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# The use of Alexa for mass education

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# Abstract

Nowadays, nearly everyone is able to fetch information on specific topics and interests in the internet at every time in every place. Nearly every child owns a smartphone or at least has access to a device connected to the internet. While children mainly focus on watching videos or playing games, scientists quickly recognized the educational possibilities. Building applications for mobile devices, that create an educational environment opens a very interesting channel to deliver knowledge in a playful and even more efficient way to children. Additionally to transferring knowledge, technology-enhanced learning creates a completely new field of personalized learning and learning analytics. Concentrating on a child's strengths and weaknesses in mass education is quite hard. Especially weaknesses are often discovered very late in the learning process of traditional learning methods. Taking the different learning types of children into consideration, it's very hard to optimize the teaching methods to address every child the same way and with the same learning effect. This thesis pays attention to the creation of an Amazon Alexa Maths Training Application for children in primary school. The aim is to increase the children's maths skills in the number series of the multiplication table in a very exciting and playful way. Combining the possibilities of an Amazon Echo Smart Speaker with the learning algorithm of the TU Graz Maths Trainer provides a very attractive learning environment for children. For the evaluation of the educational game in combination with the speech-assistant technology, two field studies were conducted in primary schools in Austria. Children loved to talk to the Alexa speech-assistant. Integrating the educational aspect of learning maths into an Alexa Skill resulted in better feedback than expected and motivated to enhance the Skill based on the results of the field studies.

Heutzutage ist fast jeder in der Lage, sich im Internet zu jeder Zeit und an jedem Ort über bestimmte Themen zu informieren. Fast jedes Kind besitzt ein Smartphone oder hat Zugang zu einem mobilen Gerät, welches mit dem Internet verbunden ist. Während Kinder sich hauptsächlich auf Videos oder Spiele konzentrieren, erkennen Wissenschaftler in diesem Zusammenhang sofort pädagogische Möglichkeiten. Die Entwicklung von Applikationen für mobile Geräte bietet einen sehr interessanten Kanal, Wissen auf spielerische Art und Weise zur Verfügung zu stellen. Zusätzlich zum Wissenstransfer schafft das technologiegestützte Lernen ein völlig neues Feld des personalisierten Lernens und der Lernanalytik. In Schulklassen ist es recht schwer mit traditionellen Lernmethoden auf Stärken und Schwächen von einzelnen Schülern einzugehen. Vor allem Schwächen werden leider oft erst sehr spät im Lernprozess entdeckt. Unter Berücksichtigung der verschiedenen Lerntypen ist es sehr schwierig, die Lehrmethoden so zu optimieren, dass jedes Kind auf die gleiche Art und Weise und mit dem gleichen Lerneffekt angesprochen wird. Diese Arbeit beschäftigt sich mit der Erstellung einer Amazon Alexa Mathematik Training Applikation für Kinder im Grundschulalter. Ziel ist es, die mathematischen Fähigkeiten im kleinen 1x1 auf sehr spannende und spielerische Weise zu trainieren. Die Kombination eines Amazon Echo Smart Speakers mit dem Lernalgorithmus des TU Graz Mathe-Trainers bietet eine sehr attraktive Lernumgebung für Kinder. Für die Evaluierung des Lernspiels in Kombination mit der Sprachassistententechnologie wurden zwei Feldstudien in österreichischen Volksschulen durchgeführt. Die Kinder liebten es, mit dem Sprachassistenten Alexa zu sprechen. Die Integration des pädagogischen Aspekts des Mathe-Trainers in einen Alexa Skill führte zu einem besseren Feedback als erwartet und motivierte uns, den Skill auf Basis der Ergebnisse der Feldstudien weiter zu optimieren.

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# 1 Introduction[1]

Before the digital era, information was not accessible by the majority of people (Wikramanayake, 2005). Wikramanayake further describes in his publication, that even those accessed were unable to obtain current information as we are able today. While observing information only through traditional sources like schools, teachers or libraries, there was also a strong dependency and limitation in education. The technology advantages have opened up many avenues of learning as information is accessible from anywhere by everyone, so Wikramanayake.

The meaning and impact of technology are very important in many fields especially in education in the 21st century (Ghavifekr, 2015). Ghavifekr mentions, that technology has become the knowledge transfer highway in most countries. Technology integration nowadays has gone through innovations and transformed our societies that have changed the way people think, communicate with friends and family and how people work (M. Grabe and C. Grabe, 2007).
Even more important than these changes is the new way of how people or students gather, organize, access and share information and knowledge and how to interpret and combine those from different sources. These changes pose some very important challenges as to how we organize teaching and learning in schools (Arnseth and Hatlevik, 2010).
Ghavifekr introduces the term ”Integration of Information, Communication, and Technology” (ICT) which is a technique to assist teachers to

[1] Parts of this chapter have been published in:

Peter Schoegler, Markus Ebner, and Martin Ebner (in review). “The use of Alexa in mass education”

replace traditional teaching methods with a technology-based teaching and learning method. ICT in education refers to the use of computer-based communication that incorporates into daily classroom instructional process while ICT has the capability to provide a perfect dynamic and proactive teaching-learning environment. Teachers are seen as the key players using ICT in their classrooms to prepare students for the current digital area and introduce them on how to gain and validate information with the use of technology (Ghavifekr, 2015). All the information resources on the internet in combination with computers or mobile devices are no replacement for highly qualified teachers. Instead of replacing, these technologies are a tool or add-on for teachers by combining their pedagogical skills with a set of information resources and applications for a better teaching-learning experience. The integration of ICT in schools also enables teaching possibilities while not being physically in the same room or even the same country. In general, it's a continuous integration in the daily education process providing a proactive teaching-learning environment (Young, 2003).

Applications in the form of games provide a perfect environment by making use of the information on the internet and deliver data in a controlled way to the user. Children's motivation for games is far higher than their motivation for traditional curricular content. Traditional learning methods appear seamless to young people in comparison to the interesting, fast-growing, digital world. Prensky describes the idea of combining digital games with curricular content and introduces the phrase Digital Game-Based Learning (DGBL) (Prensky, 2003).

Computer games, the internet, and other new communication media are often seen to pose threats and dangers to young or inexperienced people, according to Buckingham and Willet (2013). Adding that they also provide new opportunities for creativity and self-determination. It's in the parent's responsibility to monitor their children's interaction on the internet. So-called internet parental styles have to be applied (Valcke et al., 2010). In recent years, electronic games have assumed an important place in the lives of children and adolescents. Children acquire digital literacy informally, through play, and neither schools nor other educational institutions take sufficient account of this important aspect (Gros, 2014). Gros further explains that multimedia design for training and education should combine the most powerful features of interactive multimedia design with the most effective principles of technologically mediated learning.

By making use of new teaching and learning technologies combining curricular information in games or learning applications, big amounts of user-specific data is collected. George Siemens and Phil Long (2011) describe the most dramatic factor shaping the future of higher education would be something that we cannot touch or see. The name ”big data and analytics” as the core role of to enable user-centered, personalized learning processes. Furthermore, the role of big data and data analysis in government and other business sectors follow this trend anyways and strengthens this approach. Siemens and Long describe learning analytics as the trigger to penetrate the fog that has settled over the whole educational system. (Siemens and Long, 2011). The main question addressed by Erik Duval (Duval, 2011) is what exactly should or can be measured and which data could be evaluated against already existing data to enhance the learning progress.
Graz University of Technology has a special focus on the topic of learning analytics (LA). They already made use of the advantages of combining digital games with curricular content. Apps for children to test competences in multiplication are developed. Those apps deal with estimating the competence of the user and also adapt to the individual development of the student or child. All the data is collected and analyzed by the system in the background to optimize user feedback and the personal learning curve of the student. Ebner and Schön state, that LA is: ”...the assistance of instructors, teachers, and lectures with appropriate data to enhance the learning behaviors of every single learner – individualized and personalized.” (Martin Ebner and Schön, 2013).

This thesis discusses the implementation of an Amazon Alexa Skill for children in primary school with the aim, to increase the 1x1 multiplication table calculation skills of a child by playfully integrate calculation questions in an interactive story game. It displays the technological challenges of smart speakers in combination with the Amazon Alexa while building a Skill that communicates with children between the age of 6-10. Furthermore, it describes the possibilities and challenges to provide personalized content for each child to maximize the learning curve and motivation to play the game. The thesis describes how to find a reliable way to permanently store specific data via the Alexa Skill and how to authenticate users in the system to apply the learning analytics algorithm. The maths skills of children in primary school strongly vary, so it’s crucial to provide tasks that align with the child’s competence level. This assures, that children stay motivated starting the Alexa Skill and play the story game again and again while unconsciously training their math skills.

# 2 How we learn[1]

## 2.1 Learning Styles

According to Vincent (Annette Vincent, 2001), a learning style indicates a student's or child's preferred method of learning. It guides the development of instructional strategies that integrate the appropriate content and context. In some respects, learning styles function as teaching blueprints, so Vincent.

In general, there are three different main learning styles which are defined as the followings (Gilakjani, 2012):

1. Visual learning type
   Those types of learners need some kind of visualization of the problem. They think in pictures and visual images. To foster their understanding and increase their ability to gather information, non-verbal cues like body language are very helpful. Visual learners prefer sitting in front of the classroom (Gilakjani, 2012).
   Strategies for teaching visual learners are (Vincent and Ross, 2001):
   - Using video equipment
   - Providing assignments in writing
   - Using charts and pictures

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2. Auditory learning type
   Auditory learning types learn best from listening, talk things through or discussions with other persons. By listening to tone of voice, speed, and other nuances, they interpret the underlying meaning of the heard speech. These persons may have less understanding of some written text (LdPride, n.d.).
   Strategies for teaching auditory learners are (Vincent and Ross, 2001):

   - Record class notes and learn by listening to them
   - Remember details by trying to remember hearing previous discussions again
   - Always try to participate in class discussions
   - Ask questions to start conversations
   - Read assignments out loud and answer correct question by saying it loud

3. Kinesthetic learning type
   These are the typical persons who cannot sit still for long periods and get unfocused after some time. They have to explore everything on their own and learn best through a hands-on approach (LdPride, n.d.).
   Strategies for teaching kinesthetic learners are (Vincent and Ross, 2001):

   - provide many hands-on activities to allow students to participate and explore
   - enable physical movement within the classroom
   - provide action triggered stories
   - encourage children to summarize their daily experiences in their notes

But teaching a student or child by applying exactly his or her preferred learning style doesn’t automatically lead to the most valuable result. Daniel T. Willingham, professor of cognitive psychology at the University of Virginia says: ”What cognitive science has taught us is that children do differ in their abilities with different modalities, but teaching the child in his best modality doesn’t affect his educational achievement.” (Willingham, 2005). He further explains: ”What does matter is whether the child is taught in the content’s best modality. All students learn more when content drives the choice of modality.” (Willingham, 2005). So, the best learning results could be achieved by combining the most suitable modality for the processed topic combined with the recommended teaching techniques for all learning types.

## 2.2 Learning Mathematics

Children nowadays grow up in a technology-focused everyday life, which is based on mathematical concepts. Computers, mobile phones, and other assistance devices guide their childhood. It’s crucial in a child’s education process to evolve a healthy and easy understanding of numbers and their combinations and interactions. Kilpatrick states mathematical proficiency in five strands (Kilpatrick, Swafford, and Findell, 2001):

- conceptual understanding – understanding the mathematical concept and their operations and relations
- procedural fluency – ability or skill to project procedures in different problem formulations
- strategic competence – formulate, represent and solve problems
- adaptive reasoning – skill to generate logical links
- productive disposition – see mathematics as important, useful and efficient

Kilpatrick also adds that the most important observation of those five strands is the interdependency of each other. These strands are the fundamental pillars of how children learn to solve mathematical problems and gives direction in how teachers have to integrate those in their process.

The first interaction with numbers often starts in very early stages in childhood when parents encourage their children to count their sweets to share it equally with their siblings. Or for example, counting all the stairs when going to bed from the first to the second floor. Connecting simple games with mathematical problems that have a link to everyday questions is always the first approach to explain mathematical thinking to a child. This often results in a basic understanding of whole numbers and the way to sum or multiply them in a very fundamental way. (*Easy Ways to Add Math to Everyday Routines: A Home-School Connection Post* 2015)

Neil Mercer explains in their publication (Mercer and Sams, 2008) how to use language to support mathematical understanding and solve problems. The study describes the benefit of discussing problems with a partner or within a group and use language as a tool to work on mathematical problems by their “thinking together” approach. The study draws out the importance of getting different perspectives on a problem while getting input from other members in the group. Furthermore, it outlines the importance of a teacher’s role in how to explain problems and how to closely guide students or children in a problem-solving way.

# 3 Technology Enhanced Education[1]

## 3.1 State Of The Art

”In this 21st century, the term ”technology” is an important issue in many fields including education. This is because technology has become the knowledge transfer highway in most countries.” (Ghavifekr, 2015). The technology integration in our everyday life has changed the way people think, act, work, live and communicate (Ghavifekr, 2015). Children have to be prepared to live in a fast-growing digital world. Educational institutions and especially schools have the responsibility to prepare young students to live in a knowledge society and therefore need to fully integrate the concept of ”Integration of Information, Communication, and Technology” (ICT) in their curriculum (Simin Ghavifekr and Salleh, 2012).

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## 3.2 Benefits of Integrating Technology In Education

The integration of ICT in education means technology-based or computer-based teaching and learning combined with pedagogical learning techniques in schools. Children are already familiar with the use of mobile devices and already know how to obtain information from different digital sources. Children or students will learn better in a technology-based environment and the integration of ICT in classrooms brings big advantages for teachers and students. As the use of new technologies in education brings a huge benefit in the pedagogical aspect, the use, and support of ICT elements and components lead to an even more effective learning environment (Simin Ghavifekr and Salleh, 2012).

