *Questions* section of this chapter)	View Answers screen shows an overview of the user's comprehension answer to each lesson. (See further explanations in the *Review Answers* section of this chapter)	Edit Answers screen gives the option of editing the answer to each lesson. (See further explanations in the *Review Answers* section of this chapter)

Tab. 3.3   *mCartoLearn* screens

1. Initial Route Map Screen	2. Default Route Map Screen	3. Detailed Route Map Screen

Initial Route Map screen shows the loading of Google Map terrain view tiles and the notification if the user wants to allow the application to access device's location. If the user selects *Allow,* the self-positioning button is going to be displayed on the screen, otherwise not.	Default Route Map screen displays the route with marked checkpoints. It also has a *Back* button that leads back to the *Group Details* screen for editing the details, *Info* button that leads to Instructions screen, *Reload* button that updates the camera view location, angle, and zoom level to the default view of the complete route (as shown on the figure above), *Self-positioning* button that updates the camera location with the physical position of the mobile device, and *To Quiz* button which leads the user to the Quiz screen.	By clicking the marker, its lesson's name (topic) is shown on the Map screen.

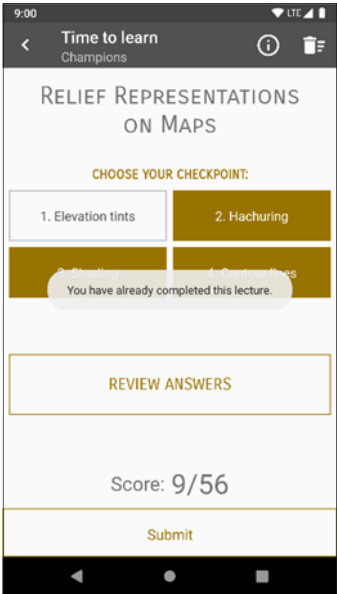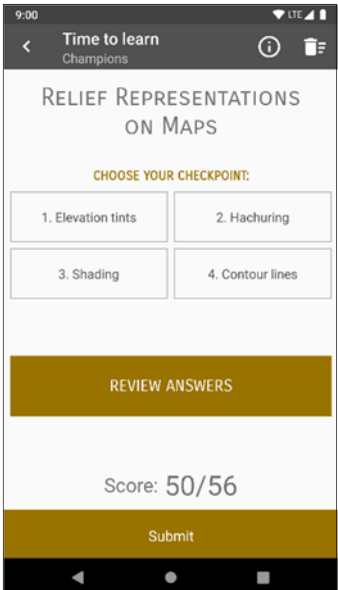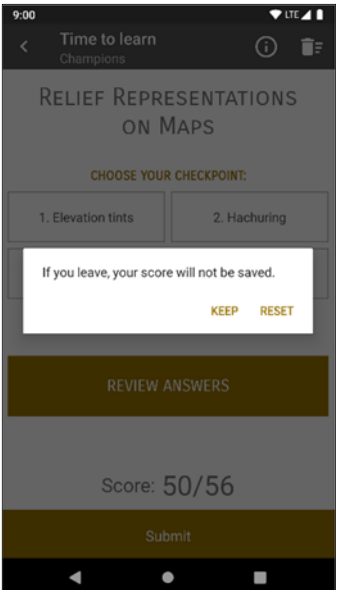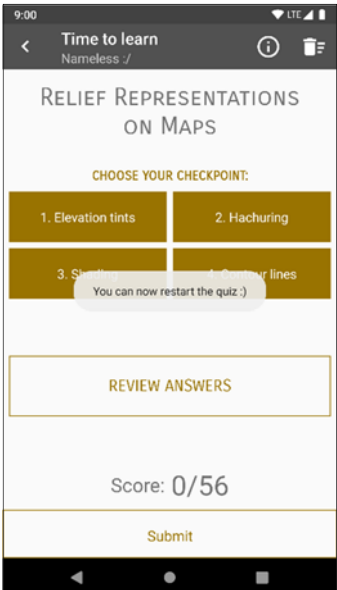Tab. 3.4   *mCartoLearn* Route Map screens

Quiz
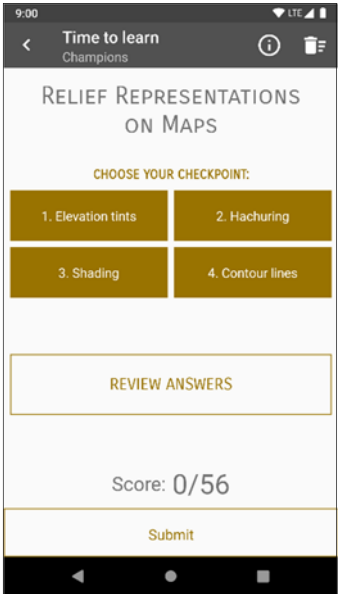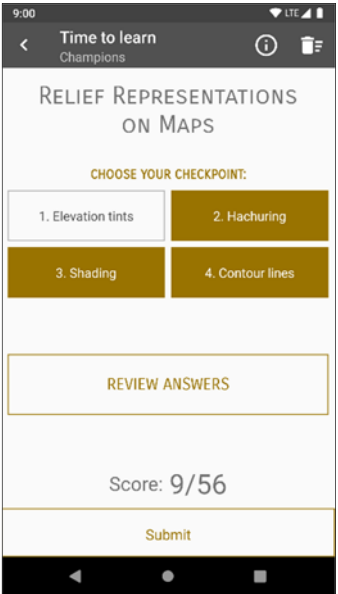
The Quiz screen has two main button groups: (1) *Checkpoints' button group,* and (2) *Answers' button group.* The first group, Checkpoints' button group, is displayed on the top of the screen and consists of the lessons (i.e., topics) covered along the route. Those lessons also correspond to the checkpoints' names marked on the Route Map screen (see Tab. 3.4 for the Elevation tints example on the Detailed Route Map screen). These buttons are by default enabled when first starting the Quiz screen. The second buttons' group – Answers' button group – is displayed below the first buttons' group, on the bottom of the screen, and contains buttons that lead to reviewing comprehension question's answers and submitting the latter and the score to teachers for students' performance evaluation. These buttons' group is by default disabled until completing all lessons. The overview of Quiz screens with their descriptions is in the Tab. 3.5.

Questions

Each lesson consists of two logical parts: (1) questions and context-related tasks; and (2) comprehension question. Firstly, students have to answer questions that reflect the theoretical background on the topic and solve context-related tasks based on real-world examples. Secondly, after completing those questions and tasks, students have to answer the comprehension (wrap-up) question to show their understanding of the topic. The

screens that reflect the first logical part are depicted in the Tab. 3.6, and the screens that reflect the second logical part of the Tab. 3.7.
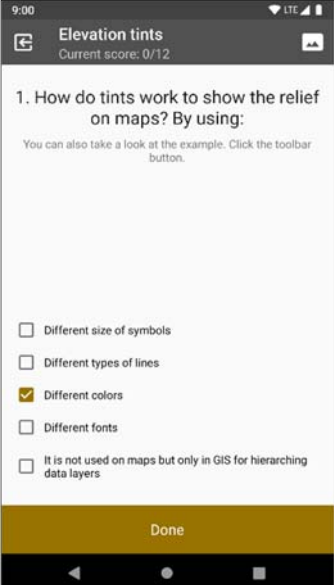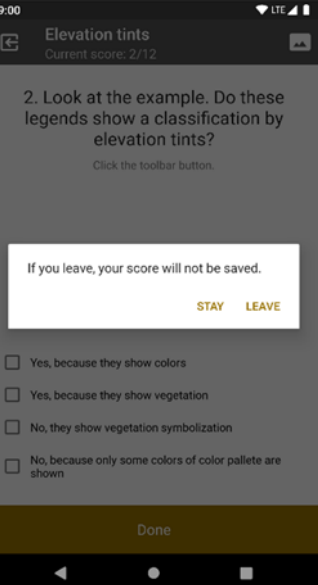
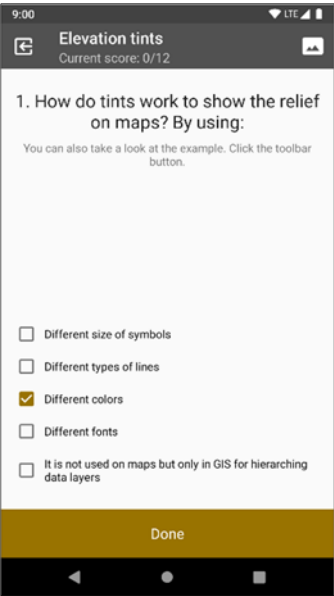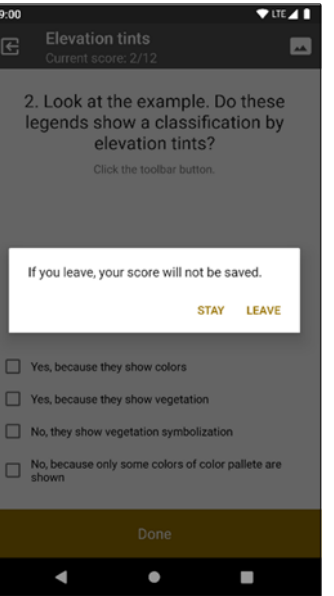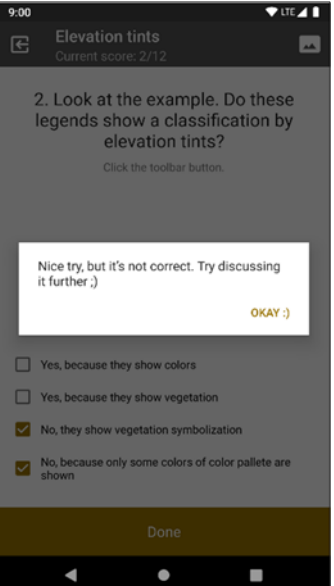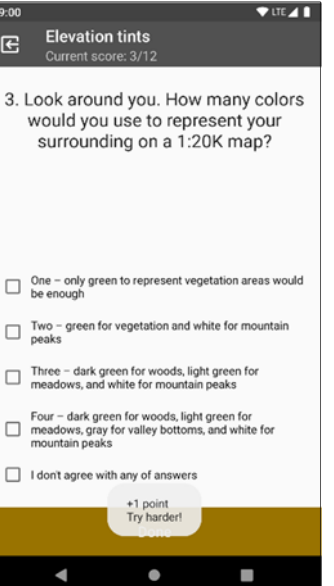| 1. Default Quiz Screen	2. Quiz Screen	3. Quiz Screen
This is the Default Quiz screen when no lessons have been yet completed. The *Checkpoints'* group buttons are enabled, and therefore colored in the application's accent color, while *Answers'* group buttons are disabled, and therefore colorless.	This is the Quiz screen when the lesson *Elevation tints* has been completed. The *Elevation tints* button is thus colorless to indicate that it has been disabled, i.e., lesson completed.	This is the Quiz screen giving the information that the *Elevation tints* lesson has already been completed upon clicking on it.
4. Quiz Screen	5. Quiz Screen	6. Quiz Screen

This is the Quiz screen when all lessons have been completed; thus, Checkpoints' group buttons are now colorless, while the Answers' group buttons (*Review answers* and *Submit*) are colored in the application's accent color to show that they are enabled.	This is the Quiz screen after pressing the *Reset* button showing a notification that if the users leave the quiz, the score will be reset, i.e., nulled.	This is the Quiz screen after restarting the quiz showing the notification that it is now possible to replay it.
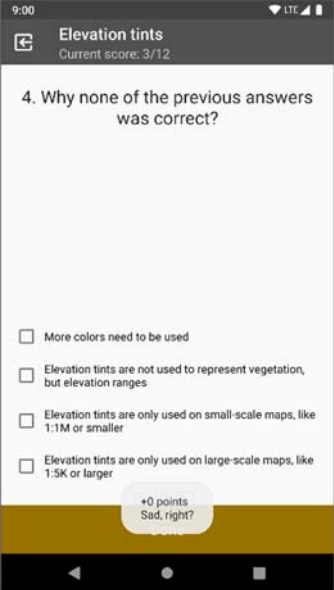
Tab. 3.5   *mCartoLearn* Quiz screens

Review Answers

The *Review Answers* button on the Quiz screen leads users to screens where they can read their answers to comprehension questions, and edit them before submitting them. The screens that are part of these functionalities are depicted and described in the Tab. 3.8.