Besides the benefits of increasing quality, accessibility and cost-efficiency of the delivery of information and instruction from teachers to students, the integration of ICT also includes the advantage of networking the learning communities to face the challenges of globalization (Albirini, 2006). Young also mentions in his publication "Integrating ICT into second language education in a vocational high school", that integrating ICT is not done in a single step. It's more a continuous ongoing process that fully supports teaching, learning and information resources and thereby provides a proactive teaching-learning environment. Young further explains, that integrating ICT in education is crucial because, with the help and support of ICT elements and components, teaching and learning is not only happening in the class or school environment but also enables this process even if students and teacher are physically separated from each other (Young, 2003).
It's a fact that through technology-based tools and devices, almost the whole range of subjects in school like languages, maths, science, humanistic and arts will be learned more effectively. Implementing ICT helps students and teachers as additional support when it comes to effective learning with the help of computers to provide the content of learning aids at it's best (Jorge et al., 2010).

The use of technology in education offers various interesting opportunities for teachers. Using, for example, educational videos, store user-specific data in permanent storages by using databases, guided exploration, games, the world wide web, music or brainstorming methods enhance the typical learning process in a very new and interesting way with the possibility of various combinations of those aids. This supports teachers to design and implement a lesson plan in a more creative, more interesting, interactive and enables the approach of active learning (Finger and Trinidad, 2002). Also, students benefit from these teaching methods as they are not bound to the traditional methods of the curriculum. Additionally, to the common resources, hands-on activities are enabled in a technology-based environment. Students get a deeper understanding of the specific subject or topic by following a learning by doing approach. Several researches discuss the integration of ICT in classes and highlight, that this approach will maximize the ability of students in active learning by manifesting covered topics with own experiences (Finger and Trinidad, 2002; Jorge et al., 2010; Young, 2003; Jamieson-Proctor et al., 2013).

According to Hermans, Tondeur, Van-Brakk and Valcke (Hermans et al., 2008), there are three pillars for ICT which are highly valued and considered by teachers:

1. Integration
   The integration part is about the correct implementation of ICT in specific subject areas to improve students' skills and their learning curve. While implementing the ICT in specific subject areas, also the curriculum has to be considered and reviewed. The focus should be set on the main aims of the subject area. An unnecessary large amount of different ICT components tackling too many different use cases should be avoided.

2. Enhancement
   This approach is about giving great emphasis to the specific subject by implementing ICT. Presentation software, for example, can be

used in a very innovative and creative way to increase the attention and enhance the importance of the topic. By presenting a topic this way, discussions can be triggered which lead to idea exchange and result in creating different interesting perspectives.

3. Complementary
The complementary approach is about the supporting role of ICT. This approach enables students to use ICT elements as an additional helper by gathering information from different online sources, communicate or discuss topics online, submit their work via email from any location and so on.

Statistics on the use of mobile technology report, that the world is going to be mobile in terms of accessing data. People use their smartphones to access the internet and handle all kinds of digital communication. Besides communication, people can gather information via their mobile devices from any location. Which comes with the effect, that students have the opportunity to learn from every location they want to (Ally, Grimus, and Martin Ebner, 2014a).

### 3.2.1 The challenge of data validation

With the increasing amounts of new technologies, the variety of possibilities of how to gather information rises. People or students encounter more information, in a greater amount of formats via different interfaces and technologies than ever before. Having a good knowledge of software or hardware doesn't guaranty a meaningful use of the obtained data and information out of it. Technology is a portal through which we interact with enormous amounts of data sources containing correct but also incorrect or irrelevant data. The big challenge is to handle or teach students on how to interact with different sources and how to validate all the observed data in a correct way (Katz and Macklin-Smith, 2013).
Katz further explains in his study: "These skills—known as Information

and Communications Technology (ICT) Literacy—comprise a 21st-century form of literacy, in which researching and communicating information via digital channels are as important as reading and writing were in earlier centuries." (Katz and Macklin-Smith, 2013).

### 3.2.2 Role Of The Teachers

It's not meant, that technology or computers should replace qualified teachers in their jobs but it should assist or support teachers as an add-on supplement needed to enable enhanced teaching and learning methods. Teachers, in general, are seen as the key players when preparing students for the digital era by integrating ICT in classrooms. Teachers can create a proactive, dynamic learning-environment by combining the capabilities of ICT with their pedagogical skills in the right way (Arnseth and Hatlevik, 2010).

#### Problems Of Teachers

Besides the engagement of a teacher in implementing ICT elements, there are some other technical side effects to accomplish with. Technical problems within a school's infrastructure become a major issue and result in the frustration of teachers and students. This also results in interruptions of the teaching and learning process and discourage teachers and students from working with the intended ICT elements. So if there is missing technical know-how on the user side or a lack of technical support, teachers feel discouraged of using those technical equipments again (Jamieson-Proctor et al., 2013).
This topic is also discussed in a study of Yalin Türel and Tristan Johnson in 2012 where interactive whiteboards are introduced for teaching and learning (Türel and T. Johnson, 2012). The study also reveals that technical problems become a major barrier for teachers. The reasons could be some

kind of infrastructure problems having a poor or not working internet connection, a not working printer or some more technical problems like software issues or even virus attacks.

Of course, the engagement and skills of the teachers build a fundamental part in the use of ICT in education. The mindset and readiness are playing an essential role. A teacher's decision of implementing ICT in a classroom requires sufficient technical know-how and a high confidence level in trying something new with the possibility of failing. Additionally to their technical skill sets, insights into the pedagogical part of ICT is required by teachers to apply those elements in a correct and meaningful way in the teaching process (Hennessy, Ruthven, and Brindley, 2005).

A study of Arthur Winzenried in 2010 discusses the teacher's confidence after admitting ICT courses. It reveals that teachers are more encouraged and confident in using technology as supplemental tools in their classes as those, who never had some training and have no experience in using these tools. Teachers without any experience even avoided using ICT elements in their classes (Winzenried, Dalgarno, and Tinkler, 2010). Hennesy also discusses this behavior in detail with the conclusion, that teachers might be worried to get embarrassed by more skilled students when trying to implement technical tools in their curriculum (Hennessy, Ruthven, and Brindley, 2005).
This also aligns with the claims in the publication of Warwick and Kershner (2008) who say, that the significance and advantage of ICT should be perceived by teachers to enhance the possibilities of their teaching methods with a meaningful use and implementation of ICT elements (Warwick and Kershner, 2008). They further point out, that teachers must attend courses to get used to the technological opportunities and getting confident in applying it in the classroom. There are different approaches of how to prepare teachers accordingly. Peer-tutoring, for example, is a concept, where already skilled teachers support and guide less skilled teachers with the integration of ICT in their teaching process. In general, there are a lot of factors which are playing a role in the successful integration of ICT. Having skilled teachers, a working infrastructure and

available technical supports build the fundament for a successful and sustainable integration (Kontagora, Watts, and Allsop, 2018).

Cox and Marshall mention in their research, that teachers are having high confidence in using ICT in the classroom and also deliver the necessary competences. Teachers recognize the value of integrating ITC and see it as a tool to increase the learning process by showing the relation to real-life practices. This creates value and knowledge for students. The result of the study reveals, that a healthy combination of confidence and competence is required. (Cox and Marshall, 2007).

Larry Cuban (2001) reveals in his study ”Oversold and Underused. Computers in the Classroom” how the efficacy of teachers change regarding their age and their years of experience in teaching. Cuban shows, that by increasing the experience and age of the teacher, the efficacy decreases. He blames the school management for not anticipating these facts. He describes, that if there have to be certain possibilities in schools which provide some kind of interaction between teachers. This means that has to be a shared knowledge base for teachers to reflect or review currently used teaching methods. Further, it encourages teachers to collaborate in the form of collegial interaction to share experiences and resources. Cuban mentions, that the school management is in charge of creating this environment and culture to enable those possibilities for their teachers. This also aligns with the previously described approaches of sending teachers to specific trainings for professional development to make it easier to integrate ICT in classrooms and enhance the daily learning process (Cuban, 2001).

Children or young students who grow up in a technology-dominated world, also called ”Net Generation’ or ”digital natives” (Van Eck, 2006) are having high expectations on the integration of ICT in their education. Chien and Wu (2014) reveal in their publication, that the younger the students are, the higher their expectations are in having technological integration in the learning process. They add, that teachers and also students are more likely to use ICT elements outside the classroom, no only inside, and the main barriers while integrating ICT in schools are again the confidence and competence of teachers. Those factors would strongly influence the percentage of ICT integrations in classroom (Chien, Wu, and Hsu, 2014).

### 3.2.3 The Role Of The Government

Ghavifekr and Rosdy (2015) named to following points to be fulfilled by the government to support and promote the integration of ICT in a country at it's best (Ghavifekr, 2015):

1. Foster students motivation and creativity by surrounding schools with innovative and interesting learning environments

2. Enable students to gain knowledge from different sources by accessing the knowledge base of the world wide web and support them to get a global outlook on things

3. Support students with capabilities of processing gained pieces of information more efficiently and powerfully

4. Foster young children's' attitudes of a life-long learning

### 3.2.4 Conclusion

Ally, Grimus, and Ebner (2014) outline the discussed topics with the following words:

> ”...the most important change will be training teachers, both in pre-service programs and through professional development, to use the technology to design and deliver education and to create bridges to informal learning. As mobile technologies

> emerge, teachers have to keep up with the changes so that they can take advantage of the power of the technology to design and deliver education.” (Ally, Grimus, and Martin Ebner, 2014b)

Ghavifekr and Rosdy (2015) revealed in their study, using technology in the right way to provide technology-based learning methods is more effective in comparison to traditional learning techniques. Enabling an active learning environment by applying ICT tools and elements creates a more efficient, more motivating and more interesting learning process for students and teachers (Ghavifekr, 2015).
These insights also align with the results of the study of Steve Macho (2019) which proved, that integrating ICT leads to better learning results for students. It further proves that students are more motivated and the learning curve increases in subjects, where ICT is part of the lessons. Also, teachers agree to the positive impact of ICT on students. They would be more interested and engaged in specific topics. The participants of the study agreed, that technology-enhanced education opens new doors for teachers in planning lessons and making them more interesting and in parallel fosters students’ learning effect (Macho, 2019).

Ghavifekr and Rosdy (2015) further emphasized that the first and most important step to build the fundament to a successful integration of ICT is preparation. It’s the school’s top management’s responsibility to enable those first steps by providing a suitable environment and proper support. When the base for this first step is given and the management commits to continuous maintenance, the integration of ICT will result in great success and students and teachers will benefit from it. During the integration, teachers will face lots of unknown areas that are not explained in theory so they will also have to commit to tackle new challenges and also fail on one or the other approach on the first try. But exactly this kind of trial-and-error process manifests the knowledge of teachers and students in a very strong way (Ghavifekr, 2015).
Ghavifekr (2015) also adds, that on top of the school management level, also the government of a country has to set the right steps to enable

schools and especially teachers as the key players in the integration of ICT. Without having any technical communication devices, technology-enhanced education won't be possible. Providing proper equipment to schools and teachers is crucial to apply new practical oriented learning methods and increase the learning curve of students by using state of the art technological supplements.

# 4 Digital Game Based Learning[1]

## 4.1 State Of The Art

Hilda K. Kabali (2015) discussed the children's ownership of media platforms like tablets or smartphones in the age of 1- 4 years in their study "Exposure and Use of Mobile Media Devices by Young Children". The result of the study shows, that more than 80% of children by the age of 4 make daily use of mobile devices to watch videos, play games or use apps (Kabali et al., 2015). This also means that children are surrounded by mobile devices and games since they can think and it has become an integrated part of their social and cultural environment (Oblinger, 2004). With the attraction of video games and the motivation of increasing levels and solve given problems, also the motivation for traditional curricular contents decreases, so (Prensky, 2003). He describes the approach of Digital Game-Based Learning (DGBL) with his conclusion: "It, therefore, makes a great deal of sense to try to merge the content of learning and the motivation of games. . . " (Prensky, 2003).

Ethel and Jamet define DGBL as the following:

> "Digital game-based learning (DGBL) is a competitive activity in which students are set educational goals intended to promote

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> knowledge acquisition. The games may either be designed to promote learning or the development of cognitive skills or else take the form of simulations allowing learners to practice their skills in a virtual environment.” (Erhel and Jamet, 2013).

The aspect of DGBL is more present than ever. There are more and more publications discussing the power of digital games in terms of education and their impact on young children. Rick Van Eck (2006) calls them “Net Generation” or “Digital Natives” (Van Eck, 2006). He also says that those children get disengaged by traditional instructions. They would assume multiple information streams and require quick interaction with content paired with demanding visual effects.

Rick Van Eck summarized three main factors which lead to increasing global interest in the effect of Digital Game-Based Learning (Van Eck, 2006):

1. The first factor is the ongoing research in the field of DGBL
   Dozens of studies have been published in the last years. Figure 4.2 shows the number of published researches discussing the power of Game-Based Learning (GBL).

2. The second factor is the rise of the ”Digital Natives”
   As mentioned before, Van Eck introduced this label for children, who grow up in a digital world. Children who are experts in using technological tools and devices. Those children are bored and disengaged by traditional learning material. Van Eck describes the needs of the ”Digital Natives” as the followings: ”They require multiple streams of information, prefer inductive reasoning, want frequent and quick interactions with content, and have exceptional visual literacy skills…” (Van Eck, 2006).

3. And the third factor is the increasing popularity of games
   A very important indicator is the increasing popularity of games. The video game revenue increased by 18% from 2017 to 2018 as the total revenue tops $43 billion in 2018 referring to (Shieber, 2019).