1. Question Screen	2. Question Screen	3. Question Screen
This is the Question screen that shows the question, hint (e.g. to take a look at the example and where to find the button leading to it), *Example* button to open the example, multiple choice answers, *Done* button to check if the selected answer(s) is correct, and *Leave* button to leave the lesson and return to the Quiz screen.	This is the Question screen that shows the example map by (Lencer 2012) to help students answering the question.	This is the Question screen that asks the user whether to leave the lesson and return to the Quiz screen upon clicking the *Leave* button.

4. Question Screen	5. Question Screen	6. Question Screen
This is the Question screen that shows the question, hint (e.g. to take a look at the example and where to find the button leading to it), *Example* button to open the example, multiple choice answers, *Done* button to check if the selected answer(s) is correct, and *Leave* button to leave the lesson and return to the Quiz screen.	This is the Question screen that shows the example map by (Lencer 2012) to help students answering the question.	This is the Question screen that asks the user whether to leave the lesson and return to the Quiz screen upon clicking the *Leave* button.

7. Questions Screen	8. Questions Screen	9. Questions Screen

This is the Question screen that shows the notification of scoring two points upon correctly answering to the previous question in one try.	This is the Question screen that shows the notification that the selected answer or multiple-choice combination is not correct.	This is the Question screen that shows the notification of scoring one point upon correctly answering the previous question in two tries.

10. Question Screen

This is the Question screen that shows the notification of scoring zero points upon correctly answering the previous question in more than two tries.

Tab. 3.6   *mCartoLearn* Question screens (Part I)
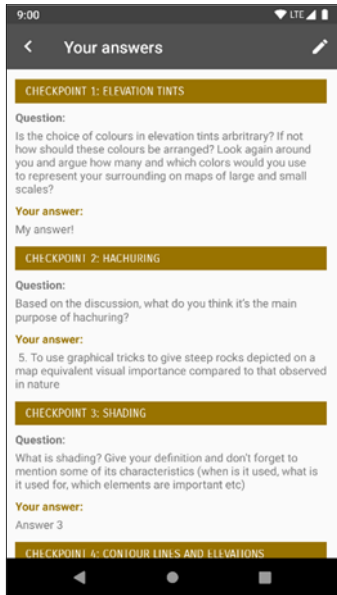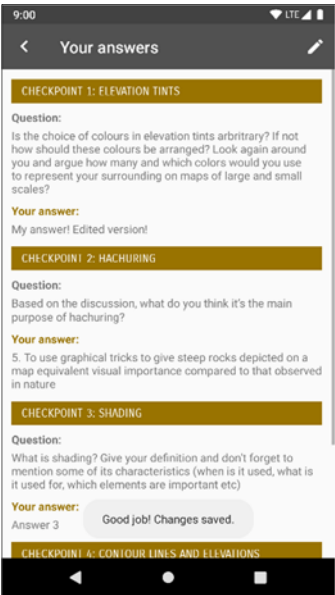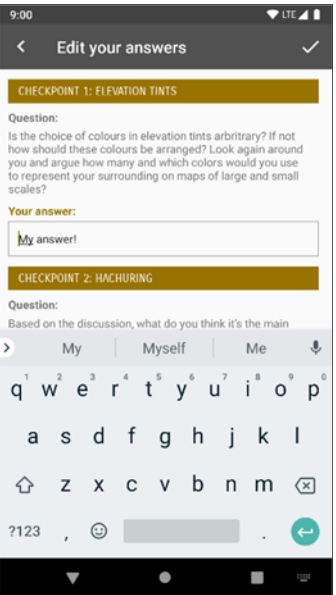
Submit

The function of the *Submit* button was not implemented in the current version of the *mCartoLearn* application due to the time limitations and the complexity of the implementation. The notification that the system gives upon clicking the Submit button is depicted and described in the Tab. 3.9below.

After the implementation of the m-learning lecture concept and the *mCartoLearn* application, the next step was to test them with users. The opportunity for the testing was the International Cartography Master student's 2017 intake which went to the ACFS excursion in October 2018. The design of the user testing is presented in the following subchapter 3.3 Usability Test.

1. Comprehension Question Screen	2. Comprehension Question Screen
This is the Comprehension Question screen that shows the lesson's comprehension question, box to type the question into, *Done* button to save the typed answer, and *Leave* button to leave the lesson and return to the Quiz screen without answering the question.	This is the Comprehension Question screen that notifies the user that an answer should be input to complete the lesson upon user's click on the *Done* button without previously typing the answer in the answer box.
3. Comprehension Question Screen	4. Comprehension Question Screen
This is the Comprehension Question screen that notifies that the lesson has been completed and the comprehension answer can be reviewed by clicking on the *Review answers* button.	This is the Comprehension Question screen that notifies users of their score of the just completed lesson.

Tab. 3.7   *mCartoLearn* Comprehension Question screens (Part II)

1. View Answers Screen	2. View Answers Screen	3. Edit Answers Screen
View Answers screen shows the question and user's answer to it for each lesson separately, and the *Edit* and *Back* buttons to proceed to edit the answers or return to the Quiz screen.	This is the View Answers screen that shows the notification that the answers' edited have been saved after clicking the *Done* button in the Edit Answers screen.	The Edit Answers screen shows the question and editable user's answer to each lesson separately, and the *Done* and *Back* buttons to save the edits, or return to the View Answers screen without saving them.

Tab. 3.8   *mCartoLearn* Review Answers screens
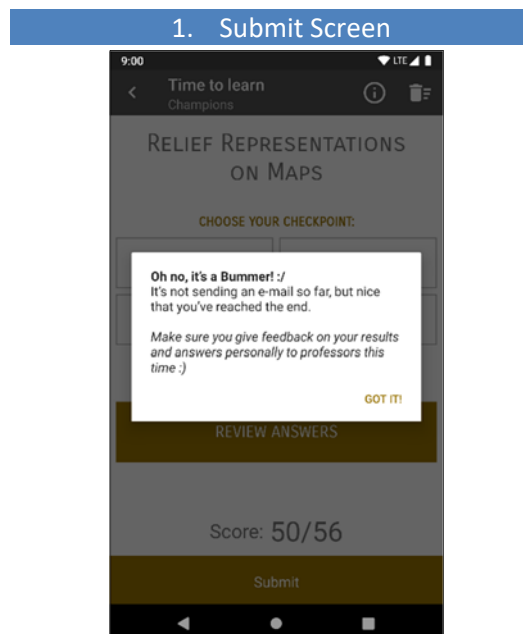
1.   Submit Screen
The Submit screen showing that the quiz results' submitting functionality is not yet implemented.

Tab. 3.9   *mCartoLearn* Submit screen

3.3   Usability Testing

The summative evaluation aims to find out if the product fulfills its purpose. It also intends to answer if the product should remain the subject of improvement and future usage and if its concept may be applied to interdisciplinary priorities (Patton 2015). Therefore, a summative evaluation of the *mCartoLearn* application was carried out to test if the designed concept and its implementation meet the research objectives. Since the researcher has to define the purpose of the evaluation by defining its priorities (Patton 2015), evaluation purposes that would apply to this research could be that the mobile application fulfills its educational purpose, the user interface is intuitive, the user experience is positive, and others. The audience for the evaluation is already known as this m-learning lecture was developed for a targeted group of users: Therefore, the evaluation audience were the International Cartography Master students who attended the ACFS in October 2018. Let us now define the premises for the usability testing exactly.

3.3.1   Premises

It is logical to divide the premises for structuring the questionnaire and defining questions into two groups. The first group intends to test if the conceptual design of the quiz-based m-learning lecture meets its purpose. The second group intends to test if the physical implementation of the quiz-based m-learning lecture, i.e., the *mCartoLearn* application, was successful. Let us take a look at both mentioned groups of premises.

Part I: Lectures

The conceptual design of the quiz-based m-learning lecture was successful for learning on the relief representation methods on maps if the students:

a) Could complete the lecture from the educational aspect;

b) Became self-confident of their pre-knowledge on relief representations on maps;

c) Perceived new information on relief representations on maps;

d) Built new knowledge on relief representations on maps based on understanding new information from c);

e) Were able to link their pre-knowledge with the new knowledge and will be able to apply it in real situations;

f) Felt comfortable about the lecture and their learning experience was positive.

Part II: Mobile Application

The concept implementation was successful if students:

a) Could complete the lecture from the technical aspect;

b) Found the user interface (UI) intuitive: could easily understand the buttons' symbolization and navigation within the application;

c) Encountered minimal system errors or crashes while using it;

d) Found the application motivating for learning.

Following these premises, a questionnaire was designed with two sets of questions. The questionnaire is described in the following section.

3.3.2   Questionnaire

As already mentioned, the questionnaire was designed to test the usability testing premises and get the answer if the conceptual design and implementation of the quiz-based m-learning system met its purpose and is useful as a context-related m-learning concept.

Questionnaire combined grading and open questions. In questions where students had to assign a grade, they could have chosen a grade from 1 to 5, where 1 was the worst grade, or "strongly disagree," and 5 best grade, or "strongly agree." The questions were defined as follows (for the questionnaire example, please see Appendix 1):

a) *Part I – Lectures*

1. How confident were you of perceiving the terrain model (reality) by reading topographic maps:

   a. Before the m-learning experience? (1 – 5)

   b. After the m-learning experience? (1 – 5)

2. How satisfied were you with:

   a. The quality of provided map examples? (1 – 5)

   b. The number of provided map examples? (1 – 5)

3. What would you improve regarding providing map examples?

4. How easy was for you to find correct answers based only on group discussion and without theoretical background available? (1 – 5)

5. In which ways would you have liked to have additional theoretical background provided within the app?

6. Do you think it was useful to have real-world examples in the quiz and why?

7. How much did this way of learning deepen your previous knowledge? (1 – 5)

8. How did you enjoy this way of learning – Using your mobile device, solving the quiz and having context-related examples? (1 – 5)

b) *Part II – Mobile Application*

1. How intuitive or easy was for you to use the app and to understand interaction (buttons') metaphors? (1 – 5)

2. What would you suggest to improve about any of question 1?

3. How satisfied were you with the app regarding:

    a. The occurrence of errors in the app's performance? (1 – 5)

    b. The occurrence of app crashes? (1 – 5)

4. If you encountered any technical problems from the question 3, or any other while using the app, please describe in which situation(s) and how often.

5. How would you rate the level of functionalities that the app offers? (1 – 5)

6. In what ways would improve the functionalities of the app?

7. How appealing or enjoyable did you find the app's interface? (1 – 5)

8. Were the app and quiz design motivating for learning and what was the reason(s)?

9. How would you improve the user experience of using the app?

10. Were you directly interacting with the app during the lectures? (YES – NO)

3.3.3 Questionnaire Results

Usability testing was conducted in two phases: (1) first, the students used the *mCartoLearn* application and complete the m-learning lecture on relief representations on maps, and (2) afterward they were asked to fill the designed questionnaire. The m-learning lecture took place on October 7, 2018, in Dachstein Alps, Austria. As planned in the scenario (see 3.1.3 Persona and Scenario), students started the lecture after the orientating exercise to the Dachstein Südwandhütte (1871 meters). The location of the first checkpoint was the Dachstein Südwandhütte itself, and students started with the first lesson – Elevation tints technique – on its terrace (see Fig. 3.15). Unfortunately, the weather conditions were getting worse, and students managed to complete the first

lesson but were not able to proceed to the route. The visibility was so low that it would have been dangerous to proceed (see Fig. 3.16). Also, in the moment of doing the first lesson, the weather conditions did not allow a clear vision due to the rain and heavy clouds (see Fig. 3.16). After the students managed to complete the first lesson at the first checkpoint, the start of the rain and further worsening of the weather demanded the abortion of the mission. The students took the shortest route to the cars and returned to the accommodation. As there was no further opportunity in the planned-in-advance 10-day excursion to repeat the m-learning lecture, students decided to complete the m-learning lecture in the accommodation, i.e., indoor. Thus, the students continued the same day with using the *mCartoLearn* application in the hotel to completing the remaining lessons. Thus, the questionnaire results had to be interpreted having this fact on the mind.

As the questionnaire was structured into two sections – on lecture (Part I) and mobile application (Part II) – its results are presented in that way, i.e., separately for each section.

Fig. 3.15   Students on the first checkpoint

Part I – Lectures

The results of the first questionnaire part reflect the user experience regarding the conceptual design of the m-learning lecture. As previously in the chapter mentioned, it consisted of open questions and questions that asked for grading. The applied grading scale was 1 to 5, where grade 1 was the worst, and 5 the best grade.

Firstly, thirteen students graded their cartographic knowledge – perceiving the terrain model by reading topographic maps – before and after using the *mCartoLearn* application with the same grade, and thirteen with a higher grade. Of the students who graded it higher, ten graded it with one grade higher, and three with two grades higher. If we take a look at the grades before and after (see Chart 3.1) the m-learning experience, the average grade of users' cartographic knowledge was 3.4 before, and 4.0 after it. Thus, the results show that the designed learning concept still had a positive impact on understanding relief representations techniques on maps.

Fig. 3.16   Weather conditions on the day of m-learning lecture

Secondly, to the questions related to provided map examples, students rated both their quality and number with 4.0. Most common suggestions of improving aspects related to map examples for the m-learning are: (1) adding zooming and panning functionalities; (2) improving their resolution and quality [Author's comment: It remains unclear if the quality refers to the graphical display (i.e., resolution), or the importance of provided example to asked question]; (3) including examples that better depict (relate to) the question, or adding a description of what examples depict; and (4) adding more

examples of different areas so they can be compared. An overview of all suggestions is given on Chart 3.2.

1. How confident were you of perceiving the terrain model (reality) by reading topographic maps?
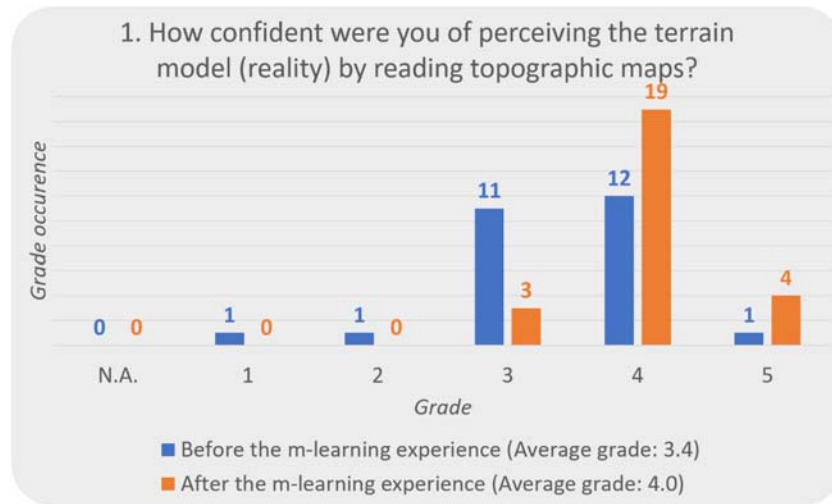
Chart 3.1   Questionnaire, Part I: Question 1

Thirdly, to the question *How easy was for you to find correct answers based only on group discussion and without theoretical background available?* students assigned the average grade 2.9. Since this grade can be considered rather low than high, they suggested in the next question they would have liked to have additional theoretical background provided as (1) introduction to the topic; (2) more multimedia (e.g. visuals, (Wikipedia) links, videos, animations, texts); and (3) vocabulary on terms, or additional information on the topic available while solving the quiz. Some also saw the quiz more appropriate for practicing the knowledge learned in traditional ways [Author's comment: Probably referring to classroom teaching], and useful for life-long learning, rather than a way of mandatory learning. An example given for introducing multimedia (see point 2), was an animation explaining how to use illumination for terrain shading technique. All suggestions are displayed in Chart 3.3.

Fourthly, when asked about usefulness of context-related tasks in the quiz, eighteen students answered *yes,* two *no,* and six students answered that they are not able to answer the question as they were not able to conduct the m-learning lecture on-site [Au-thor's comment: Due to poor weather conditions the m-learning lecture had to be stopped on the terrain and continued indoor]. Students who answered yes, explained it with: (1) being able to learn and understand better; (2) being able to compare real-world with a

map, and vice versa; (3) being able to find answers to question; and (4) being intuitive and helpful for real-life situations. The student who answered *no* argued it with "Someone may have pre-knowledge of the topic" and "I thought that the app was more theoretical." For a graphical overview of the answers, please see Chart 3.4.

Finally, students graded this m-learning experience to have deepened their previous cartographic knowledge with an average grade of 3.3, and to have enjoyed learning by using mobile-device, solving the quiz and context-related tasks with grade 3.8.

Even though the results of the questionnaire's first part show interesting and useful results that partially answer the first research questions (see 4.1 Research Findings), it is discussable in which extent can they be considered to reflect the m-learning experience designed to conduct on-site in case of good weather conditions: In that case students could have really walked along the route and experienced the real context for context-related questions. Nevertheless, useful ideas for m-learning lecture improvements could still be drawn-out (see 4.4 Recommended Improvements).
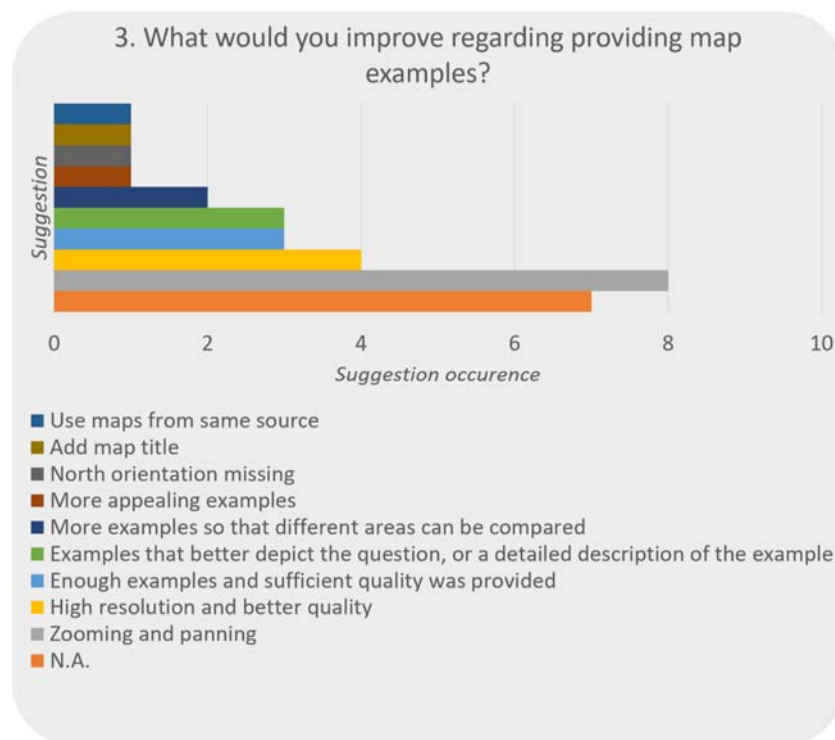
Chart 3.2   Questionnaire, Part I: Question 3
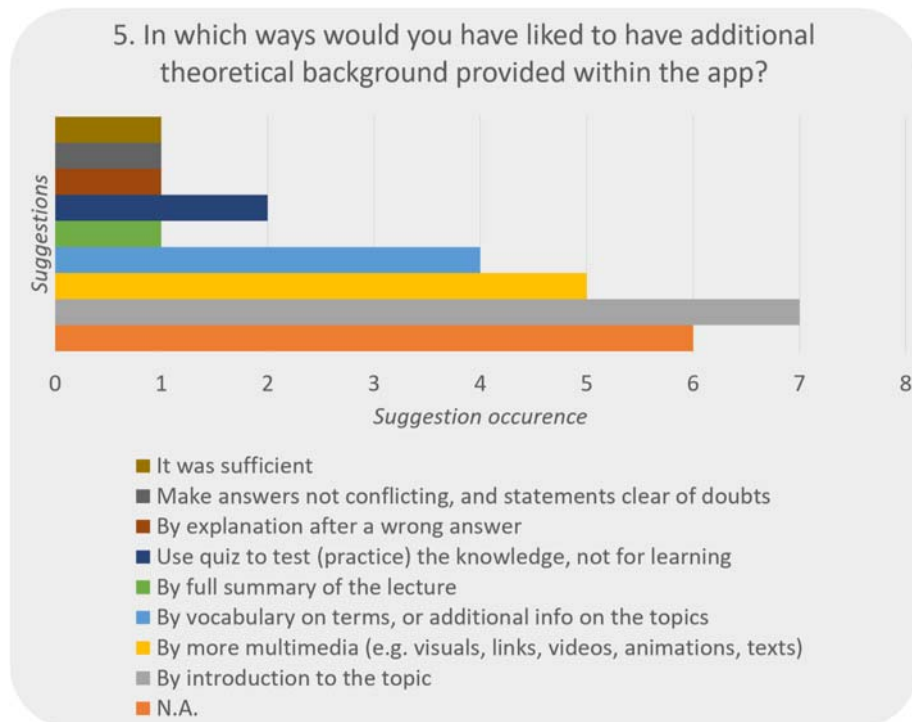
Chart 3.3   Questionnaire, Part I: Question 5
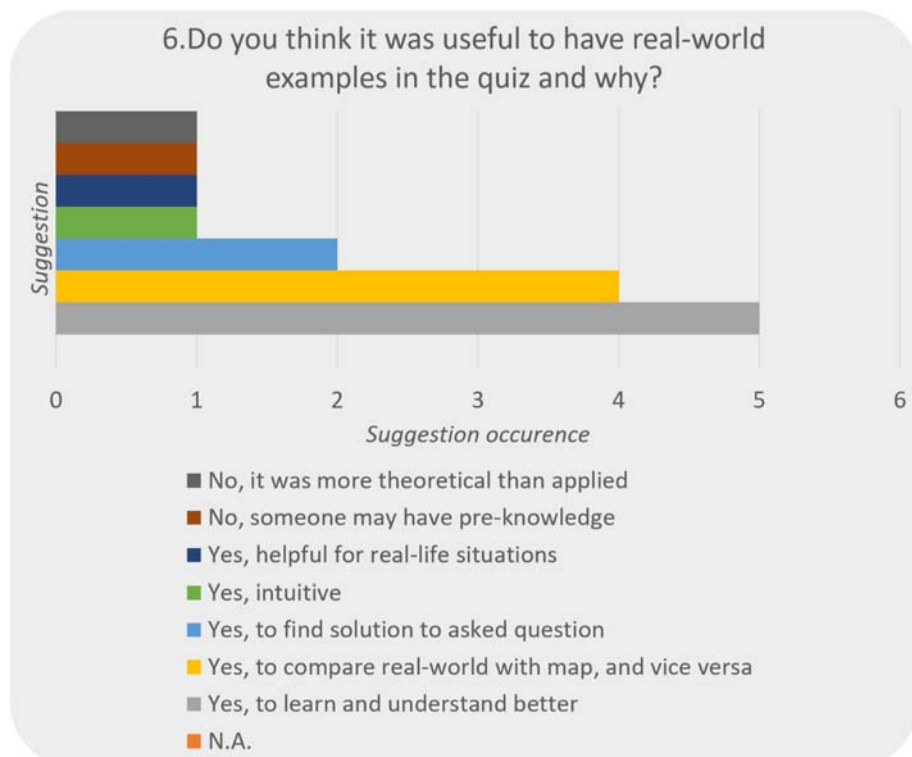
Chart 3.4   Questionnaire, Part I: Question 6