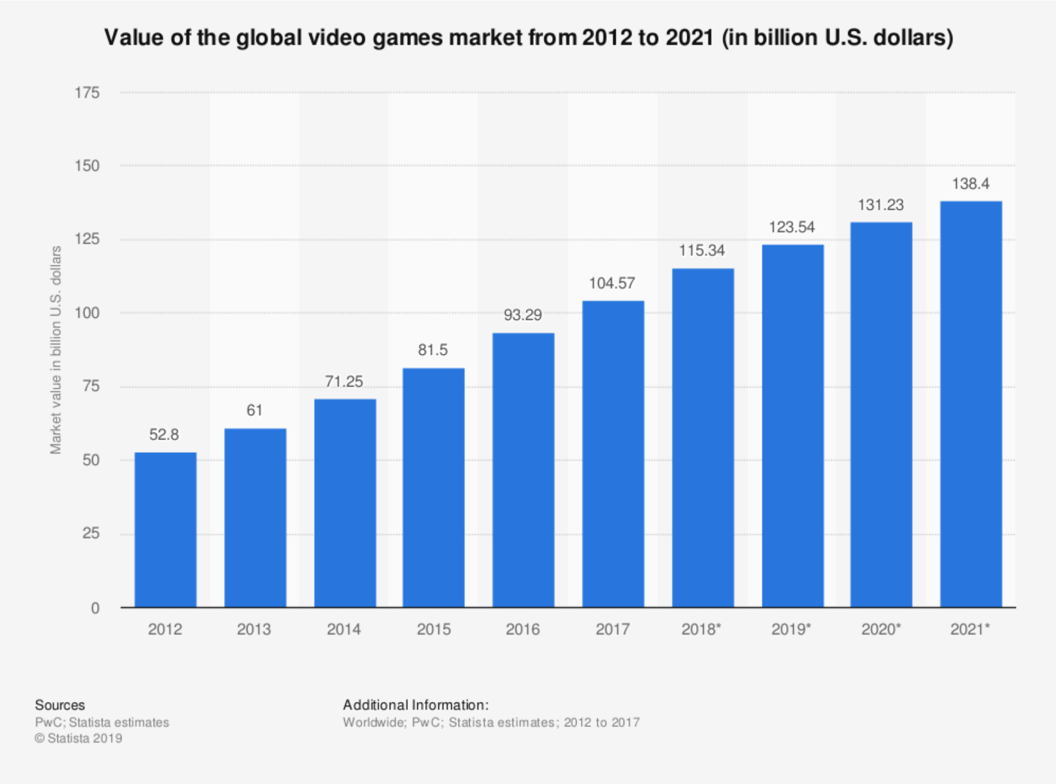


Figure 4.1: Value of the global video games market from 2012 to 2021 (Statista, 2018).

Figure 4.1 shows the raise of the value of the global gaming industry over the last years and gives a forecast until 2021.

## 4.2 Efficiency Of Games

Rick Van Eck emphasizes the potential of games with the sentence:

> ”Games are effective not because of what they are, but because of what they embody and what learners are doing as they play a game.” (Van Eck, 2006).

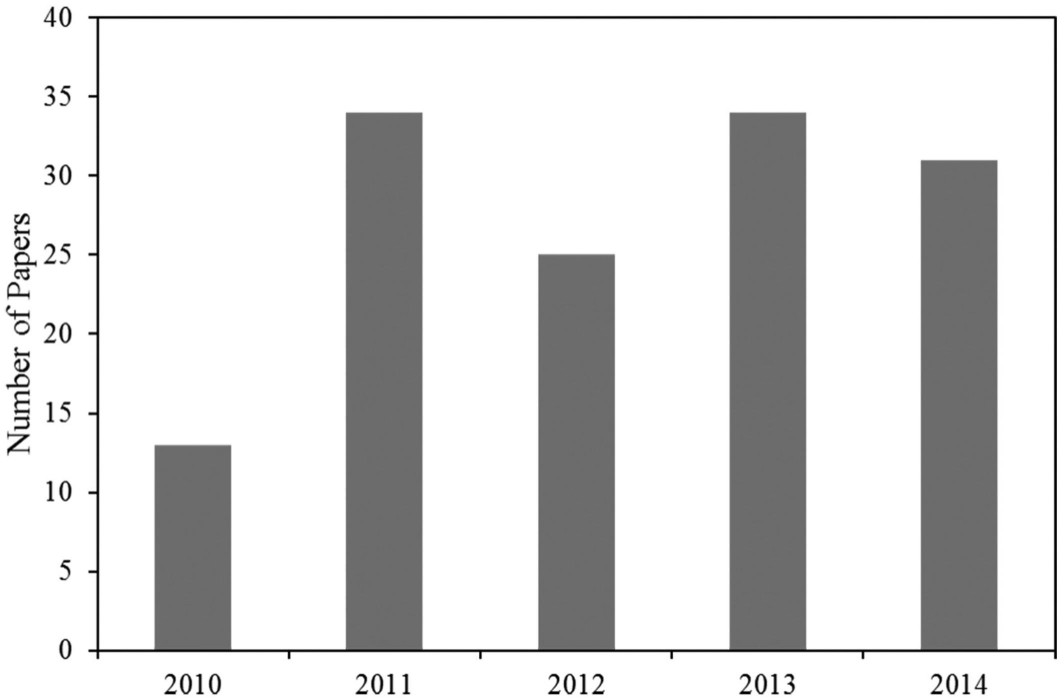


Figure 4.2: Number of published studies focused on GBL per year (Qian and Clark, 2016).

Besides enhancing lower-level skills and improving physical skills, games can teach much more than this. Games are extremely context and story-focused. So if a game catches the player in its story and environment, the player is completely into it. This fact leads to the effect, that everything a person learns within a game, is in a meaningful context environment provides. So learned lections are always connected to practical experiences through playing a game. Learning is way more effective if it's experienced in a meaningful context than without any context like it is when using traditional learning material. Scientists refer to these findings as situated cognition. Van Eck further explains, that learning by playing is common in every culture and also in many animal species and so the effect of playful learning can be observed and applied to nearly everyone (Van Eck, 2006).

Prensky's observations also align with Van Eck's perspectives. He mentions, that games include a much deeper level of learning besides physical skills like learning to fly airplanes or drive cars on simulators. Prensky summarizes the hidden learnings in (Prensky, 2003):

- acquire information from many different sources and make decisions based on them
- learn the rules of a game by playing it rather than getting told from someone else
- develop strategies to overcome obstacles
- create an understanding for complex relations trough experimenting
- collaboration with others to reach common goals

Prensky also adds in his publication, that game-playing kids already have a basic understanding of the previously listed learnings when starting elementary school. This fact, of course, leads to decreasing motivation when they are forced to learn from the traditional curriculum (Prensky, 2003).

## 4.3 Motivation Of Games

Marc Prensky (2003) highlights, that the key to successful learning is motivation and a motivated learner can't be stopped (Prensky, 2003). Many studies discuss the reason and origin of motivation in DGBL and it's often seen in the entertainment aspect of games (Annetta et al., 2009; Tobias and Fletcher, 2007; Moreno and Mayer, 2007). Daniel Moos and Elizabeth Marroquin further observed the aspect of motivation and revealed, that motivation is built on a set on physiological processes that influence our mindset and behavior in a very strong and positive way (Moos and Marroquin, 2010). Murphy and Alexander (2000) analyzed the motivation aspect in the academic context to get an understanding of how motivation originates in terms of learning (Murphy and Alexander, 2000). They emphasized the need for taking several motivation constructs into account to understand the complex process which occurs when learning deeply and sustainably. Moos and Marroquin (2010) reviewed several studies with a focus on motivation and identified four motivation construct categories (Moos and Marroquin, 2010):

- goal orientation aspect
- intrinsic-extrinsic motivation factors
- level of interest
- impact of self-efficacy

When it comes to the goal orientation aspect, there are two types of goals: mastery goals and performance goals. Mastery goals focus on generating new skills or acquiring new knowledge in specific subjects. Performance goals focus on a more competitional aspect. Performance goals focus on reaching the high score in a game or succeeding against others in defined challenges (Pintrich, 2000; Ames and Archer, 1988). These are very important insights when applying games in an educational context. Depending on the construction and possible goals of the game, students focus either on mastering goals by improving knowledge or on performing goals by with the focus on winning competition challenges (Erhel and Jamet, 2013).

In most cases, teachers are not as motivating as they should be in the classroom. Highly receptive and inquisitive students are very often not motivated and under-challenged in classroom while teachers miss out their role as pedagogical motivators (Erhel and Jamet, 2013).

As previously mentioned, the gaming industry raised enormously in the last years. During this time, game designers perfectionated their mechanisms of how to engage players to continue playing for hours while increasing their motivation step by step. Gamers are willing to reach their goals in the games while trying out things with the willingness to fail over many hours because they stay motivated and focused. If it's possible to transform these attitudes of goal orientation, interest and actively seeking information and solution in the context of education, this would open new ways of intensive, motivating deep learning. (Erhel and Jamet, 2013).

While it's sometimes in the mind of people that only boys are attracted to video games, Figure 4.3 visualizes, that people in every age and also independently of their gender are playing some sort of video games on their computers, consoles or smartphones. So developing games for an educational reason addresses all groups of people in every age. (Erhel and Jamet, 2013).

Prensky discusses the reason for the high attraction of video games. He believes, that it's not the context of the game that matters, but much more the learning the game provides. Prensky says, that humans in general love to learn when they are not forced to and computer games provide learning opportunities continuously (Prensky, 2003).

## 4.4 Education Game Design

Games, in general, provide a satisfying learning environment to engage the player in learning new things by experiencing them (Norman, 1993). Kristian Kiili (2005) observed, that games are always associated with

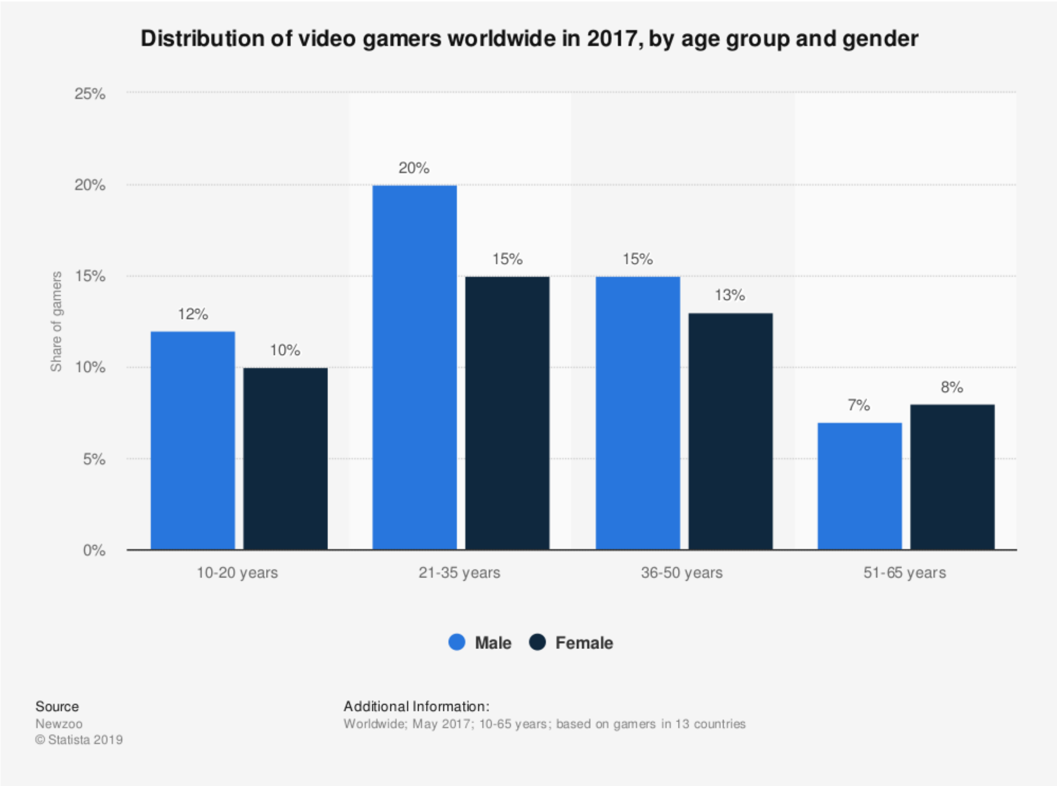


Figure 4.3: Distribution of video gamers worldwide in 2017, by age group and gender (Newzoo, 2017).

having fun, so the key aspect in designing educational games is the fun factor. Kiili adds, that educational games aim to motivate players through personal experiences within a games' environment. He also adds that those games have to provide possibilities for reflectively exploring phenomena, testing hypotheses and constructing objects (Kristian Kiili, 2005).

Mayer and Johnson declare four pillars, a DGBL environment should provide (Mayer and C. Johnson, 2010):

1. a defined set of constraints and rules
2. immediate responses after the applied user actions
3. a set of challenges to motivate the learner by experiencing self-efficacy
4. dynamically adaptive game difficulty according to the learning effect for the user

### 4.4.1 Flow-based learning

Csikszentmihalyi defines flow as a state of complete absorption in an activity that results in an optimal user experience. When a person is in this state of flow, it seems that nothing else is as important than reaching the defined goal in the game or activity (Csikszentmihalyi, 2008).
This flow state has also a positive effect on learning and should, therefore, be a fundamental part of designing educational games (Webster, Trevino, and Ryan, 1993).

Finneran and Zhang revealed, that activities, which are performed in computer games have to be broken down into main tasks and artifacts used to complete those tasks. They introduced a person-artifact-task (PAT) model which contains the major components of a person interacting with computer-related tasks. This model represents the interplay between the person, the task and the artifact and visualizes which of these elements influences the flow experience most (Finneran and Zhang, 2003).
The factors person, artifact and task and their interplay should be taken

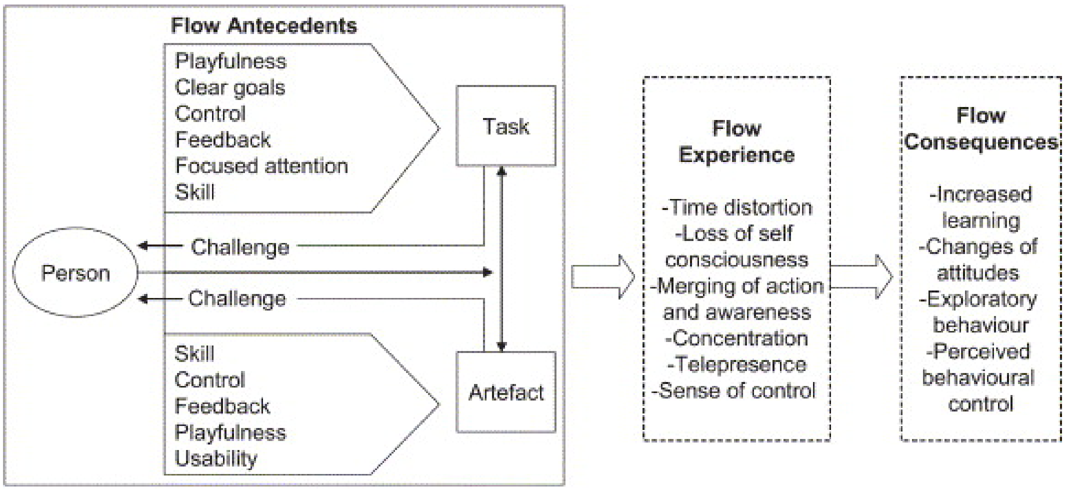


Figure 4.4: Flow Framework in computer-mediated environments including PAT model. (Kristian Kiili, 2005).

into account when designing education games (Kristian Kiili, 2005).