Part II – Mobile Application

The results of the questionnaire's second part reflect on the user experience regarding the graphical design and realization of the *mCartoLearn* application. The grading scale on non-open questions was again 1 to 5, where grade 1 was the worst, and 5 the best grade. Firstly, students graded the application's intuitiveness and symbolization metaphors with an average grade of 3.7 (see Chart 3.5) with two main suggestions for their improvement. The first is to improve the intuitiveness of going back to the question when the example map is displayed. According to students, they found it intuitive to click the *Leave* button for getting back to the question (instead of the *Example* button again), but this offers the possibility to leave the current quiz lesson instead, and not close the map example. Opening the example map by clicking the *Example* button was more intuitive than closing it by clicking the same button again. The second main improvement suggestion is to make it unambiguous if the question is single-, or multiple-choice. Students prefer having it specified clearly – directly by writing it, or indirectly by implementing radio buttons and checkboxes – if they should select one, or more answers. Besides those two most popular suggestions (each suggested by four students), providing a visual introduction explaining the application's purpose and how to use it, improving buttons' metaphors, and defining (i.e., explaining) the purpose of the group number on the Group Details screen, were also suggested. The overview of all answers is given on Chart 3.6.
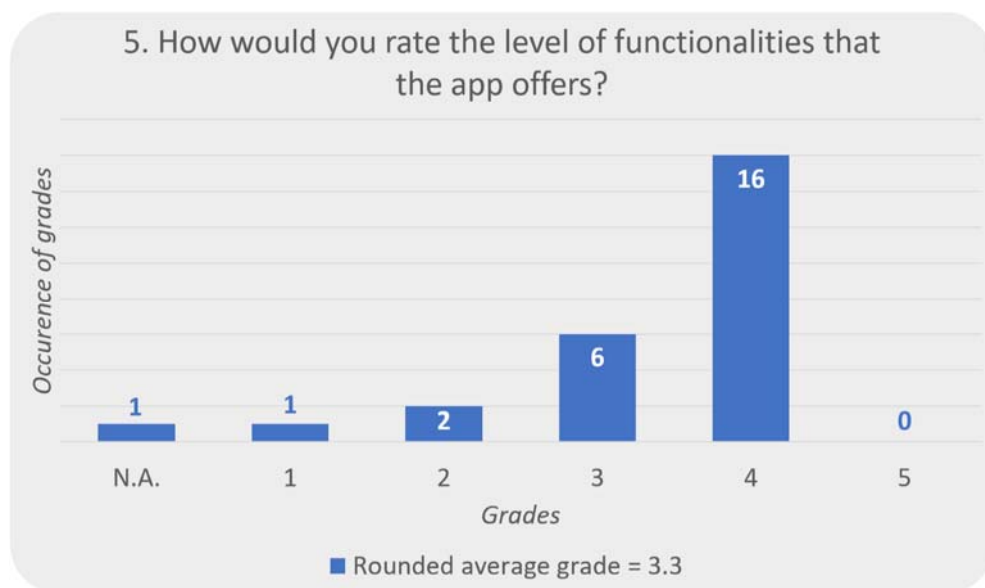
Chart 3.5   Questionnaire, Part II: Question 1

Secondly, regarding the occurrence of errors in its performance, students graded the *mCartoLearn* application with the average grade 3.6, and regarding the occurrence of its crashes with 4.0. On the occurrence of these *mCartoLearn* application malfunctions, two main issues got identified as primary issues. Like the first issue, three users encountered problems with incorrect score counting in the end of the lesson (remained unspecified which one); For example, after completing the lesson and scoring a certain amount of points in it, no points were added to the overall score displayed on the Quiz screen what so ever. As the second issue, two users had problems interacting with map examples; For example, touching the map example while it was displayed automatically activated the *Done* button and made the user lose one try in answering, and thus scoring fewer points on that question. Additionally, there were some other technical issues mentioned like not submitting the results upon clicking the *Submit* button, and not being able to install and run the application on iPhone. Both of these events were expected as, on the one hand, the results' submitting functionality was not implemented in the current version due to time limitations, and on the other hand, that the *mCartoLearn* application was implemented only for Android OS (see 3.2.3 Developing Mobile Application). The overview of the encountered technical issues is given in Chart 3.7.
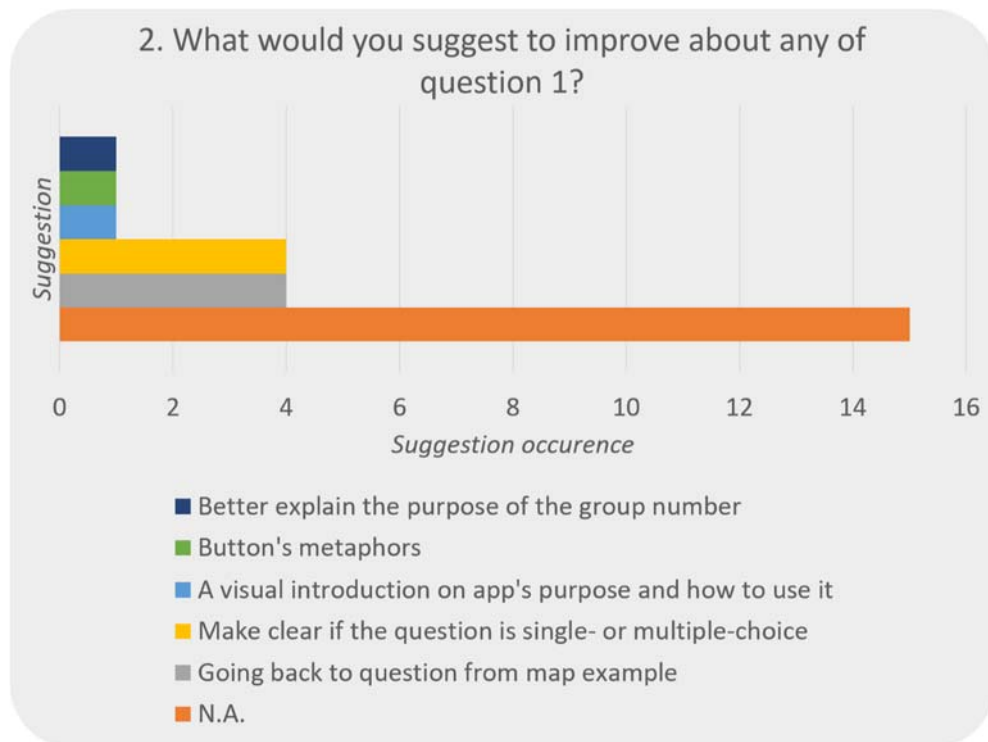
Chart 3.6   Questionnaire, Part II: Question 2

4. If you encountered any technical problems from the question 3, or any other while using the app, please describe in which situation(s) and how often.
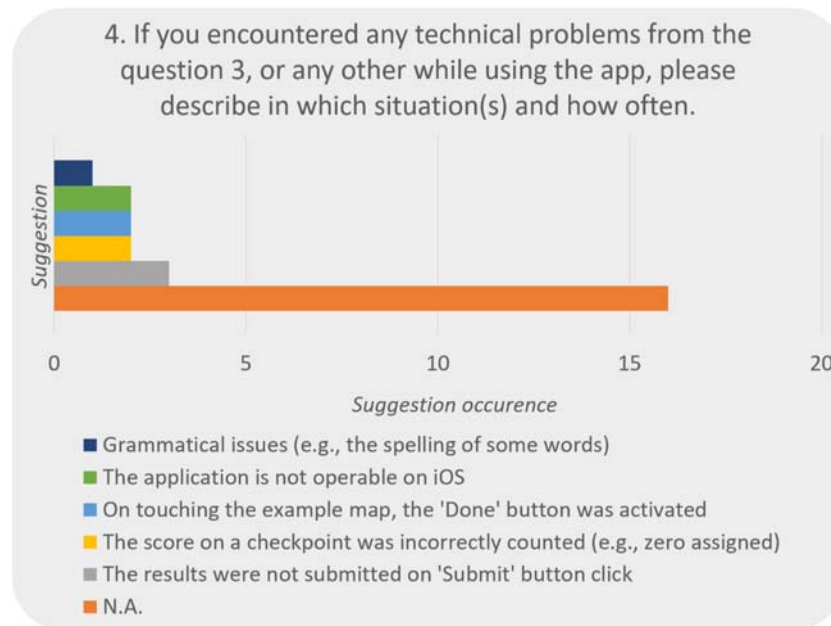
Chart 3.7   Questionnaire, Part II: Question 4

Thirdly, students rated the application's functionalities with the average grade 3.3 and gave various suggestions for improving it. The two main functionality that they would like to have implemented is zoomability of the maps' examples as pointed-out by four students, and providing a cartography-specific vocabulary on new and (or) unknown terms as pointed-out by two students. Further suggestions, mentioned by fewer students, are adding a 3D map view, improving the switch between the map example and question (already discussed above, see Chart 3.6), and giving an overview answer to the summary question after it has been answered. There were some other suggestions as well, but their relevance is not that high because those do not directly reflect on how to improve the functionalities of the application. A complete overview of answers to Question 6 is shown in Chart 3.8.

Fourthly, the *mCartoLearn* application was rated with an average grade of 3.5 regarding its interface appearance and, with 18 votes for, also as motivation for learning regarding its design (see the Chart 3.9). Furthermore, three students answered "not that much" or "somewhat," one "no," and four did not answer to the Question 8. As main reasons for the *mCartoLearn* application and quiz being interesting for learning, students listed group discussion, interesting topics with well-chosen motivating tricky questions, trying to score a high number of points, intuitiveness, and good design, interactive with map examples provided, and suitability for practicing and life-long learning. As a reason for

the *mCartoLearn* application and quiz being somewhat interesting for learning, students wrote they "[…] prefer to be given the correct answer(s) after the first incorrect answer." The student who answered that the *mCartoLearn* application and quiz were not motivating for learning did not provide an explanation why.
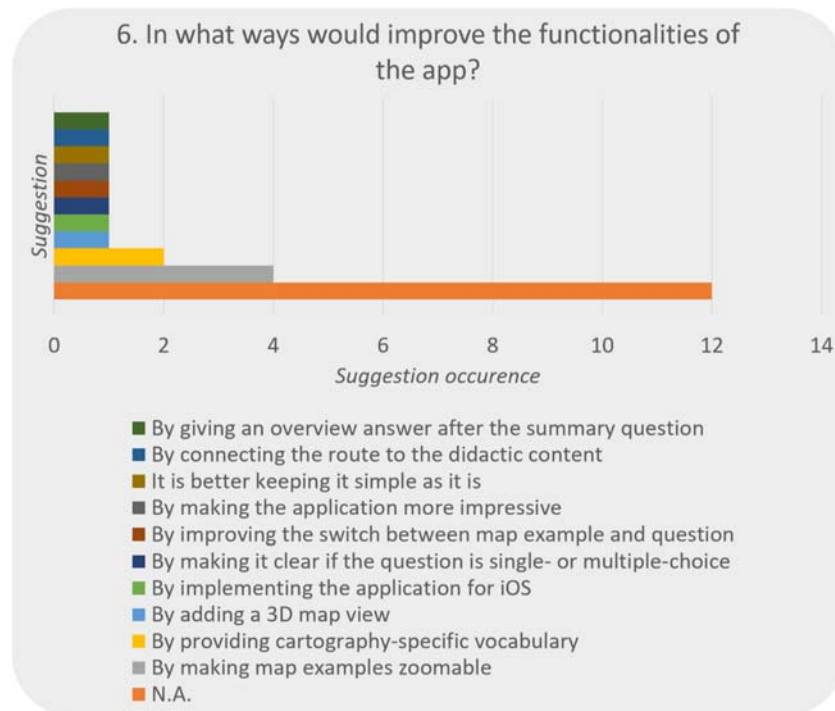
Chart 3.8   Questionnaire, Part II: Question 6
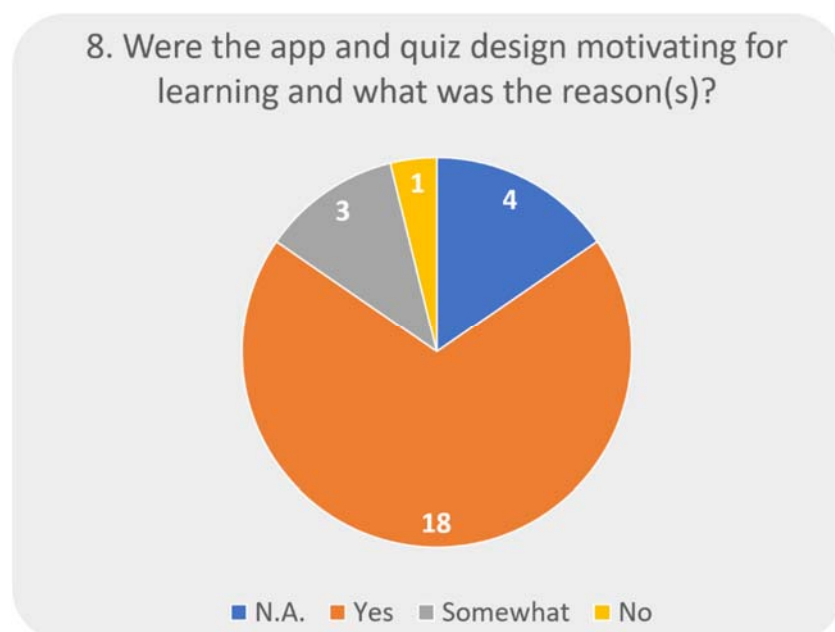
Chart 3.9   Questionnaire, Part II: Question 8

Lastly, most important suggestions for improving the user experience are: (1) making it clear if the question is single-, or multiple-choice; (2) giving better instructions on the application's purpose and how to use it, or introducing a trial at the start, (3) higher gamification level; (4) making map examples zoomable, and (5) improving the feedback provision like general progress, or instant comprehension answer review [Author's comment: Instead of reviewing it after completing all lessons]. There were some other suggestions as well; all are shown on Chart 3.10.
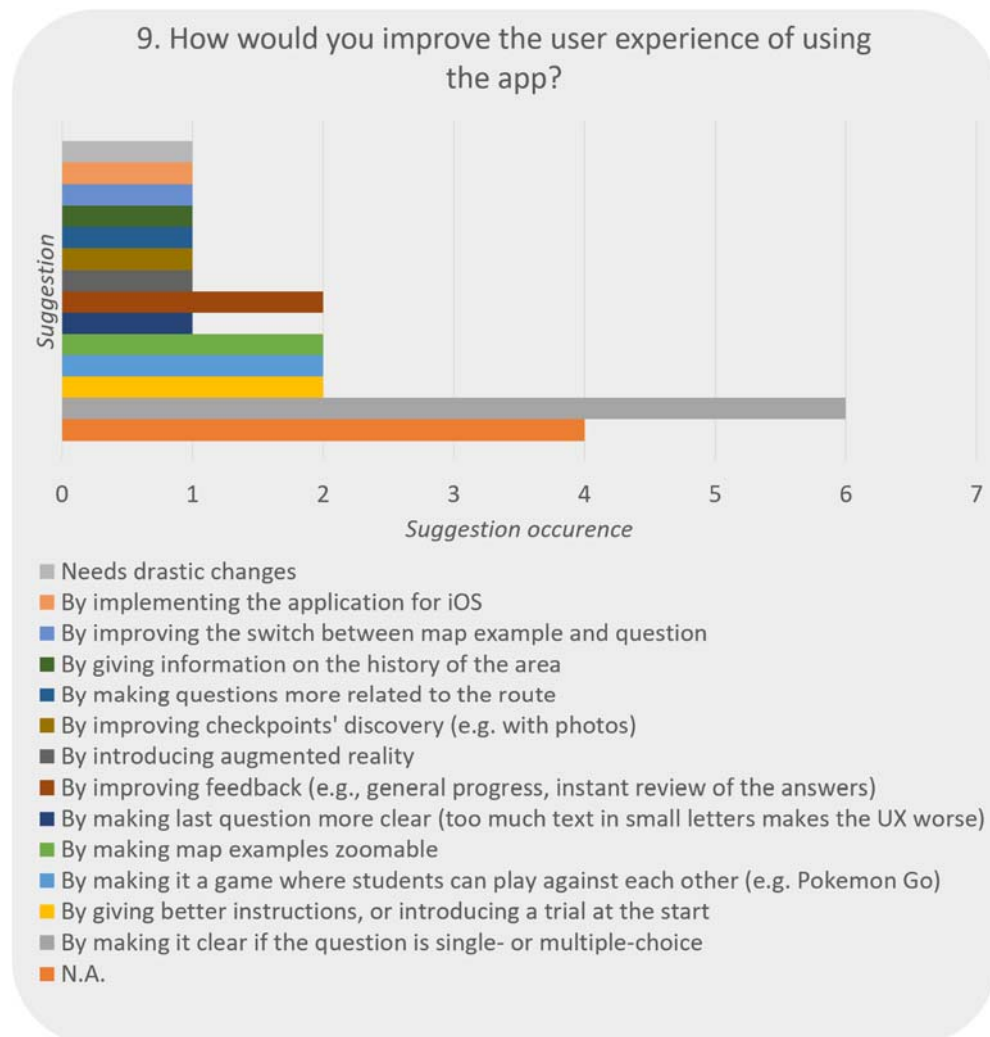
Chart 3.10   Questionnaire, Part II: Question 9

Additionally, it was also interesting to get the information that two-thirds of students have interacted directly with the application (18 of 26), while one third (8 of 26) did not. This information gives a hint of a chance the m-learning phases were not followed in all steps (see 3.1.4 M-Learning Phases, Phase II). Groups of two to three persons were

supposed to be formed and interact with one mobile device per group to improve collaboration and keep one individual group score. The number of students that have interacted directly with the application implies two things. On the one hand that either groups of planned size were not formed, or either they were but, some students were solving the quiz on their own.

On the other hand, it implies that peers changed roles during the lecture and therefore more students got a chance to interact with the application. The exact case remains unknown as these situations were not predicted, and therefore not tested by the questionnaire. From this information, the reliability of the discussion and collaboration parts' success can be questioned, and those results should be considered with caution. For the complete report/display of all questions, please see Appendix 2. The recommendations for future improvements based on the usability testing are discussed in the next chapter – 4.4 Recommended Improvements – and, in addition to it, an overview of research limitations, and possibilities for future research as well.

4 Discussion

The usability testing has led to conclusions to meeting the research objectives and answering the research questions. Furthermore, it has brought up the advantages and disadvantages of the designed m-learning concept and its implementation as the *mCartoLearn* application, as well as opportunities for future improvement. However, before having an overview of the latter, it would be useful first to consider research findings and limitations. In the end, it would be useful to think of directions into which the research could lead in the future. Thus, this chapter discusses all mentioned.

4.1 Research Findings

The conducted research provided answers to the research objectives of this master thesis, which were:

1. Developing an LBML application for the environmental context of ACFS carried out in Dachstein Alps in Austria by taking advantage of mobile technology to give students an experience of learning and interacting on engaging real-world locations;

2. Allowing students to adapt their learning pace to their own needs and wishes;

3. Deriving a generic prototype on the understanding of techniques of relief representations on maps.

Firstly, as presented in chapter 3 Results, the thesis outcome was an LBML application that was used and tested for its usability on the ACFS in October 2018. The application was designed to take advantages of the portability of mobile technology, and built-in sensors like GPS and compass. Unfortunately, on the one hand, the weather conditions during m-learning lecture execution did not allow to test if the application also efficiently takes advantages of real-world locations to help students in learning and understanding better techniques of representing relief on maps. However, on the other hand, the results of the usability testing indicate that the designed m-learning lecture allows self-pacing in learning in at least two ways:

– Students started the learning process in the field and continued it in the hotel due to poor weather conditions (rain and low visibility). It shows the *mCartoLearn* application allows learning on rates due to saving users' progress in the internal database;

− The questionnaire shows that some students think the designed m-learning could be used for life-long learning and practicing, which implies self-paced learning as both are usually free will.

Finally, if the research outcome derives a generic prototype for the relief representations' understanding remains also ambiguous, as the concept could not have been adequately tested due to poor weather conditions, as already mentioned. Thus, it is highly recommended to repeat the usability testing at the ACFS in October 2019, or to adapt it for a different area and test it there (e.g., for Sächsische Schweiz in Saxony, Germany) (see also 4.2 Research Limitations). After reminding of research objectives, the following paragraphs present research findings that answer research questions.

Research Question 1:

Which pedagogical approach is suitable for a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum?

Based on the literature review, the location-based mobile learning lecture on methods of relief representation on maps for cartography study curriculum implemented *collaborative learning with constructivist learning approach and elements of situated learning.* As already mentioned, the elements of situated learning could not have been adequately tested due to poor weather conditions, but usability testing has still given useful feedback on tested collaborative learning approach that implements the constructivist method of learning. Firstly, the usability testing results show that the designed learning concept had a positive impact on understanding techniques of representing relief on maps since students graded their map-reading skills higher (4.0) after the m-learning lecture than before (3.4) (see Chart 3.1 on page 76). Thus, students' feedback implies the combination of collaborative with constructivist learning was a sensible approach also given that they rated to have enjoyed learning by using mobile-device, solving the quiz and context-related tasks with grade 3.8, which corresponds to *agree (4)* statement on the given scale from "strongly disagree" (1) to "strongly agree" (5). Secondly, students graded this m-learning experience to have deepened their previous cartographic knowledge with an average grade 3.3, which corresponds to *neither agree, neither disagree* (3) on the given scale, which should be considered as the result of not conducting complete m-learning lecture outdoor and not being able to put the context-related tasks in real context. Thus, these results indicate that the *combination of collaborative and constructivist learning is less successful than*

the combination that additionally successfully utilizes situated learning as well which should be a premise in the second usability testing.

Research Question 2:

> *Which is the suitable conceptual design of a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum?*

Based on literature review, it was decided to conceptualize the location-based mobile learning lecture on methods of relief representation on maps for cartography study curriculum as game-based mobile learning lecture closing with a public discussion in the end. The usability testing results have shown that learning through a quiz as a gamification element of learning was motivating for students. Eighteen students answered yes to related question mainly listing as reasons for it scoring points (twice), interesting topics with well-chosen and tricky questions (twice), group discussion (twice), and preferring learning "this way" than traditional (once) (see Chart 3.9 on page 82). These answers also show that the part of the lecture where students discussed their finding was a useful addition to the quiz solving. Furthermore, it leads to answering the research question with *Gamification of learning followed by a discussion as a wrap-up gives good learning results* (see also the answer to the first research question) *and is a suitable conceptual design of a location-based mobile learning lecture on the methods of relief representation on maps for cartography study curriculum.*

Research Question 3:

> *Which user interface design of the location-based mobile learning lecture on the methods of relief representation on maps is efficient and motivating for cartography students for learning?*

Based on the conducted literature review, the location-based mobile learning lecture on methods of relief representation on maps for cartography study curriculum' concept implemented a user interface design that based on five elementary planes of user experience and appealing aesthetics. Moreover, it aimed to provide students motivation for learning and satisfying user experience. As discussed earlier, usability testing results have shown that user interface's architecture was well structured and solidly presented as eighteen students answered the *mCartoLearn* (and also quiz as part of it) design was motivating for learning. Three students said it was because the application interface is intuitive and well-designed (see Chart 3.9 on page 82). Furthermore, students graded the

mCartoLearn application's user interface to be appealing and enjoyable with an average grade of 3.5, which is between *neither appealing, neither not appealing* and *appealing* on the given scale from "highly not appealing" (1) to "highly appealing" (5). One student suggested making the application more impressive (see Chart 3.4 on page 78) which emphasizes the contribution of aesthetics in user interface design in motivating students for learning. The usability testing results imply the confirmation of the hypothesis of the *importance of user-centered design with a further accent on its aesthetics* which resulted from the literature review. Now, having research findings, it would also be useful to have an overview of the research limitations which would provide additional understanding of the research results.

4.2   Research Limitations

The thesis research had several limitations which were related to: (1) thesis' scope; (2) research scope; (3) context; and (4) usability testing. Thesis' scope was mobile learning *development and implementation* and therefore aimed at delivering a concrete product – a mobile device application – as one of the research results, instead of only focusing on conceptual design. In this way, the research scope was limited firstly with the thesis scope, that is, the fact that the concept had to be physically implemented and tested, not only conceptually designed. In the case of the latter, it would have been useful to conduct *a priori* research on user requirements. It could have been done on the one hand by asking students who have already participated in the ACFS (e.g., intake 2016) what would they have liked to experience as technology-enhanced learning.

On the other hand, it could have been done by asking students who still need to participate in the ACFS (e.g., intake 2017) in the future what would they like or expect to experience as technology-enhanced learning – and base the concept on those results. It must be pointed out that sometimes users do not know what they need or want until they get it; thus, the conceptual design was based on literature review, and not on a questionnaire with targeted users' group. Secondly, the research scope was limited by the decision that the resulting thesis product should allow students to adapt their learning pace to themselves by making the learning self-paced, and not customized. The latter could utilize machine learning, which is an opportunity for future research (see 4.5 Future Work).

This research was limited due to the chosen methods of usability testing – testing in the field and conducting a questionnaire on users' experience. The research utilized these methods two reasons: Firstly, as previously mentioned, the designed lecture was bounded to a specific context that cannot be "set" by need on another location. Thus, it was logical to conduct the usability testing on the designed area for conduction. Secondly, the questionnaire is a quantitative method of usability testing that allows gathering experiences of all participants by using grading questions, and suggestions by using open questions. Weather conditions influenced the conduction of usability testing. It could not have been planned precisely regarding weather conditions (since it was designed for outdoor), and for example postponed in case of rain and fog, nor repeated before October 2019. Thus, as already described in 3.3.3 Questionnaire Results, the results of the questionnaire's first part have to be taken with caution: They relate to the lecture's concept, but the weather conditions did not allow following the scenario of outdoor learning. The students have solved the larger part of the quiz indoor; thus, could not fully experience the possible benefits of the designed context-related m-learning lecture.