The following flow stages can be distinguished in computer-mediated environments (Hoffman and Novak, 1997; Finneran and Zhang, 2003; Kristian Kiili, 2005):

- Flow Antecedents
  This stage consists of clear goals, helpful feedback on the actions and skills needed to complete challenges.
- Flow Experience
  In this stage, the player is fully into the game with the effect of time distortion or loss of action self-consciousness while the person is highly concentrating.
- Flow Consequences
  The flow experience stage leads to increased learning and influences the exploratory behavior positively.

Figure 4.4 visualizes these stages and it's elements. It also integrates and visualizes the previously described PAT model in the Flow Antecedents stage.

Pearce and Howard explain, that in general, an educational game aims to provide learning tasks which are related to the previously described main tasks. They further mention, that challenge is to not reduce the user's attention by having too complex tasks or too complex artifacts to accomplish the task (Pearce and Howard, 2004).
Kiili mentions, that the player must not be distracted by concentrating on too many different complex challenges. He claims, that in an ideal situation, artifacts should be transparent so the player can focus on higher-order tasks of the game (Kristian Kiili, 2005).

It's also a challenging part to integrate the player's already existing knowledge and experiences into the game world. To ensure an optimal experience flow and corresponding learning, the challenges of the game have to align with the players' skills. In figure 4.5 the relation between challenge and skillset is drawn. The figure demonstrates the relation of a player's skill level to the complexity of the challenges. If a player's skills are greater than the level of challenge, the player might feel bored very fast. Vice versa if the challenge is too complex in relation to the skill level of the player, he or she might feel anxiety. Kiili also added the zone of proximal development into the model. He describes, that there is a zone to increase the challenge level if the flow channel will be extended with some guidance for the player for example to solve problems with the help of other players. A very important point which game designers have to keep in mind is, that the complexity of the game has to increase while the skill level of the player increases. This ensures to keep the player in a flow state (Kristian Kiili, 2005).

### 4.4.2 Gameplay

Andrew Rollings and Ernest Adams define gameplay in: "One or more causally linked series of challenges in a simulated environment."(Rollings and Adams, 2003). Greg Costikyan explains that good gameplay keeps the player motivated and engaged to continue playing (Costikyan, 2002).

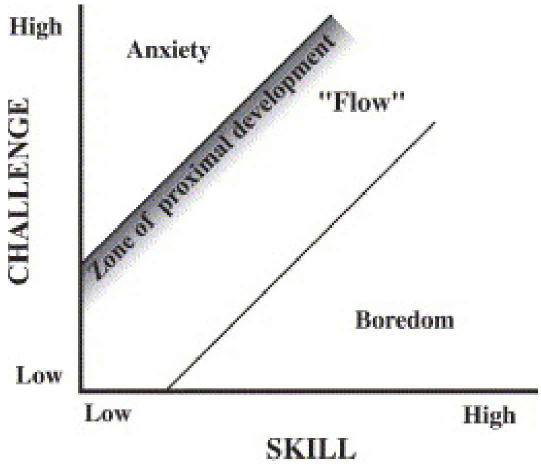


Figure 4.5: Three channel model of flow (Kristian Kiili, 2005).

Education games are often missing good gameplay which leads to disengagement and boringness of the player. Again a good balance between education goals and motivating gameplay is the key to a successful education game (Kristian Kiili, 2005).

### 4.4.3 Problem Based Learning

According to Morrison and Holyoak, problem-solving is one of the important skills of human cognitive evolution. Morrison and Holyoak explain the elements of a problem in:

> ”The representation of a problem consists of four kinds of elements: a description of the initial state in which problem-solving begins; a description of the goal state to be reached; a set of operators, or actions that can be taken, that serve to alter the current state of the problem; and path constraints that impose additional conditions on a successful path to solution.” (Morrison and Holyoak, 2003).

Dauber and Bruer describe, that one goal of education is to prepare students for new situations (Dauber and Bruer, 1994).

Games are providing a perfect environment for problem-based learning. Kiili describes a game as a big problem, which is composed of smaller causally linked problems while a problem can be anything that restricts the progress of a player in a game environment. Games, therefore, provide possibilities to set personal goals, manage and collect information and immediately evaluate and monitor the behavior of the taken actions (Kristian Kiili, 2005).

While interacting with the gameplay, the player becomes a participant in the learning process. The player or students explore possibilities by discovering different approaches, applying changes, manipulating objects and test hypotheses. This way of learning is much more experiencing and valuable than just learn things from existing material (Bruner, 1961).

### 4.4.4 Experiental Learning

Experiential learning consists of some models which emphasize the meaning of direct experience and reflective observation (Englyst, 2011). The core in the field of experiential learning is David Kolb's four stages experiential learning model. The model shows the continuous learning process containing action and response which provides a goal-oriented, continuous, circular sequence (Kolb, 1984).

Figure 4.6 shows Kolb's four stages learning cycle. In his theory, a learner touches all the bases circularly. The bases are described as the followings (McLeod, 2017):

- Concrete Experience
  The learner experiences a new situation or reinterprets the current situation according to existing experiences

- Abstract Conceptualization
  The learner has learned from her or his experiences. The learner makes generalizations, draws conclusions and finally creates a

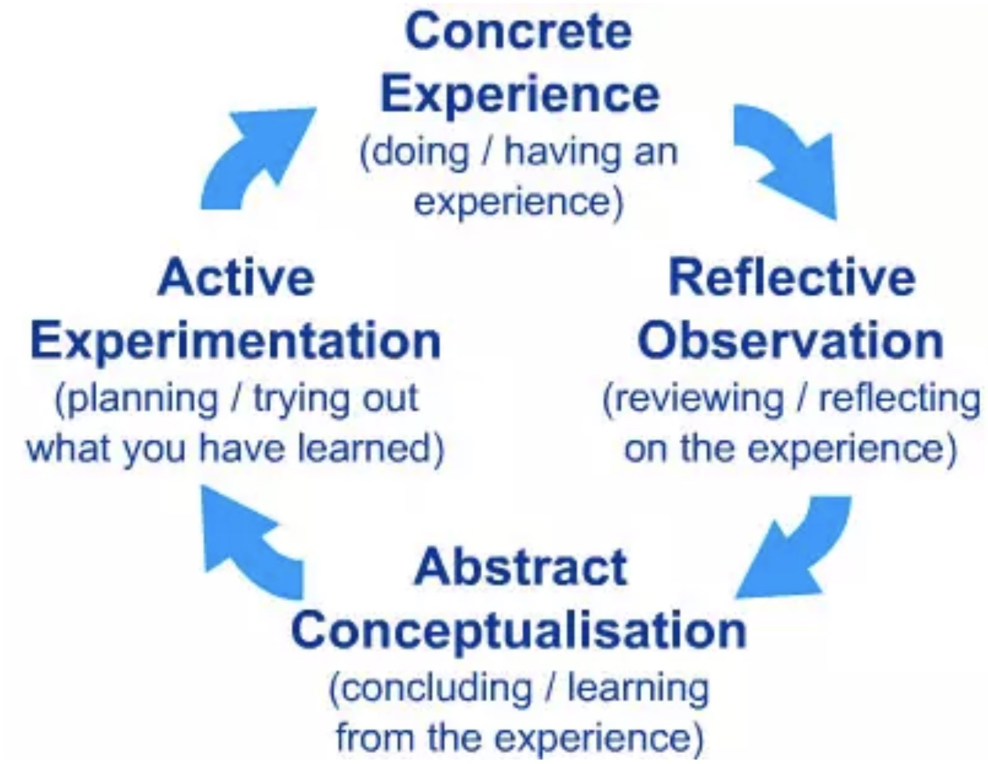


Figure 4.6: David Kolb's four stages learning cycle model (McLeod, 2017).

hypothesis based on the output.

- Active Experimentation
  The learner now tests the learnings and hypothesis in the given environment with active experimentations and continues in the ”Concrete Experience” stage.

### 4.4.5 Experiential Gaming Model

The Experiential Gaming Model merges the thoughts of the previously described experiential learning model and gameplay to engage the learner by enabling the important flow experience. It describes the cyclic experience process in the game world according to the stages in the Kolb model. The model emphasizes, that the necessary activity for learning is not only of cognitive nature but has also a behavioral or pragmatist component. While the model shows the different actions and stages of an educational game, any social interaction is not taken in consideration (Kristian Kiili, 2005).

Figure 4.7 visualizes the Experiential Game Model which consists of an ideation loop (upon the heart), the experience loop (below the heart) and in the middle between them the heart which demonstrates the challenges or problems. According to the heart in the middle, the principle and flow of the model can be associated with the human blood circulation. The heart in the middle is responsible for keeping the player’s motivation alive and increase the engagement by pumping new challenges into the blood circulation. The player then handles those challenges in the ideation loop and while creating new solutions to them (Kristian Kiili, 2005).
The ideation loop contains the components preinvative idea generation and idea generation. According to Moslow, the preinvative idea generation is a chaotic, unstructured and creative idea creation process that occurs for example when children play without a defined goal or restrictions (Maslow, 1963). Finke adds, that these unstructured thinking without

any constraints in the preinvative idea generation phase may lead to new innovative solutions to specific problems. He further explains, that after the unstructured preinvative phase, the learner creates solutions regarding existing constraints of the environment and uses the given artifacts to solve tasks. Creating those solutions in groups is the most promising approach, so Finke (Finke, Ward, and Smith, 1992).

When switching from ideation loop into the experience loop, the player or learner tests the created ideas and solutions in the given game or environment. To enable an optimal flow experience, a game should be user-friendly with clearly defined goals and appropriate feedback. While testing created solutions in the game, the player reflects all the observations and increases the skill level by creating a schematic design that leads to control over the game. (Kristian Kiili, 2005).

According to Van Eck (2006), the interaction with a game requires a constant cycle of hypothesis formulations, testing, and reworking. This process happens quickly and frequently while the game is running. This also requires instant feedback to adust the hypothesis. Games, that are too easy are not engaging the player or learner for a long time. Good game design relies on the adaptive behavior of the game depending on the player's knowledge and skill set. Keeping the player in the flow state is crucial to also keep attention and interest for the game. Good games therefore constantly claim input of the player to adjust to his or her skills. Van Rick also discusses the behavior of these adoptions. First, the adaption has to be transparent and must not tempt the player to change his or her normal behavior. A bad adaption design of the game, for example, occurs, when the player realizes, that after performing worse, the game gets easier and the goals can still be reached. Additionally, the game concept must not get changed through adaption. This would result in bad usability. To provide a meaningful education game, these things have to be taken into consideration (Van Eck, 2006).

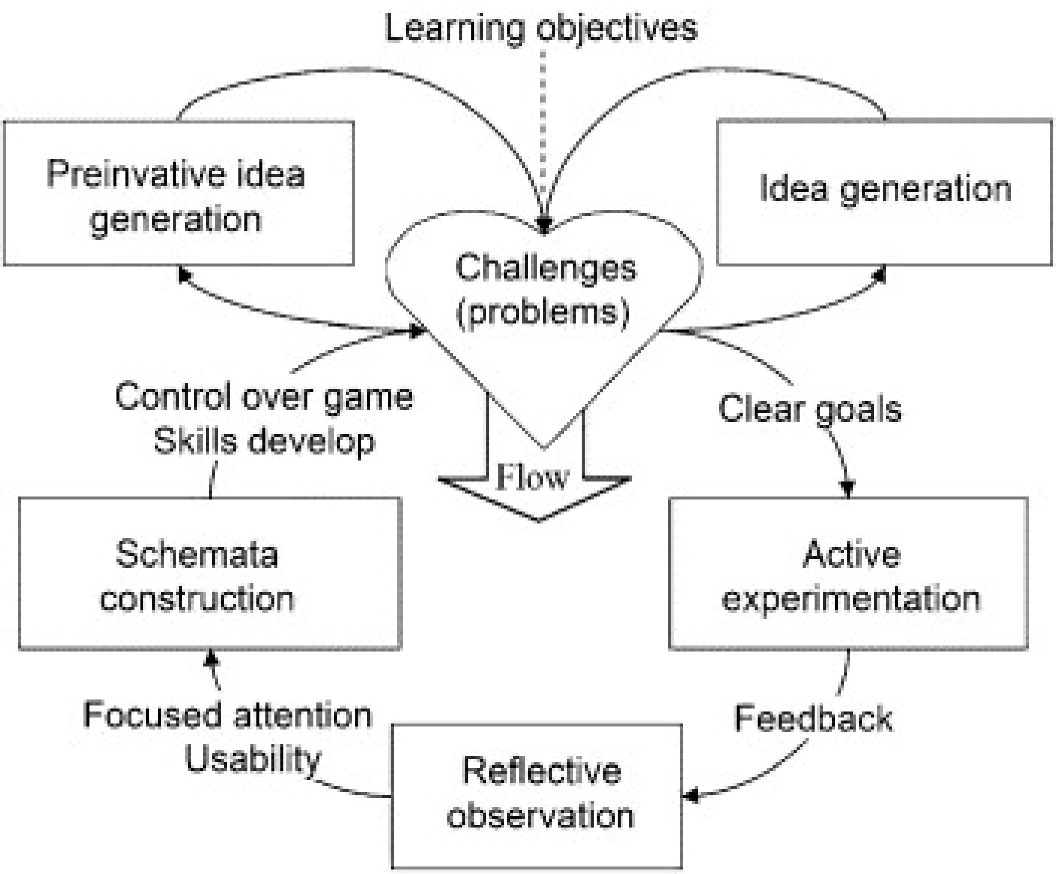


Figure 4.7: Experiental Gaming Model (Kristian Kiili, 2005).