Nevertheless, useful feedback was collected, which will allow improving the concept of the m-learning for future purposes. Future research could apply different user research methods like think-aloud or eye tracking to evaluate the usability of the m-learning application. After having an insight on the research limitations, and minding them, it follows logically to next review the advantages and disadvantages of the results basing on the feedback collected by usability testing in the following section.

4.3   Advantages and Usability Issues

The results of usability testing indicate both advantages and drawbacks of the designed m-learning concept. The first advantage resulting from the students' feedback is that students feel more confident in perceiving the terrain model after learning in groups and using *mCartoLearn* application. It has also motivated them for learning about the topics and learn from each other by collaborating and discussing. The chosen concept was relatively well accepted by the students and gave positive learning results. Thus, it indicates it is a reasonable basis for modernizing terrain-understanding-related lectures meaning by universally applying it to other locations which are didactically appropriate for the teaching content on the one hand, and used as a good way for practicing gained

knowledge to strengthen it on the other hand – which is a second advantage of the developed m-learning concept. Furthermore, this means that it is suitable for self-paced and lifelong learning. This concept provides a solid basis for extending it by applying augmented reality and machine learning, both currently relevant research questions in research.

Besides advantages, the designed m-learning concept has also shown some drawbacks. Firstly, the approach to presenting single- and multiple-answer questions the same way, confused students as they did not understand how many answers they need to select, and it was also hard sometimes to proceed to next question if they could not have found the correct combination of answers in several tries. Secondly, students' feedback has shown the m-learning's implementation included too few multimedia, and they would have preferred it more with additional links to information sources (e.g., to Wikipedia), animations, videos, and similar. Thirdly, there was too little theory as an information source before answering the questions. Again, this would be in contrast with the concept of learning by doing but is an aspect to consider in improving the concept. Finally, the concept, even though solidly accepted by students, has shown to implement too low gamification level which is also one possible way for future improvements to make the designed concept even more exciting and motivating. Thus, the following subchapter considers future improvements.

4.4   Recommended Improvements

Participant of the usability testing suggested some essential improvements for enhancing the user experience regarding the learning process and the *mCartoLearn* application usage. On the one hand, recommended improvements for the learning process, which reflect on the conceptual design are:

a) *Improving the quality and number of examples* – Firstly, it would be recommended to improve the resolution quality of the examples, make them reflect questions better, and include information like title and a short description to be more understandable. Secondly, it would also be recommended to provide several examples for a question, so that they can be compared and differenced in the terrain structure detected.

b) *Providing additional theoretical background* – This could take place in three different moments: For example, one moment could be before starting the quiz lesson by

introducing the topic. Another moment could be while solving the questions by providing a vocabulary on the new cartography-specific terms, and after second wrong answer, by explaining the correct and wrong answer(s). The third moment could be after completing a lesson by giving a summary of the topic.

c) *Including more multimedia* – This could make the m-learning experience more exciting and would allow exploring topics more in-depth by seeing videos, animations, following online links, and similar.

On the other hand, recommended improvements for the *mCartoLearn* application, which reflect on its usability are:

a) *Making it understandable if the question is a single- or multiple-choice* – This could be done, for example, by introducing radio buttons for single-choice answers, and keeping checkboxes for multiple-choice answers (see Tab. 4.10). Furthermore, on multiple-choice questions, the number of correct answers could be indicated: For example, by adding a counter which counts down the number of selected answers to zero on the screen. Additionally, the *Done* button functionality could be disabled until the correct number of answers is selected. This is further explained on the first question of the Contour lines lesson example. There are three correct answers to that question (displayed in the Tab. 4.11 as Multiple-Choice Question Screen). At first, before selecting the correct number of answers (3), the screen displays an answers' counter, and the *Done* button is disabled. Afterward, upon selecting one answers, the counter gives updated feedback on how many more answers are needed. At last, upon selecting three answers, the counter disappears, and the *Done* button becomes enabled (as shown in table – Now, the user can click on it and check if he answered correctly.

b) *Improving the switch between map example and question* – This could be done by improving the intuitiveness of the buttons for opening and closing the map example. For instance, the misleading symbolization can merely be replaced with text "Example" and "Close" like shown in the Tab. 4.12 at Question Screen and Example Screen (1). Another solution could also be opening the map example in the full-screen size, and adding a common "X" symbol for closing it to return to the question – as shown in the Tab. 4.12 at Example Screen (2). Both of these

solution combinations would improve the intuitiveness of the switch between the two screens.

c) *Disabling question background when map example is active* – In the tested version, the image view which is showing the map example is set invisible by default, and by clicking the *Map Example* button, it becomes visible on the top of the Question screen. Thus, it is necessary to disable the interaction with any content that is not being currently displayed to prevent situations when the *Done* button, one of the multiple-choice answers, or any other functionalities are automatically activated when interacting with the map example displayed above it.

d) *Implementing results-submitting functionality* – In order for teachers to successfully evaluate students' performance, it is necessary to implement results' submitting functionality. One possible solution could be sending the result by e-mail. In this case, it could be logical to give the user an option of adding a free-choice sender e-mail address as input, while the recipient's e-mail address could be the default (e.g., lecturer's official university e-mail address), but still allowed to change it if needed.

The Single-Choice Question screen could implement radio buttons which allow selecting only one answer by default.
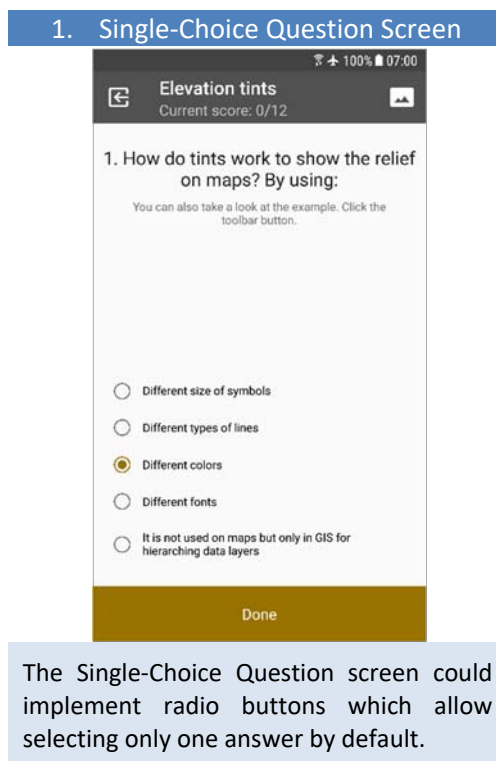
Tab. 4.10   Question screen redesigned: single-choice

1. Multiple-Choice Question Screen	2. Multiple-Choice Question Screen	3. Multiple-Choice Question Screen
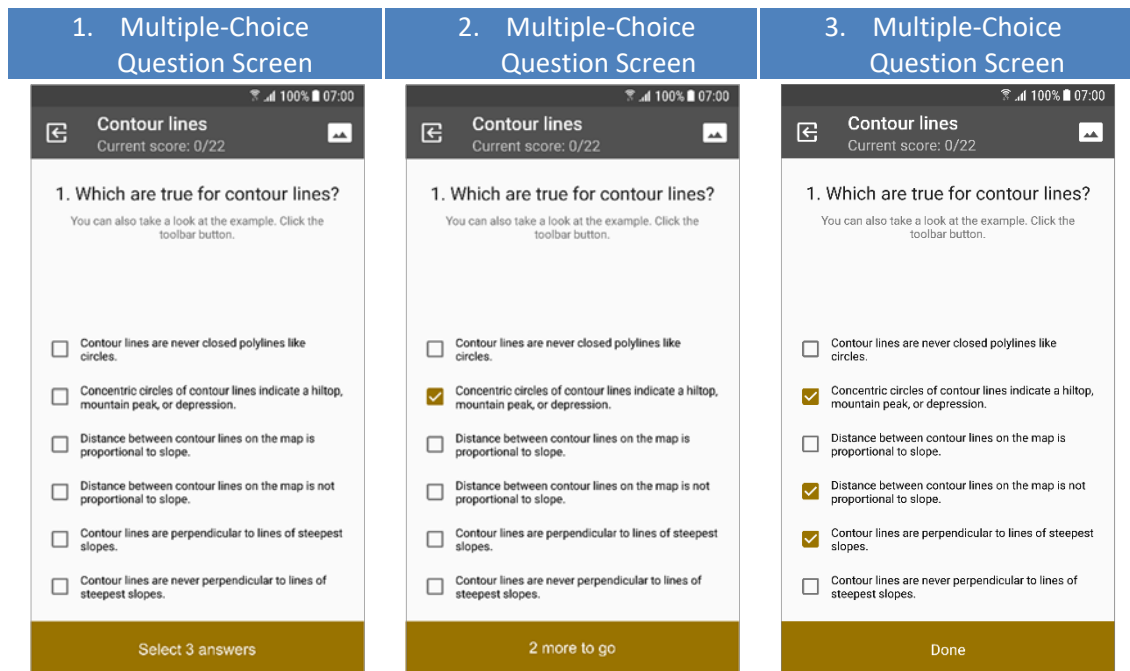
The Multiple-Choice Question screen could implement a selection counter which enables the *Done* button only if a right amount of choices is selected giving the feedback on their number at the same time.

Tab. 4.11   Question screen redesigned: multiple-choice
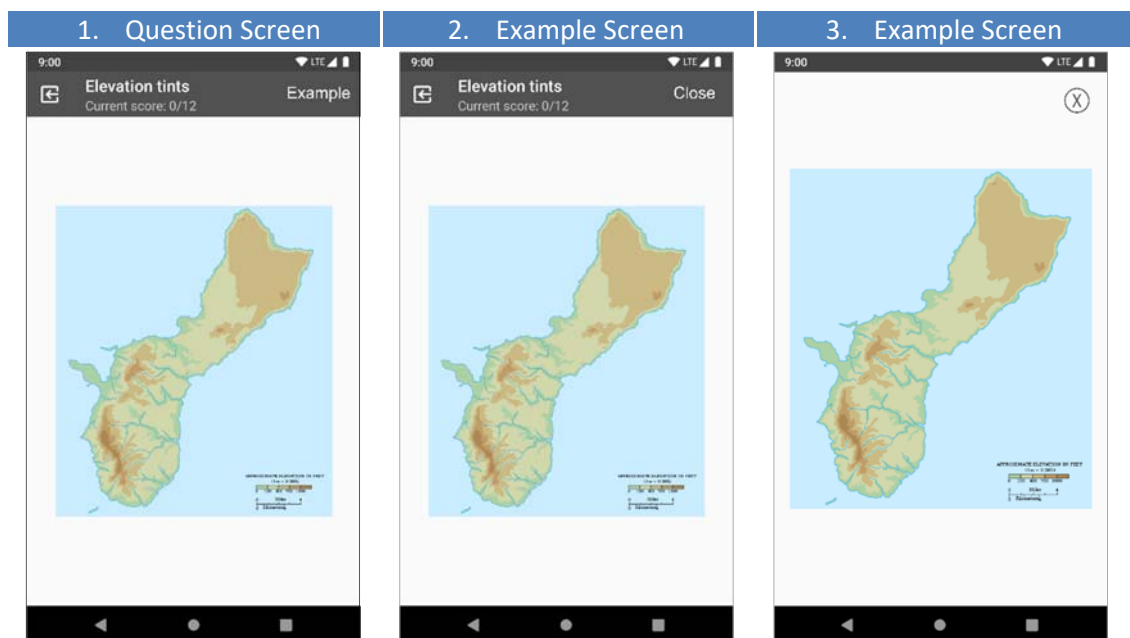
1. Question Screen	2. Example Screen	3. Example Screen
The Question screen could have a textual reference to opening the map example by instead of current image symbol.	The Example screen could have a textual reference to closing the map example and returning to the question as one option.	The Example screen could take the full-screen size and have a standard "X" symbol for closing the map example and returning to the question as another solution.