### 4.4.6 Storytelling In Games

According to Robert Seagram and Alan Amory (2004), the story of a game integrates the challenges into a larger task or a problem (R. Seagram, 2004). Rollings and Adams explain, that using stories in games is an important part of designing games (Rollings and Adams, 2003). They further explain that the need for a story is directly proportional to the complexity of the game. So the more complex a game is, the more important is the story behind the tasks or challenges.

In the publication ”Operation Splash” in 2004, the authors describe, how the player assumes the role of an underwater explorer who commands a submarine while taking care of the correct functionality by maintaining the technical stuff of a submarine. The main task for the player as an underwater explorer is to collect samples of marine animals. The story is quite simple, but the game could be very educative. While the game can be separated in interactive gameplay like collecting the samples, there is also a non-interactive part in the game - the story behind it. When playing the game, the player gets confronted with facts worth knowing and therefore the game brings an educational benefit besides keeping the player engaged by interactive gameplay (T. Yuen and Reimer, 2004).

### 4.4.7 Cognitive Overload

The cognitive load theory emphasizes, that working memory limits the amount of information that can be processed in our brain. So if the brain’s working memory is overloaded no more information might be processed very well. This leads to poor receptivity and wrong understanding which also results in demotivation (Sweller, 1994).

Kiili claims, that the main problem of multimedia learning material is the overload of the brains working memory caused by inappropriate ways of presenting the important content (K. Kiili, 2004). He adds, that also educational games might overload the player's working memory Therefore it's very important for an educational game to response with haptic feedback. By using haptic technology, the player gets a feeling for the game and will be more integrated in the role or the story (McGee, 2002).

Several studies discuss three different sources of cognitive load (Sweller, Van Merrienboer, and Paas, 1998; Kristian Kiili, 2005):

- Intrinsic Cognitive Load
  Is nature (chemical composition) or the structure of the material. It refers to the intrinsic nature of the task or learning material. The intrinsic cognitive load is high if the learning material consists of many elements which are related to each other.

- Extrinsic Cognitive Load
  This refers to the irrelevant objects or tasks in a game. The extrinsic cognitive load is high if the game design is bad or not understandable so the player is confronted with too many unnecessary things, loses focus and the learning effect will be reduced.

- Germane Cognitive Load
  This refers to the effort that is needed to create schemata. Optimizing the germane cognitive load leads to a deeper understanding of the underlying problem and the ability to process tasks better.

Kirschner reveals, that encouraging learners in educational games strongly depends on the optimal distribution of the cognitive working load to not exceed the memory limit of human brains. Thus, a good game design should not have too many unnecessary elements but should focus on a good user interface and appropriate challenges and tasks to keep the user in the flow and increase the learning effect (Kirschner, 2002).

### 4.4.8 DGBL Implementation

#### Approaches

Rick van Eck observed the outcomes of the literature according to DGBL and summarized three approaches of integrating DGBL into the learning process (Van Eck, 2006):

1. Students creating and implementing educational games
   In the first approach, students take the role of game designers. They create the story of the game by integrating the educational content into it. Students have to study the specific content of the educational subject and create problem-solving skills in the planning process. While implementing the game, students additionally make experiences in computer science while learning necessary programming languages. The games, in general, do not necessarily have to have commercial quality, the actual learning process takes place during the game development process. To enable this approach, teachers need the skills to explain and support the development process.

2. Developers/educators build educational games
   This approach is seen as the ”Holy Grail” approach to DGBL by many people because it enables the integration of learning and entertainment. To be most effective in teaching the content and offering good gameplay, the quality and functionality of the game has to be very similar to commercial off-the-shelf (COTS) games. Thus, the creation and implementation phase is very time and resource consuming.

3. Use existing commercial off-the-shelf (COTS) games
   This approach makes use of existing games, which are not intentionally served as educational games. These games are implemented in the classroom with the benefit, that game design is done by professional developers and the design of learning is done by skilled educators. This approach is also the most cost-effective of all three

approaches.

### Applications

(Erhel and Jamet, 2013) examined the environmental conditions under which DGBL is most effective. Jamet and Erhel, therefore, analyzed the effect of two different instruction types:

- Learning Instruction
  (Connolly et al., 2012) explains, that instructing learners to use the environment playfully with no explicit mention of any educational goal might place the learner in a so-called incidental learning situation.

- Entertainment Instruction
  Encourage players to just have fun within the game, mostly engage them to successfully achieve performance-oriented goals in the games (e.g. making the high score) (Erhel and Jamet, 2013).

The result of the study shows, that learning instructions lead to deeper learning in comparison to entertainment instruction without a decrease in motivation. The study further shows, that if learners get continuous feedback on their activities and performance, the entertainment instruction approach also results in deep learning. They conclude, that an optimized game environment and the correct instruction technique is crucial to achieve deep learning while motivating the player or learner to keep on playing (Erhel and Jamet, 2013).

A flash game called iGeo was developed at Graz University of Technology (TU Graz). The game addresses children at the secondary school level and aims to improve their skills in the subject of Geography. A field study tested two groups against each other. One group was supported by the online learning game, the other group was non-assisted. The experiment revealed, that the group using the online game reached significantly better results than the other group in the final examination. This study emphasized, that learning by playing a game leads to more fun and motivation and additionally results in a better learning effect in described topic (Boeckle and Martin Ebner, 2011).

Another study at Graz University of Technology focused on training children to avoid common mistakes and pitfalls of the German orthography. An iPad App Prototype named ”The Chocolate Factory” has been developed to playfully increase the german orthography skills of children in primary school. Children interact in a beautifully designed game environment, which enables children to collect ingredients to manufacture their virtual chocolate by correctly completing given sentences or phrases. A field test was conducted to test the iPad App Prototype in an appropriate environment with 10 male and 6 female primary school children. Within a timeframe of 30 minutes, 1900 answers were submitted by children in the game. Continuous feedback after submitting answers helped children to understand their mistakes and to increase their learning curve. Wrapping a nicely implemented user interface, telling the story of the chocolate factory around the process of learning the german orthography, perfectly combines the entertaining and the learning part (Schwaiger, Markus Ebner, and Martin Ebner, 2018).

# 5 Learning Analytics

George Siemens predicts in his publication ”Penetrating the Fog” (Siemens and Long, 2011), that the most dramatic factor which is going to shape the future of higher education is not only new technologies in the classroom or innovative visual displays. It’s much more something that people cannot touch or see. It’s about ”big data” and ”data analytics”. The role of data analytics and big data will have a big impact on higher education. This trend can be derived from the existing importance of analysis techniques and technologies in business sectors and the government. According to Siemens (Siemens and Long, 2011), the value and benefits after applying these techniques influence the education system in two ways:

- support in steering reform activities in the higher education sector
- assistance of educators in teaching and learning processes

The importance of learning analytics was identified by the 2011 Horizon Report where it’s seen as a key future trend in learning and teaching (L. Johnson et al., 2011). After the growing interest in gathering educational data to validate and analyze can be recognized, a new research area was defined as learning analytics (LA) in the last years (Chatti et al., 2012).

Tracking the impact of an educator’s teaching plan and the influence of the applied teaching methods to maximize the learning value is very time-consuming. Lots of questions have to be taken into consideration to analyze the learning effect (Elias, 2011):

- How effective is the course program?
- Which interactions are effective, which not?

- Does the curriculum match the needs of the students?
- How to support the needs of the learners more effectively?
- How to improve the teaching methods or course program?

Generally, these questions are partially answered by the end of the course. Traditionally, this is done by evaluation sheets and analyzing the grades, which makes it quite hard for teachers or educators to anticipate problems in the early stages.
Learning analytics can help in allocating resources, developing competitive advantages and, most importantly, improving the quality and value of the learning experience, so Siemens and Long (Siemens and Long, 2011).

## 5.1 Definition

Rebecca Ferguson refines the definition of LA according to the first international Conference on Learning Analytics and Knowledge in 2011 as the following:

> ”Learning analytics is the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs.” (Ferguson, 2012)

Ferguson further explains in her publication, that it’s coupled with the two assumptions, that LA makes use of machine-readable preexisting data and that its techniques are able to process ”big data”.
Tanya Elias defines LA in her study ”Learning Analytics: Definitions, Processes and Potential” as ”an emerging field in which sophisticated analytic tools are used to improve learning and education” (Elias, 2011).
The 2011 Horizon Report explains, that ”Learning analytics refers to the interpretation of a wide range of data produced by and gathered on behalf of students in order to assess academic progress, predict future performance and spot potential issues.” (L. Johnson et al., 2011).

LA includes many disciplines like machine learning, artificial intelligence, information retrieval, statistics or visualization and is a fast-growing area of Technology Enhanced Learning (TEL), that has emerged in the last years. It's strong connection to the fields of business intelligence, web analytics, educational data mining, and recommender systems attracted researchers to identify the goals that can be achieved, but also to identify what has to be done to achieve these goals (Chatti et al., 2012; Ferguson, 2012).

## 5.2 Learning Analytics Process

Chatti et al. describe the process of learning analytics in Figure 5.1 as an iterative three-step cycle (Chatti et al., 2012):

1. Data collection and pre-processing
   Collecting data from many different educational environments and systems is the first pillar in the LA process cycle. As the collected data may contain a lot an irrelevant and unnecessary data, some kind of data pre-processing methods have to be applied to the raw dataset to enable a meaningful data analytics process (Liu and Bing, 2007). Methods from the field of data mining like data cleaning, data integration, data transformation data reduction, data modeling, user identification, and path completion can be used to format the collected data in standardized usable formats for further processing (Chatti et al., 2012; Liu and Bing, 2007; Han, Kamber, and Pei, 2012).

2. Analytics and action
   The task in the analytical part is to discover hidden patterns out of the pre-processed data which should help to increase the learning experience. Besides analyzing and visualizing the data, actions like monitoring, analysis, prediction, intervention, assessment, adaption, personalization, recommendation, and reflection are the primary aim of the second part in the cycle, so (Chatti et al., 2012).

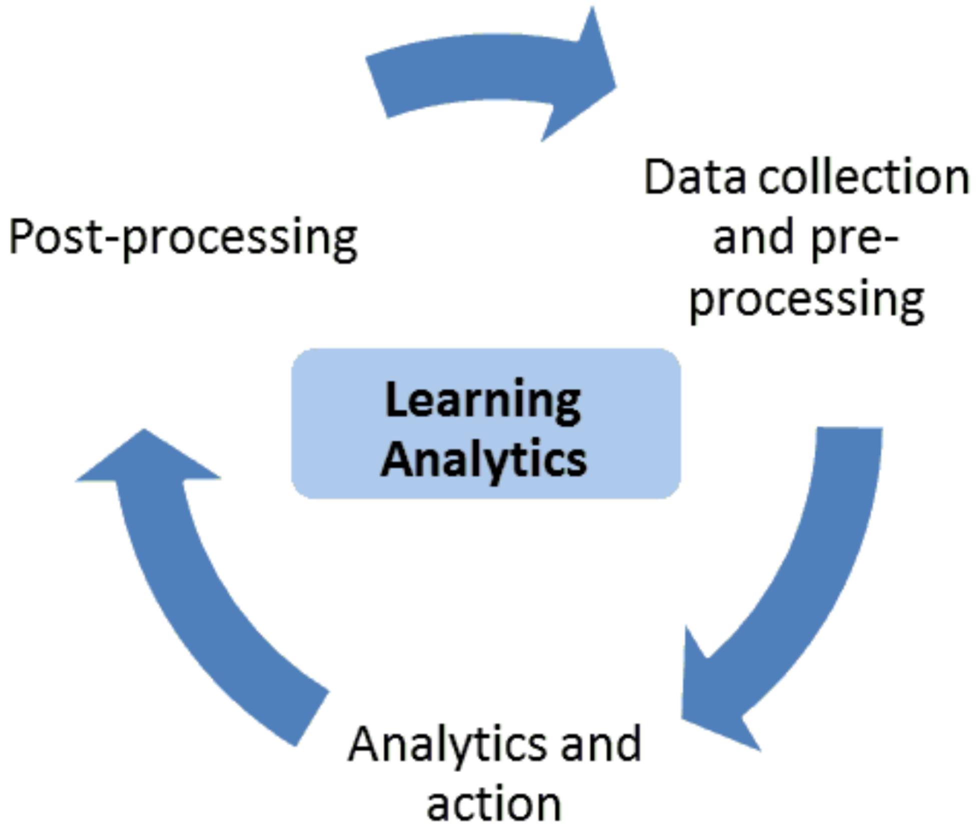


Figure 5.1: LA process cycle (Chatti et al., 2012).

3. Post-processing According to Chatti et al., post-processing is crucial for the continuous improvement of the analytics exercise. Tasks like refining the data set, determining new attributes as an input for the next iteration, modifying variables or applying new analytics methods to the existing data are the main steps that are taken in the post-processing data (Chatti et al., 2012).

## 5.3 Applications

At Graz University of Technology, many educational apps have been developed within the last few years with the focus of game-based, technology-enhanced learning and learning analytics. Three of them address core maths operations for children in primary school:

- The Multiplication Trainer (Schön, Martin Ebner, and Kothmeier, 2012)
- The Multi-MathCoach (Martin Ebner, Schön, Taraghi, et al., 2014)
- The Addition / Subtraction Trainer (Martin Ebner, Schön, and Neuhold, 2014)

The structure of each application is quite similar. While school children play the game provided in the application, each answered question gets stored on a centralized database on a webserver. The server validates the correctness of the answers and asks further questions according to the calculated skill level of the current user. To avoid wrong competence classifications when answering a calculation correctly by chance, each question has to be answered correctly twice. To anticipate possible weaknesses of specific school children, an overview of the current result is given to the teacher (Greller, Martin Ebner, and Schön, 2014).