Tab. 4.12   Question and Example screens redesigned (map example by Lencer (2012))

e) *Fixing points miscounting issues* – Usability testing detected an issue with points miscounting; However, since the students' feedback was not detailed enough, it is advised to conduct a usability testing by observing users' behavior to detect where precisely the problem appears, and in which circumstances. Then, with having that information, program code issues could be precisely detected, and code debugged.*Interacting with map example* – According to the usability test, it is also recommendable to enhance the interaction with the map example, for instance by making it zoomable, available in resolutions for different zoom levels, and allowing to pan on zoom levels where the map boundaries are outside of the screen.

f) *Providing vocabulary on new cartography-specific terms* – It is recommendable to implement explanations of used vocabulary that are accessible from the Question screen. This handy functionality could enable users to understand the questions better and offered answers in cases when they encounter expressions which they are not familiar with or are not sure what they refer to (e.g., hachuring).

g) *Providing better instructions of learning goals and application usage* – The application should focus on offering better instructions on how to use the application. For example, a demo in means of a video simulation of using the application could follow after the Welcome screen – and available afterward via a *Demo* button in the Instructions interface.

After presenting the usability test results and how can the concept and *mCartoLearn* application be enhanced, it is also necessary to review the limitations of the research and think of the directions of future work. The next chapter will thus refer to these two aspects.

4.5   Future Work

Besides implementing the improvements of the existing concept and *mCartoLearn* application in ways mentioned in the previous subchapter, it would also be advisable to iterate further usability tests, as mentioned in 4.2 Research Limitations. However, there

could also be some other intriguing directions for enhancing the m-learning concept. Some of those could be:

a) *Replacing the route with a larger area of interest* – This way, there would be no requirements to complete the route at once: If lessons' locations would be in a larger area, there may be (1) higher chances to compensate for the situations of poor weather conditions, and (2) more real-world examples eligible to the questions. Both may improve the learning experience and increase the motivation to learn. Furthermore, by covering larger, or different areas, users would get opportunities for practicing and getting even more confident on the gained knowledge.

b) *Further gamification of the concept* – A higher motivation for learning could also result by further gamification of the learning: For example, there was a suggestion made in the usability testing to continue developing the concept into the direction of Pokémon Go. This way, students may be more motivated to collaborate; however, it may also be sensible to set certain limitations as the mountainous areas (for conducting the m-learning), although exciting for exploring, also bring risks of accidents in situations when students do not pay enough attention the steep or rocky terrain. Another handy functionality to it may also be adding a chat function so that teams could communicate if they decide to separate for completing the game faster.

c) *Incorporating 3D terrain models and augmented reality* – These two techniques, while not being cartographic techniques to represent the relief on the maps, may still be attractive additions to the m-learning concept. For example, a 3D terrain model does not require cartographic expertise to perceive the terrain: It shows the terrain directly as it is – in three dimensions. Thus, it may be an exciting functionality to help understand traditional cartographic visualization better. The same goes for augmented reality (AR) – it can provide exact additional (supplementary) information to the map which may be very useful when a topographical map is overloaded with information – sometimes it can be tough for an inexperienced user to extract needed information from a map.

d) *Customization of learning* – Mobile learning could allow students to adapt their learning pace to their own needs and wishes. For implementing it, future

research could be extended to utilize machine learning which would follow even more the direction of contemporary education development (see 1.1 Background).

All of the mentioned examples of future work could be the basis for exciting future research, and worthy additions for enhancing concepts of the context-related mobile learning systems. Now, after concluding the discussion with the latter, let us proceed to the research conclusion in the following chapter.

5 Conclusion

Inspired by mobile learning and location-based mobile learning being current topics in modernizing the education (Kukulska-Hulme et al. (2009), Sharples et al. (2009), McQuiggan et al. (2015), Sailer et al. (2015)), this research aimed at finding a new, or improving an existing way of context-related environmental learning at universities by using mobile devices. It intended to do so by combining the mobile learning process with real-world observations on predefined locations as a method for teaching cartographic content.

Firstly, to reach the research objectives, related literature, and relevant case studies were reviewed, and indicated what pedagogical, and conceptual and user interface design approaches to use in the location-based mobile learning design. The mobile learning lecture was then designed based on the collaborative learning approach combined with elements of constructivist and situated learning approaches and by following the concept of five planes of user experience in creating user-oriented interfaces. The mobile learning lecture's conceptual design was implemented for mobile devices running Android OS – *mCartoLearn*. Particular attention in implementation was on its aesthetics and design.

Secondly, the *mCartoLearn* application was tested in October 2018 in the area chosen for mobile lecture implementation – Dachstein Alps in Austria where International Cartography Master students of the 2017 intake participated in the Alpine Cartographic Field School. Unfortunately, poor weather conditions were the reason that the mobile learning lecture could not have been completed outdoor – by following the designed route and stopping on designed checkpoints. After completing the first lesson on the first checkpoint, students had to return to the accommodation, and finish the other lessons indoor. For this reason, the conducted questionnaire's results did not entirely reflect the user experience but still lead to useful conclusions that offer satisfying answers to research questions.

Thirdly, students got familiarized with techniques of representing relief on maps and structured their definitions on it based on their understandings of the techniques. They came to these conclusions by collaborating in groups and discussing the results. This has confirmed that the conceptual design based on:

1. *collaborative learning implementing the constructivist method of learning and elements of situated learning,*

2. *gamification of learning followed by a discussion as a wrap-up gives good learning results, and*

3. *importance of user-centered design with a further accent on its aesthetics*

was the appropriate concept in reaching research objectives: This means that it could be a solution to enriching and modernizing cartographic teaching at universities. On the one hand, the mobile learning lecture concept has shown further advantages like this way of learning being solidly accepted by students, motivating for learning, giving positive learning results, and being a suitable model of self-paced and lifelong learning. On the other hand, usability testing uncovered several suggestions for improving the interface design: For example, it is recommended to differentiate between single- and multiple-choice questions, or to provide the theoretical background on topics not known by the user. All these, as well as implementing augmented reality and utilizing machine learning (for customizing the learning process) are opportunities for future improvement and research.

Finally, the scientific innovation of this thesis is *extending cartographic lecturing at universities from indoor-based traditional and e-learning into outdoor-based m-learning by combining three learning methods: (1) mobile learning, (2) context-related learning, and (3) collaborative learning.*

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Appendix 1: Usability Testing Questionnaire

Alpine Field School 2018, Intake 2017   Ramsau am Dachstein, _____

QUESTIONNAIRE

Dear student, this is a questionnaire on your experience of using the **mCartoLearn app** for a context-related mobile-learning lecture on relief representations on maps. Please, fill this questionnaire to provide a useful feedback on the concept.

Part I: *Lectures*					
1. How confident were you of perceiving the terrain model (reality) by reading topographic maps:					
a) Before the m-learning experience?	1	2	3	4	5
b) After the m-learning experience?	1	2	3	4	5
2. How satisfied were you with:					
a) The quality of provided map examples?	1	2	3	4	5
b) The number of provided map examples?	1	2	3	4	5
3. What would you improve regarding providing map examples?					
4. How easy was for you to find correct answers based only on group discussion and without theoretical background available?	1	2	3	4	5
5. In which ways would you have liked to have additional theoretical background provided within the app?					
6. Do you think it was useful to have real-world examples in the quiz and why?					
7. How much did this way of learning deepen your previous knowledge?	1	2	3	4	5
8. How did you enjoy this way of learning - Using your mobile device, solving the quiz and having context-related examples?	1	2	3	4	5

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Part II: *Mobile Application*					
1. How intuitive or easy was for you to use the app and to understand interaction (buttons') metaphors?	1	2	3	4	5
2. What would you suggest to improve about any of question 1?					
3. How satisfied were you with the app regarding:					
a) The occurrence of errors in the app's performance?	1	2	3	4	5
b) The occurrence of app crashes?	1	2	3	4	5
4. If you encountered any technical problems from the question 3, or any other while using the app, please describe in which situation(s) and how often.					
5. How would you rate the level of functionalities that the app offers?	1	2	3	4	5
6. In what ways would improve the functionalities of the app?					
7. How appealing or enjoyable did you find the app's interface?	1	2	3	4	5
8. Were the app and quiz design motivating for learning and what was the reason(s)?					
9. How would you improve the user experience of using the app?					
10. Were you directly interacting with the app during the lectures?		YES		NO	

Appendix 2: Usability Testing Results' Charts

PART I – LECTURES

1. How confident were you of perceiving the terrain model (reality) by reading topographic maps?

Before the m-learning experience (Average grade: 3.4)
After the m-learning experience (Average grade: 4.0)

2. How satisfied were you with:

a) The quality of provided map examples (Average grade: 4.0)
b) The number of provided map examples (Average grade: 4.0)

3. What would you improve regarding providing map examples?

- Use maps from same source
- Add map title
- North orientation missing
- More appealing examples
- More examples so that different areas can be compared
- Examples that better depict the question, or a detailed description of the example
- Enough examples and sufficient quality was provided
- High resolution and better quality
- Zooming and panning
- N.A.

4. How easy was for you to find correct answers based only on group discussion and without theoretical background available?

- Average grade: 2.9

5. In which ways would you have liked to have additional theoretical background provided within the app?

Suggestions (y-axis) / Suggestion occurence (x-axis)

- It was sufficient
- Make answers not conflicting, and statements clear of doubts
- By explanation after a wrong answer
- Use quiz to test (practice) the knowledge, not for learning
- By full summary of the lecture
- By vocabulary on terms, or additional info on the topics
- By more multimedia (e.g. visuals, links, videos, animations, texts)
- By introduction to the topic
- N.A.

6. Do you think it was useful to have real-world examples in the quiz and why?

Suggestion (y-axis) / Suggestion occurence (x-axis)

- No, it was more theoretical than applied
- No, someone may have pre-knowledge
- Yes, helpful for real-life situations
- Yes, intuitive
- Yes, to find solution to asked question
- Yes, to compare real-world with map, and vice versa
- Yes, to learn and understand better
- N.A.

7. How much did this way of learning deepen your previous knowledge?

Grade occurence

| N.A.	1	2	3	4	5
1	1	2	8	14	0

Grade

■ Average grade: 3.3

8. How did you enjoy this way of learning - Using your mobile device, solving the quiz and having context-related examples?