Figure 5.2 shows the User Interface of the Multiplication Trainer. On the left side, there is an overview of all answered questions. On the right side, the current question is visualized as a calculation task and an input field to enter the correct answer. A progress bar on the bottom indicates the remaining time for answering. As a motivating aspect, a rabbit is shown on the bottom which gets closer to the carrot on the right when answering correct questions.

Figure 5.3 shows the aspect of learning analytics. The graphic demonstrates an overview of given answers of each child to the teacher. The name of the child is displayed in the first column. Each calculation can be seen in a specific row where colors indicate if the question was mastered well (dark green), is known (lime green), is not known (red) or is not


Figure 5.2: The Multiplication Trainer (Greller, Martin Ebner, and Schön, 2014).

answered (grey). The second column indicates the skill level of a child visualized as traffic lights. A yellow or red field says, that the teacher should be aware, that the skill of the student lags. Getting to know these weaknesses in the early stages enables the teacher to analyze in which way the school child is struggling and how the help him or her (Greller, Martin Ebner, and Schön, 2014).

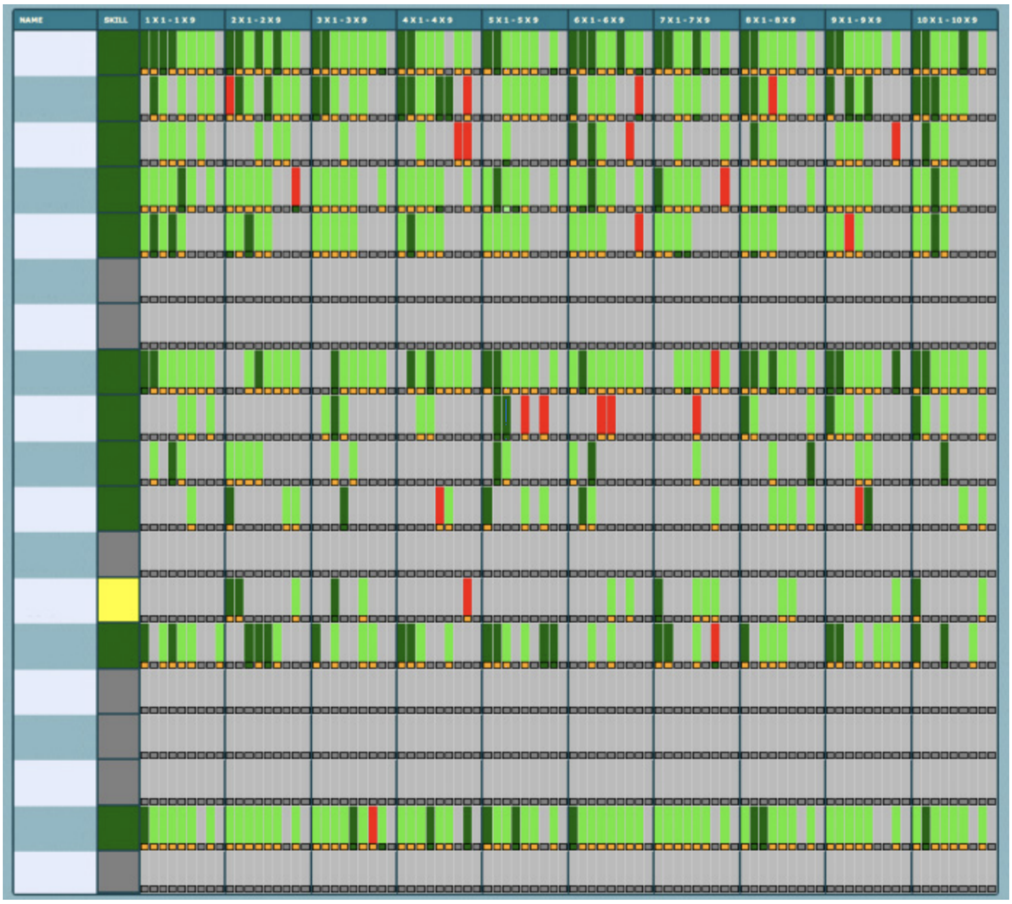


Figure 5.3: Answer Overview for the teacher (Greller, Martin Ebner, and Schön, 2014).

# 6 Alexa Math Learning Skill[1]

This chapter describes the motivation for creating new approaches to enhance children's math learning skills. Combining the current hype of smart speakers with the possibilities of the Alexa Skill KIT opens new ways of creating an attractive and effective learning environment.

## 6.1 Motivation

As described in the previous chapter, Graz University of Technology has a strong focus on creating different learning environments for children. The TU Graz learning lab on "https://schule.learninglab.tugraz.at/" (Last Access: 12 January 2020) contains the currently available web apps and apps that are successfully developed and evaluated by students and professors of TU Graz. The apps focus on increasing the skills of children in the german orthography, reading, and maths. The first challenge of those apps is to provide an attractive User Interface for children. The second challenge is to keep children in the game flow by adapting the difficulty depending on the learning progress of the player. And the third very important discipline is to gain, store, process and evaluate the given input data of the player to visualize the learning progress and to recognize weaknesses in early stages. The practical part of this master thesis deals with a different technology-enhanced learning approach. Based on the

[1] Parts of this chapter have been published in:

Peter Schoegler, Markus Ebner, and Martin Ebner (in review). "The use of Alexa in mass education"

hype and the attraction of smart speakers and especially Alexa Skills for children, a new math learning environment was created by making use of an Amazon Echo and the Alexa Skill KIT. Based on this technology, a math learning game in the form of an Alexa Skill was implemented and evaluated.

## 6.2 Intelligent 1x1 Trainer

The TU Graz started in 2011 the project of an intelligent math trainer ”Intelligenter 1x1 Trainer” focused on multiplications of numbers from 1 to 10. The trainer aims to support children in primary school in learning and manifesting the small one-off by individually align the speed of the learning progress to the child. An intelligent algorithm validates the answers given by the child and remembers the weaknesses of specific calculation tasks. The system ranks the child according to the given answers and tries to improve its skills by asking previously wrong answered questions in defined intervals. The goal of this procedure is to motivate the child by starting with easy questions and only increase the level of complexity after the calculation tasks of the current level have been manifested in the child’s mathematical skill (Martin Ebner, 2011). By now, a couple of web and mobile learning apps for children make use of this trainer. All those apps are collected on https://schule.learninglab.tugraz.at/math (Last Access: 12 January 2020) and can be used by primary schools for free.

## 6.3 Smart Speakers And Alexa Skills

Besides laptops, smartphones, and tablets, a new area of human assistance was enabled by providing speech recognition systems like Amazon’s Alexa. A study from Deloitte Deutschland reveals, that 13% of all homes in Germany are using a smart speaker in 2018 whereas the number of installed devices increases since 2015 (Deloitte, 2018). The concept is quite

simple, so when you ask an Alexa enabled device like the Amazon Echo "How is the weather going to be tomorrow?" the device is recording the voice and sends it to the Amazon Alexa Voice Service (AVS) to be analyzed. The Voice Service then applies complex operations such as Automatic Speech Recognition (ASR) and Natural Language Understanding (NLU). AVS processes the response and uses external sources to fetch the latest information about the asked question (Krishnan, 2018).
Alexa's Apps are called Skills. Amazon provides a Skill KIT for developers to build custom apps for Alexa enabled devices. This opens new possibilities of fetching data on demand by just asking a simple question to a device. The functional scope of an Alexa Skill is not limited in answering just only one question, it provides space for completely customizable logic and decision trees combined with an internal session storage. This allows developers to make use of a new interface to implement interactive, session-based learning games. After publishing Skills with a developer account they can be downloaded by Amazon enabled device via the Amazon Store if there are no explicit restrictions set. There are already approaches to math training Skills for children in the Amazon Skills Store which are trying to help children to improve their skills in basic mathematical operations with whole integers. The Skill is a kind of virtual teacher for a child asking some math questions and helps to solve it.

## 6.4 Alexa Maths Skills Research

Currently, there are some Skills in the Amazon Store available which deal with asking and validating maths questions according to the number series of the multiplication table. An evaluation of these Skills was done to observe benchmarks and get a bigger picture of the state of the art. Of course with the aim to recognize possible technical pain points as also game flow weaknesses to learn from existing solutions.

### 6.4.1 Alexa Skill ”Mathemonster”

#### Description

The player has the choice of three different mathematics disciplines: addition, multiplication and division tasks. The Skills supports three different difficulty levels which have to be selected at the beginning of the skill and cannot be changed in between one session. The Skill is available on Amazon under:
”https://www.amazon.de/BTB-GmbH-Mathemonster/dp/B07BFTQ3CG”
(Last Access: 12 January 2020).

#### Skill Flow

- Start skill with invocation name ”Mathemonster”
- Choose difficulty level
- Define the highest number in the calculations
- Skill starts asking questions randomly considering the previously defined highest number being part of the calculation task
- When the skill doesn’t recognize any answer, the question will be asked again. If there is still no answer, the skill quits.
- If the user answers with a wrong result, the skills gives the correct answer and asks the next question
- After every question, the Skill asks the user if he or she wants to continue or end the Skill
- The skill stops when saying the words ”Stopp” or ”Abbrechen”

#### User Experience

Sometimes, the Skill invocation name ”Mathemonster” is not recognized by the smart speaker or the Skill which is sometimes a little bit annoying. In some other cases, the answers were not understandable for the Skill and were therefore validated as wrong. The Skill motivates the user after giving the right or a wrong answer to continue playing and not giving up, which might keep the user in the game flow for some questions. The skill has no further visible learning analytics component and is not personalized, so it's not possible to analyze the results and weaknesses of the player. The Skill also doesn't automatically adapt to the user's maths skills. With the definition of the highest possible number and the configurable difficulty level, the child or the parents can predefine one gaming session. After restarting the game, the configuration is reset.

### 6.4.2 Alexa Skill "Das kleine Einmaleins"

#### Description

The Skill provides three programs of learning mathematics:

- Learn
  The skills says the calculation task and the result of the 1x1 calculations for each number from 1 to 10
- Test
  The Skill asks calculation questions according to the 1x1 calculations of one specific number with the iteration of 1 to 10
- Profi
  The Skill asks 1x1 calculation tasks randomly

The Skill is available on Amazon under "https://www.amazon.de/Das-Jott-kleine-Einmaleins/dp/B07B544X49" (Last Access: 12 January 2020).

#### Skill Flow

- Start skill with invocation name "Kleine Einmaleins"
- Choose one the programs "Learn", "Test" or "Profi"
- Learn
  - Choose the number series of the multiplication table
  - The Skill tells the calculation task and the answer for every calculation of the selected number series

    - After finishing the series, the user gets asked for switching the learning program again
- Test
    - A random number series of the multiplication table will be asked and has to be answered by the player
    - If the player answers with a wrong result, the skill says the correct answer
    - If there is still no answer, the skill quits.
    - After finishing the series, the user gets asked for switching the learning program again

    - 20 randomly chosen calculation tasks are asked to the user
    - If the player answers with a wrong result, the skill says the correct answer
    - If there is still no answer, the skill quits.
    - After finishing the series, the user gets asked for switching the learning program again

#### User Experience

Giving the child the option to learn the number series of the multiplication table by just listening to it is a great idea. Although, there is very less game flow in the skill as there are no motivation speeches. It really feels like talking to a boring computer. There is also no option of personalization and no personalized learning analytics elements included.

### 6.4.3 Alexa Skill ”Kopfrechnen üben”

#### Description

The Skill again provides the mathematical disciplines addition, subtraction, multiplication, and division. Every session consists of 10 randomly

asked questions of each specific discipline. The Skill is available on Amazon under the following link:
"https://www.amazon.de/gp/product/B07576XV7R" (Last Access: 12 January 2020).

#### Skill Flow

- Start skill with invocation name "kopfrechnen üben"
- The Skill asks 10 randomly chosen questions
- The question is not asked again after not answer within some seconds and the skill quits
- The skill stops when saying the words "Stopp" or "Abbrechen"

#### User Experience

This Skill is kind of a mix of the two previously described Alexa Skills, but with fewer options and possibilities. Thus, the motivation of learning with this skill could be quite low after some minutes as there is no game flow and motivation while communicating with Alexa. Sometimes, answers are not recognized and the Skill quits.

### 6.4.4 Conclusion

In general, the technology provides a completely new and interesting learning environment for children. As Smart Speakers are very common and quite cheap today, the technique could be applied nearly everywhere - homes, schools, etc. According to the defined learning types of (Gilakjani, 2012), this approach perfectly addresses children of an auditorial learning type. Those children learn best from listening, talk things through or discuss things with others. By wrapping the mathematical tasks in a story and respond with appropriate answers which engage the child to think through it again, some kind of learning by doing (trial-and-error) principal can be observed. Keeping the player in the game flow is crucial as discussed in previous chapters. Basically, there are some important things that can be observed from the analyzed Skills to enable game flow and optimize learning effects:

- Provide a story with defined quests to motivate and entertain the child
- Provide appropriate answers and hints when giving wrong questions
- Dynamically adapt the difficulty to the player's maths skills

Those observables were integrated into the concept of the practical part of this thesis, trying to satisfy all of these points to maximize the game flow and learning effect of the implemented Alexa Skill.

## 6.5 Personalized Learning Approach

For the question and answer concept of the prototype, the previously discussed Intelligent 1x1 Trainer (Maths Trainer) algorithm is a main part of the system architecture. The algorithm of this module takes care of making questions and validating the given answer of the user. Connecting the Alexa Skill to the API of the Maths Trainer requires some parameters like an authorized user. Therefore, a user has to be registered on the TU Graz learning lab via the registration form on "https://schule.learninglab.tugraz.at/user/register" (Last Access: 12 January 2020). Having a registered user, the API of the Maths Trainer can be used to enable personalized training or learning within the given maths learning environment of the Maths Trainer. In the Basic Version of the prototype, a global maths user was registered. This user was used for authenticating the Skill user with the Maths Trainer. For the first validations and the proof of concept, this approach was fully sufficient. The disadvantage of this approach is the missing assignability of the user and the given answer. So the Skill in general works like a random mathematical question engine, but the most important benefits of DGBL and LA are not supported. With the basic approach, we can not adjust the difficulty of the Skill to the learning progress of the user and further, there is no way

of personalized analytical insights of specific weaknesses for different number series of the multiplication table.
To exploit all the possibilities of the Alexa Skill and to offer the user the best possible learning effect using the Maths Trainer, an additional approach was tackled. A concept of how to map the Amazon User ID to a registered TU Graz learning lab user was created and implemented into the Alexa Skill Flow. This enables the user of the Alexa Skill to decide if he or she wants to connect to the learning lab profile or just play the Skill with randomly asked questions. Additionally, the answered questions are listed and validated in the User Interface of the Maths Trainer for learning analytics purposes.

## 6.6 Research Methodology

To evaluate the implemented Skill and the overall concept, field tests with the target group are crucial. It's essential to conduct field tests to find out possible weaknesses of the concept or show stopper regarding the technology. The learning effect of technology-enhanced learning and digital game-based learning depends on some previously described key aspects like providing an attractive learning environment, preserve the game flow and dynamically align the difficulty of the quests to the child's skills.
All of these aspects have to be evaluated practically. To observe the problems which children face while interacting with this technology and the Skill, notes, photos, and videos were taken. Additionally to that, children have been interviewed after playing the Alexa Math Skill. As children are usually very shy in answering questions, the ranking technique has been applied additionally. After each game, the children were asked some simple questions like, if they found it easy or difficult to play the game, if they liked to play the game and if they would like to play the game again or at home. To answer those questions, children could decide between five smileys expressing ranges from neutral to very happy. Based on the impressions during the field test, the interviews with the children and the

ranking method, valuable insights could be observed.

To evaluate the onboarding process of connecting the TU Graz learning lab user to the Amazon User ID within the Amazon Alexa Skill, parents were asked to follow the instructions of the Amazon Alexa Skill. Therefore, the Thinking Aloud method was approached the analyze possible pain points in the onboarding process in terms of technical struggles and ambiguities in the procedure. This kind of user experience tests have been conducted a few times with different personas while incorporating the feedback after every iteration.

# 7 Implementation[1]

This chapter describes the story and the game design of the Alexa Skill ”Bake a cake 1x1”. Additionally, a big picture of the system architecture is given und the Alexa Skill Software Framework is visualized combined with code snippets according to the implementation of the Skill. In the last step, the game flow and the decision tree of the created game is demonstrated. The Amazon Alexa Skill aims to train a child's capabilities in the number series of the multiplication table. It's available for all Alexa enabled devices. The Skill can be downloaded and enabled via the Alexa App, connected to an Alexa enabled device like the Amazon Echo.

## 7.1 Story and Skill Game Design

As described in the chapter Digital Game-Based Learning, good gameplay keeps the player motivated and engaged to continue playing (Costikyan, 2002). Education games are often missing good gameplay which leads to disengagement and boringness of the player. Again a good balance between education goals and motivating gameplay is the key to a successful education game (Kristian Kiili, 2005). To bridge the gap between keeping the player motivated and transfer knowledge within the Alexa Skill, a story behind the calculation questions was introduced. The Skill is not just about answering maths questions of the multiplication table. The story

[1] Parts of this chapter have been published in:

Peter Schoegler, Markus Ebner, and Martin Ebner (in review). “The use of Alexa in mass education”

behind the game is about baking a cake. Alexa asks the player in the beginning if he or she can help by calculating the right amount of ingredients to successfully bake a cake together. Then, Alexa asks the child questions of the multiplication table hidden in the context of how much gramm or pieces they would need according to the recipe. Alexa also motivates the player after successful answers. If the player answers wrong, Alexa repeats the question and enables a second and a third try, so the child can rethink the question and give a correct answer to continue the game and finish the cake. After ten successfully answered calculation questions, the cake is baken and Alexa congratulates the player and motivates for the next session. This concept implements some of the key aspects of how to build an education game which is discussed in previous chapters (DGBL or Learning Analytics). Giving continuous feedback to engage the child and wrap the game into a story, the child can identify with. Additionally, the whole story contains small quests that sequentially lead to the overall goal - finishing the cake. As Alexa leads the player through the game, the whole story and the tasks should be self-explanatory. Introducing a story, which is fun and suitable for children between the age of 6 to 10 and combining it with a quite new, attractive technology like smart speakers and voice recognition algorithms creates promising and alternative learning methodology.

## 7.2 System Architecture

Figure 7.1 describes the basic System Architecture and gives an overview of all interacting components when talking to the Amazon Echo and getting some response. The Amazon Web Service (AWS) provides all the necessary functionalities and takes care of the hosting. The following steps briefly describe the flow model.

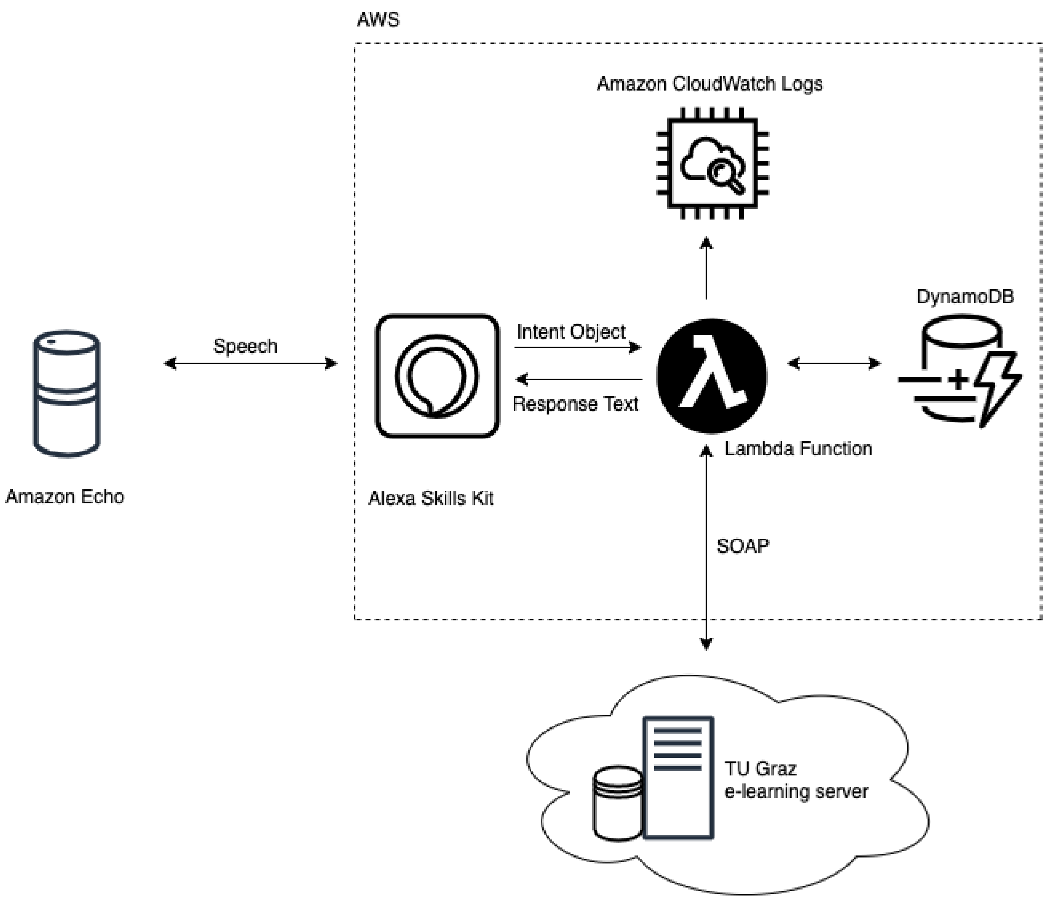


Figure 7.1: Overview of the base System Architecture

### 7.2.1 Amazon Echo

The Skill has to be installed on the Amazon Echo with the connected Amazon Account and the Amazon App. After installing the Skill, the endpoint to send the data to is known to the Amazon Echo. To start the Alexa Skill, the general invocation name “Alexa” followed by a specified “Skill Invocation Name” triggers the launch of the installed application. The invocation name has to be set in the Alexa developer console.

### 7.2.2 Alexa Skills Kit

A so-called Interaction model has to be added to the Alexa developer console. The skill interface in the Alexa Skills Kit parses the input speech and maps it according to the defined interaction model. After finding a match, an event will be sent to the specified endpoint – the AWS Lambda Function.

### 7.2.3 AWS Lambda Function

The lambda function implements some defined event listeners to handle the parsed speech of the user accordingly. Despite the skill service implementation, the lambda function establishes a connection to the TU Graz e-learning Server via the SOAP API. In this way, questions will be fetched and answered will be sent and evaluated. This functionality is described in detail in the Alexa Skill Software Architecture in the following chapter.

### 7.2.4 DynamoDB

The linked database enables the persistent storage of user data. After the first field test, we enhanced the system by this DB to enable user authentication with the TU Graz e-learning Server and provide a mechanism to link the Amazon user of the Amazon Echo to a registered user in the e-learning system.

## 7.3 Game Flow

The Alexa Skill is built in two steps to integrate the feedback of the first version into the second one. There is a group mode and a personal mode to select at the beginning. The prototype is split up into two versions to keep it simple. The basic and the extended Version are launched by saying the words: “Alexa, starte Mathekuchen!”. With the invocation text, the Skill starts the game flow and prepares the data accordingly.

### Basic Version

The basic version was conceived to focus on the Speaker technology by influencing it with noise disturbances of the environment. The Skills launches and introduces the user to the math game with an introduction text which says: “Los geht’s, rechnen wir gemeinsam einen Kuchen aus. Ich lese das Rezept vor und du hilfst mir beim Ausrechnen der Mengen der Zutaten. [Ok, let’s bake a cake together. I will read through the recipe and you need you to help me calculating the ingredients]”. With the assumption, that children love cake, the cake baking thought is integrated as a learning game in the Skill. Alexa directly starts to ask the first question with the words: “Als erstes brauchen wir <firstNumber> mal <secondNumber> Gramm Butter. Wie viel ist <firstNumber> mal <secondNumber>? [First we need <firstNumber> times <secondNumber> gram of butter. What gives < firstNumber > times <secondNumber>?]”. For the answer text, there are also some excepted phrases configured in the previously described Skill interface. The Skill then tries to evaluate the answer and gives positive feedback to the user to motivate for the next questions. Alexa also tells what is understood as the answer to the user by repeating it. If the result is incorrect, Alexa also repeats the given answer and asks the question in a motivating way again to give the user a second chance to think about it. If the given answer could not be matched against the Skill Interface Model, Alexa kindly asks to repeat the given answer with the feedback, that it could not be recognized.

The core of the learning system is, of course, the integration of the TU Graz Maths Trainer. The basic version establishes a connection with the server by authenticating with a default user. All the questions are fetched from the Maths Trainer. All the correct and wrong answers are also sent back to the Server to store the question and answers for further learning processes. During a gaming session, the algorithm of the Maths Trainer tries to figure out math weaknesses. If questions are answered wrong, the same question will appear again in one of the next questions asked by Alexa to train those iteratively. For the basic version, the authenticated default user of the Maths Trainer is not directly associated with exact one specific child or player. This also influences the parameters for the algorithm as there are many players having different strengths and weaknesses.

### Extended Version

For the extended version, a simple and feasible way to map players with users in the e-learning system was explored. The aim is to use the full power of the learning algorithm by authenticating with exactly one user for the Alexa Skill. Therefore, a user has to be registered initially on the TU Graz e-learning platform. The SOAP Interface provides some user management routes to fetch a user's id by the given username. By extending our Alexa Interface Scheme we provide the functionality to just simply spell the username and Alexa converts it to the full word. All the questions and answers can then be fetched and posted with the associated user by just adding the user's id. This mechanism empowers us to use the learning algorithm for exactly one child and increase the learning curve in the best way.

Additionally, to the authentication process, we tried to improve the user onboarding progress. While the first approach always needed the username spelling before, we could map the user, we came up with a second approach to store some mapping. The idea is to store the Amazon user id which can be accessed from the Skill in combination with the responded user id from the Maths Trainer. Therefore, the Amazon DynamoDB was introduced. In general, we don't want to store any sensible user data and keep the prototype GDPR compliant. By just storing ids according to the user mapping of two completely different systems in the DynamoDB, no additional values are needed.
So for the next invocation of the Skill, our logic tries to find the mapping in the connected DynamoDB and continues the training according to the previous question, answer history.

## 7.4 Alexa Skill Software Architecture

This section describes the components and modules which are necessary for providing an Alexa Skill. First, the definition of the Interaction Model of a Skill will be explained and the integration of the Model in the Skill "Bake a cake 1x1" will be visualized. Afterward, the intents event listener skeleton will be presented according to the implementation of the prototype. This section also describes the logic part of the Skill in the cloud-based lambda function. In the next step, the integration of the TU Graz Maths Trainer into the actual Alexa Skill will be visualized.

### 7.4.1 Skill Interaction Model

After adding a Skill on the Amazon Alexa Developer Console (ADC), some definitions like the invocation name and the interaction model have to be taken during the whole configuration process. Amazon provides a quite clear User Interface for those configurations in the ADC. The interaction model describes the voice interface for users to speak with the Alexa Skill.