Grade occurence

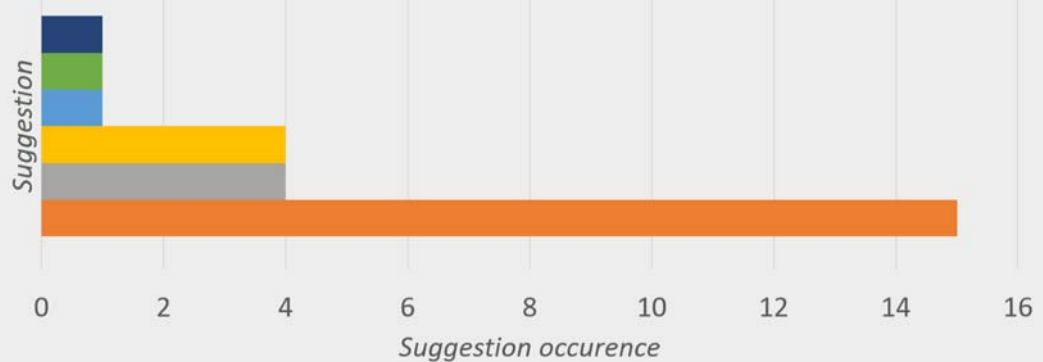| N.A.	1	2	3	4	5
0	2	0	6	12	6

Grade

■ Average grade: 3.8

PART II – MOBILE APPLICATION

1. How intuitive or easy was for you to use the app and to understand interaction (buttons') metaphors?
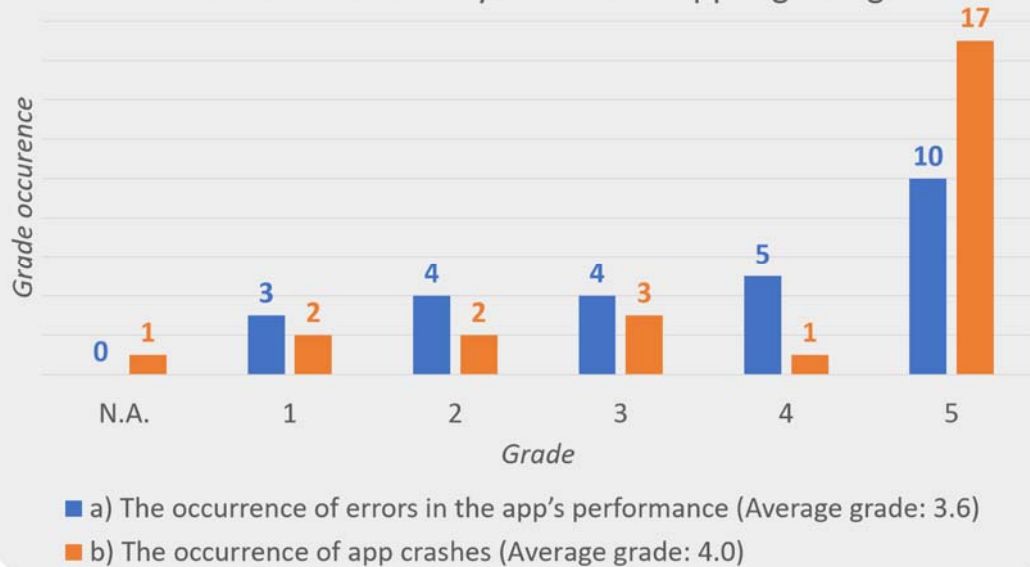■ Rounded average grade is 3.7
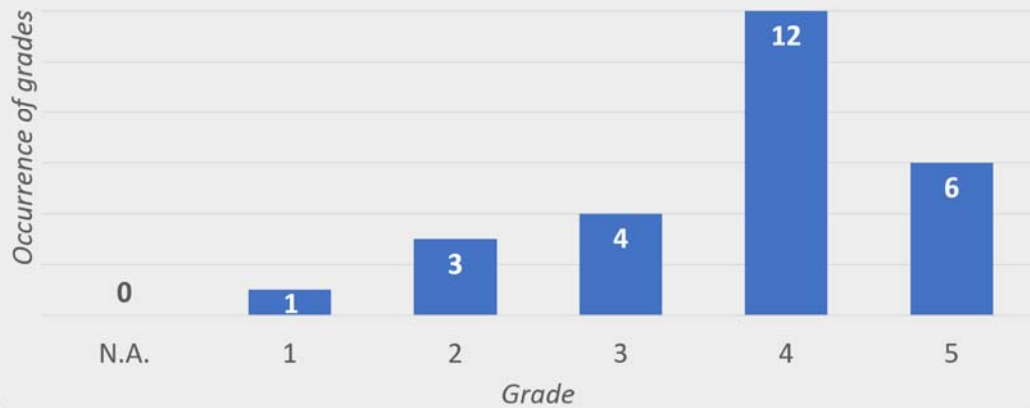
2. What would you suggest to improve about any of question 1?
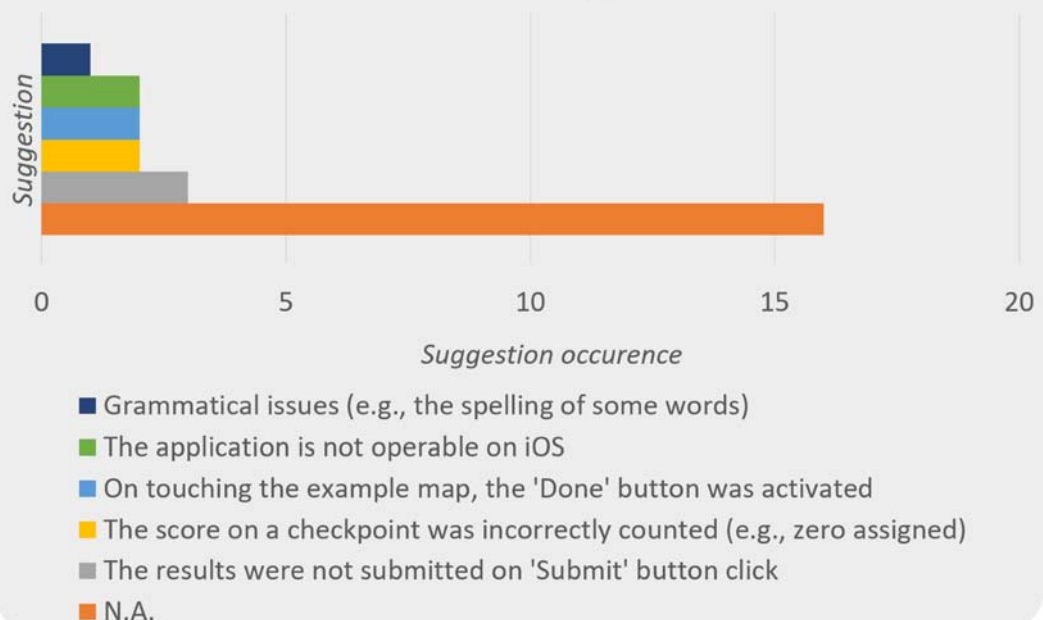
■ Better explain the purpose of the group number
■ Button's metaphors
■ A visual introduction on app's purpose and how to use it
■ Make clear if the question is single- or multiple-choice
■ Going back to question from map example
■ N.A.

3. How satisfied were you with the app regarding:

a) The occurrence of errors in the app's performance (Average grade: 3.6)
b) The occurrence of app crashes (Average grade: 4.0)

4. If you encountered any technical problems from the question 3, or any other while using the app, please describe in which situation(s) and how often.

Grammatical issues (e.g., the spelling of some words)
The application is not operable on iOS
On touching the example map, the 'Done' button was activated
The score on a checkpoint was incorrectly counted (e.g., zero assigned)
The results were not submitted on 'Submit' button click
N.A.

5. How would you rate the level of functionalities that the app offers?

Average grade: 3.3
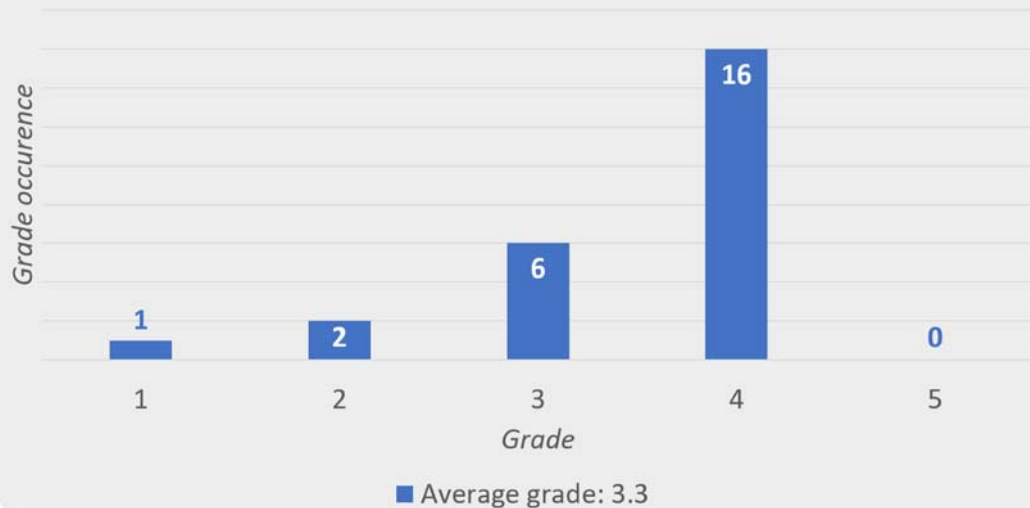
6. In what ways would improve the functionalities of the app?
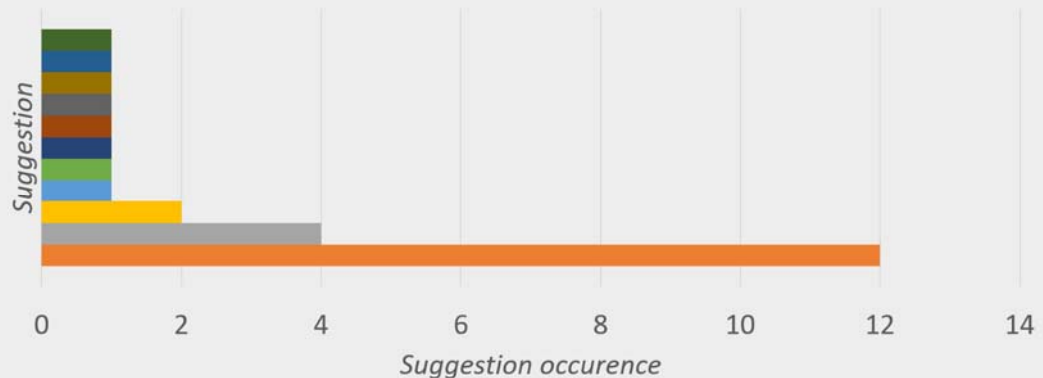
- By giving an overview answer after the summary question
- By connecting the route to the didactic content
- It is better keeping it simple as it is
- By making the application more impressive
- By improving the switch between map example and question
- By making it clear if the question is single- or multiple-choice
- By implementing the application for iOS
- By adding a 3D map view
- By providing cartography-specific vocabulary
- By making map examples zoomable
- N.A.

7. How appealing or enjoyable did you find the app's interface?

Average grade: 3.5

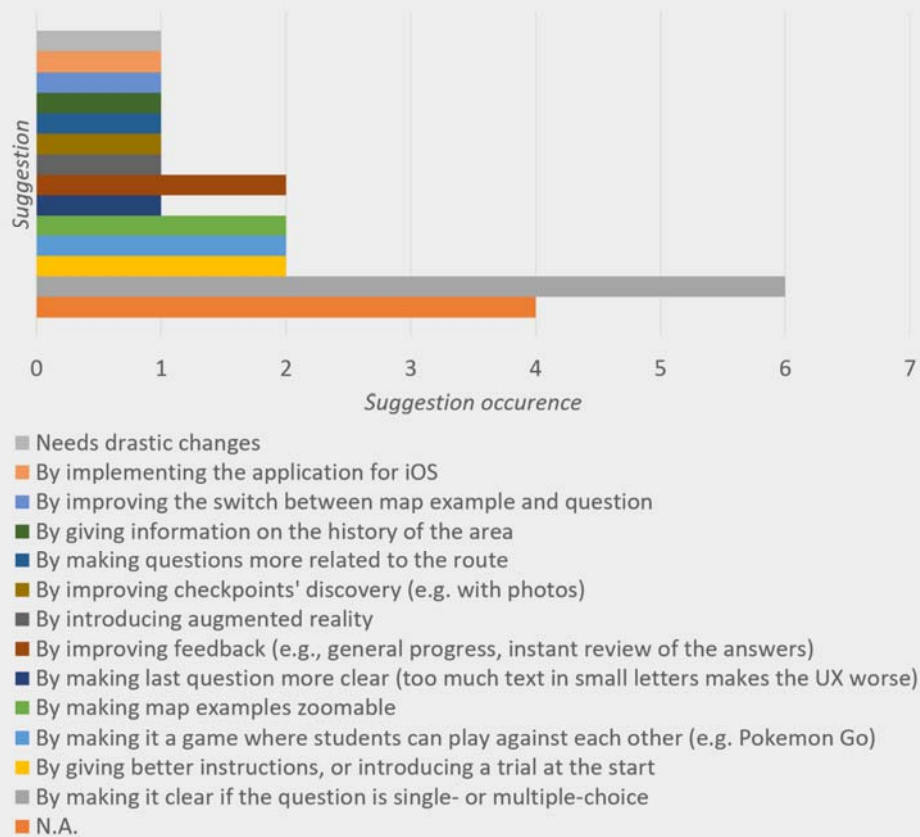## 8. Were the app and quiz design motivating for learning and what was the reason(s)?

N.A.   Yes   Somewhat   No

9. How would you improve the user experience of using the app?

- Needs drastic changes
- By implementing the application for iOS
- By improving the switch between map example and question
- By giving information on the history of the area
- By making questions more related to the route
- By improving checkpoints' discovery (e.g. with photos)
- By introducing augmented reality
- By improving feedback (e.g., general progress, instant review of the answers)
- By making last question more clear (too much text in small letters makes the UX worse)
- By making map examples zoomable
- By making it a game where students can play against each other (e.g. Pokemon Go)
- By giving better instructions, or introducing a trial at the start
- By making it clear if the question is single- or multiple-choice
- N.A.

10. Were you directly interacting with the app during the lectures?

■ N.A.   ■ YES   ■ NO