To map the input of the spoken text by the user, intents are defined to handle the input and invoke the specified logic in the Intents Handler of the cloud-based lambda function.
To define the mapping of the user's input to the logic, intents, utterance samples and slot types have to be declared. These are described in detail in the Amazon Alexa Skill Documentation. The interaction model is typically specified in a JSON file, which can be uploaded to the developer console or created directly in there. The following briefly describes the main components of the interaction model file (Amazon, 2019a):

- Intents
- Sample Utterance
- Slot Types

### Intents

The intents section in the interaction model JSON file describes the interface of the user's spoken text for the lambda function logic. It consists of the object keys name, slots, and samples. The code snippet 7.1 visualizes the structure of the intent ”AnswerQuestion” and ”SetUser” as part of the interaction model JSON file. The intent has some arguments (slots), which are expected to pass to the logic. Those parameters include a name and a type.

### Sample Utterances

Sample Utterances are phrases that are spoken by the user to get a specific answer or trigger a specific question. These phrases are directly mapped to the intent. For best results, there should be as many representative utterances as possible, so the spoken phrase can be matched against the correct intent and trigger the right action implemented in the lambda function of the intents handler. The code snippet 7.1 contains four potential phrases, which might be spoken by a player or child when answering the asked calculation question. As previously described, Alexa's first question in the Skill is, that we need X times Y grams of butter - how much is X times Y. According to that question, the user might answer with just the result or might repeat the calculation and add the result at the end, or there might be some additional words while answering like ”Hmm” or ”Ich glaube”. All of these phrases would map to the intent ”AnswerQuestion” and passed to the logic after parsing the slots out of the phrase.

### Slot Types

The key ”slots” in the JSON file code snippet 7.1 declares the specific key variables which might be in the context of the answer and have to be parsed and passed to the logic part. For answering, three variables have been declared: the first number and second number of the calculation and the result. With the defined name and data type of each slot, the Alexa Skill algorithm matches the words out of the phrases of the sample utterances. The main data types are predefined in the library provided by Amazon. For some special cases, also custom types can be defined and used for the declaration of slot types.
As previously described, the Skill provides the option for personalized learning. Therefore, the user name of the registered user in the TU Graz learning lab has to be connected to the Skill to create the id mapping in the linked dynamo DB database. For this purpose, the player is required to spell the letters and/or numbers of the learning lab user name after invoking the intent ”SetUser”. Matching a specific name is not working with the built-in data types, so the custom type ”LETTER_OR_NUMBER” was introduced. For the ”SetUser” intent, the slot with the name ”char” and type ”LETTER_OR_NUMBER” is declared. There is exactly one sample that consists of the text ”Benutzername” and a series of chars that can contain values described in the custom type. Numbers from 0 to 9 and all letters from the alphabet are declared separately to enable the spelling functionality. The length of the user name is therefore also restricted to the number of chars that are declared in the sample.

```
{
"interactionModel": {
"languageModel": {
"invocationName": "mathe kuchen",
"intents": [
{
"name": "AnswerQuestion",
"slots": [
{
"name": "NumberResult",
"type": "AMAZON.NUMBER"
},
{
"name": "FirstNumber",
"type": "AMAZON.NUMBER"
},
{
"name": "SecondNumber",
"type": "AMAZON.NUMBER"
}
],
"samples": [
"{NumberResult}",
"Ich glaube es ist {NumberResult}",
"{FirstNumber} mal {SecondNumber} ist {NumberResult}",
"Hmm {NumberResult}"
]
},
{
"name": "SetUser",
"slots": [
{
"name": "char",
```

```
"type": "LETTER_OR_NUMBER"
}
],
"samples": [
"Benutzername {char} {char} {char} {char} {char} {char} {char
   } {char} {char} {char} {char} {char} {char} {char} {char}
   {char} {char} {char} {char} {char}"
]
},
],
"types": [
{
"name": "LETTER_OR_NUMBER",
"values": [
{
"name": {
"value": "0"
}
},
{
"name": {
"value": "9"
}
},
{
"name": {
"value": "8"
}
},
...
]
}
]
}
}
```

```
}
```

Listing 7.1: Answer Questions and Set User Interface definition of the Interaction Model of the Alexa Skill Prototype

### 7.4.2 Lambda Function Implementation

To define the logical part triggered by the Interface Definition of the Interaction Model, the intents handler has to be provided. As previously described, the logical part is running as an AWS Lambda Function. The chosen programming language is Python 3.6. Amazon, therefore, provides the skeleton of the function for the intents handler.

#### Lambda Main Handler

The handler function in 7.2 visualizes the use of the main handler function ”lambda_handler”. This function gets invoked every time the user interacts with the Alexa Skill. So for every intent interpretation in the interaction model, the lambda handler function will be invoked and handles the interpreted request by checking the event request type in the passed event object variable. The Skill differentiates between three basic intents. The Launch Intent, triggered by the words ”Alexa, start <Invocation Name defined in Interaction Model>”, the Request Intent, matched by intents definition in the model and the Session End Request, which is triggered by some default phrases like ”Stopp” or ”Beenden” during the session. To keep track of the occurrences and state of the current session, the actual event object contains a session container variable. Additionally to the request event handling categorization, the Skill checks if the Amazon User ID fetched from the System variable of the event context is already stored and mapped in the dynamo DB. If so, these identification variables are written to the session.

```
# --------------- Main handler ------------------
def lambda_handler(event, context):
# check if amazon user id is already mapped in dynamoDB
# if mapped -> write userId and username to session
# if not mapped ask for play or user mapping
amazonUserId = event['context']['System']['user']['userId']
currentSession = event['session']
if 'attributes' not in currentSession:
currentSession['attributes'] = {}
currentSession['attributes']['amazonUserId'] = amazonUserId

# get stored userUd and userName from dynamoDB
existingUserId, existingUserName = getUserIdAndUserNameByAmazonId(
    amazonUserId)
if existingUserId != 0:
# set user id to session
currentSession['attributes']['userId'] = existingUserId
currentSession['attributes']['userName'] = existingUserName
else:
currentSession['attributes']['userId'] = idUser

if event['request']['type'] == "LaunchRequest":
return onLaunch(event['request'], currentSession)

elif event['request']['type'] == "IntentRequest":
return onIntent(event['request'], currentSession)

elif event['request']['type'] == "SessionEndedRequest":
return onSessionEnded(event['request'], currentSession)
```

Listing 7.2: Lambda Main Handler Implementation

### Intent Handler Implementation

After mapping the intent with the model definition and calling the main handler function, the actual intent of the user will be processed. The passed request object variable contains the defined name of the mapped intent. The appropriate functions will be invoked by the defined intent name and the intent object and the current session variable is passed to the next function as demonstrated in 7.3.

```
def onIntent(intentRequest, session):
""" Called when the user specifies an intent for this Skill """

intent = intentRequest['intent']
intentName = intentRequest['intent']['name']

# Dispatch to the skill's intent handlers
if intentName == "ChooseUser":
return chooseUser(intent, session)
elif intentName == "SetUser":
return setUser(intent, session)
elif intentName == "Start":
return getWelcomeResponse(intent, session)
elif intentName == "AnswerQuestion":
return answerCurrentQuestion(intent, session)
elif intentName == "AMAZON.HelpIntent":
return getWelcomeResponse(intent, session)
elif intentName == "AMAZON.CancelIntent" or intentName == "AMAZON.StopIntent":
return handleSessionEndRequest()
else:
title = "Unknown Intent"
return didntUnderstandResponse(session, title)
```

Listing 7.3: Intent Handler Implementation

### Integration of the Maths Trainer

The Skill integrates the TU Graz Maths Trainer to fetch questions from the provided SOAP API und also answering questions with this API. For the interaction with the SOAP API, a registered user is required. Fetching data and updating data required the user id of the registered user in the TU Graz learning lab. To get this user id, the SOAP API provides an additional function which returns the user id by entering the registered user name. To enter the user name via the Skill, the model and intent implementation "SetUser" was introduced. By spelling the user name, the Skills connects the letters and numbers to a full user name string and then tries to fetch the according user id via the SOAP API. After

successfully fetching the learning lab user id, the event system user id will be mapped to this id persistently in the dynamo DB. According to the Amazon Developer Docs (Amazon, 2019b), the event system id does not change until the Skill is installed.
After every launch of the Skill, there is a logic, which checks if there is an existing mapping in the dynamo DB yet. If so, the Skill automatically resolves this mapping to get the learning lab user id and to fetch and answer questions with the registered user to enable the learning analytics methods the Maths Trainer provides. Additionally to that, Alexa greets the registered user on Skill launch if the mapping could be resolved. This automatically tells the user or the child which account is currently linked in the Skill and enables a clear and smooth start.

# 8 Research Study[1]

As already mentioned, there is an existing platform showing currently available learning apps developed by TU Graz. To prove the concept, the reliability of the technology, the fun-factor for children and most important the learning effect for each child, field tests with groups of children are indispensable. The base to enable and conduct a meaningful field test is the reliability of the technology of the Speaker. Smart Speakers are quite sensible when listening to speech in noisy areas. Especially in groups of children, someone is always talking and generates disturbing background noise for the device. To validate the impact on the speaker, the field tests took place in noisy areas with a large amount of children surrounded. The second part was to validate the children's behavior while interacting with the implemented decision tree of the Alexa Skill. At the beginning of the first field test, a group of children surrounded a table with an Amazon Echo on it. They were briefly introduced to how the game is structured and how they start the game. To challenge the sensibility of the Speaker and the error handling of the Skill, always two children were asked to play the game together by helping each other giving the correct answers. After finishing the game, another team of two children was invited to start the Skill and play the math game. While playing the game, we monitored the following points precisely:

- Are there problems to start the Skill?

[1] Parts of this chapter have been published in:

Peter Schoegler, Markus Ebner, and Martin Ebner (in review). "The use of Alexa in mass education"

- How does ambient noise influence the Amazon Echo?
- Are there problems following the game?
- How motivated are children to play the game and answer all questions?
- Are similar problems occurring in the teams of children?

As we built our prototype in two versions, we tried to conduct the first field test in a very early stage of the development process. The first field test took place at TU Graz in the course of the so-called ”Maker Days” where children can get some insights into interesting and for children relevant topics. Beside some others, we had a station with a table, some chairs around it and the magnificent Amazon Echo in the middle of it. Children were able to attend the exercises at each station. To avoid chaos, groups of 4 to 6 children were assigned to the stations.
We prepared our setup by connecting the Amazon Echo to the internet and tried to get a not too noisy location as it was quite loud anyways. For our test groups we setup our Skill to authenticate with the default user and setup 7 calculation questions. We prepared some introduction for all the attendees on what this is about, how it works and how to play the game. Mostly every child already knew or at least heard about the Amazon Alexa, but the excitement while talking to it was always very as you could see it in the face of each child. Most of the children already knew how to invoke an intent and which built-in functionality exist, so there were no difficulties to handle the Amazon Echo in the first steps.

We managed to play the game with 12 children at the age of 6 to 13. All in all, 92 questions were answered as some children wanted to start the game again after it was finished. Only 4 questions were answered incorrectly and have been corrected with the second try. To parse the answers, we prepared some different options in our Skill Interface to enable more phrases for answering. But we didn’t need any other phrase than the exact result as the children always answered with just one word – the result number. The feedback of the children was great and we encountered some points to enhance and focus on for the next field test. The first thing we observed was, that if it’s too noisy, the Skill is just not working as it understands some wrong words while waiting for the answer and even stops the application in some cases. We cannot handle this behavior at all. There have been three main outcomes of the first field test. The first thing was, that German words, especially the sound of the number 9 in German sounds like the word “no”, in German ”nein”, which led the Skill to quit the application as “no” is a general escape word for the skill if not handled. The second thing was the invocation name for starting the Skill. We set up the Skill Interface to listen to a too-long sequence for words for the invocation name which often resulted in wrong understanding. The third thing we observed was the long latency when fetching data and evaluating it with the SOPA API of the TU Graz Server. We tried to analyze the day and especially the three main problems in detail and worked out some solutions for the second field test.

The second field study took place in a primary school in Austria. Therefore, we reimplemented our flow of API calls to decrease the use of API calls and optimized the network latency time. Furthermore, we tried to handle the wrong understanding of the number 9 in the German language by handling the word “no” in the Skill Interface. To start the game, we also reduced the length of the invocation name to just 2 words to avoid misunderstandings of long phrases.
For the field test in school, we set up our device in a classroom to avoid disturbing surrounding sounds. We conducted the field test with 12 children at the age of 9 to 10. Not more than 4 children are in the classroom at the same time. We introduced the game to the children and allowed them, to play the game together with one partner to help each other. The children answered about 122 questions. They all asked for restarting the game after the first try and were super excited. The interaction with the API was fast and Alexa understood all the answers perfectly as there was less noise in the background. The Speaker always allowed some whispering between each team to discuss the answer. Figure 8.1 shows a group of children playing the Alexa calculation game in a primary school in Austria in the course of our field test.

Figure 8.1: Children playing the Amazon Alexa calculation game in a primary school in Austria

While one group was in the classroom attending the game, the other groups who already played the game were asked to give us feedback regarding the understanding of the Smart Speaker and the tasks, the difficulty of the questions, the fun factor of calculating the ingredients of a cake together with Alexa, and if they would like to play the game again. For answering those questions, each child got one feedback sheet with the questions on it and a pencil. Every question could be answered by ticking one of five smiley faces ranged from neutral to very happy. The feedback of the children reflected our impressions at the field test. All of the children answered our feedback sheet with the happiest smiley for all our feedback questions. For some of the children, the small one-off was not very challenging. Others had to struggle especially with high numbers and needed the help of their friends. We noticed, that the skill level of children who are of the same age and in the same school class is quite different.

# 9 Conclusion[1]

This thesis analyzes the opportunities and also the technical limits of currently available Smart Speakers in combination with the Amazon Alexa Skill Kit. Always in our minds, how to open new ways of game-based learning while making use of speech assistance techniques. As nowadays nearly every eighth household uses some kind of a smart speaker, it would be great to always use it as a learning friend for the children living in this household. The feedback of the realized field studies was very positive and lead us to focus on the technology and the possibilities in detail. Especially with the easy connection and authentication with the TU Graz Maths Trainer, we provide a mighty learning engine connected to a simple and attractive user interface – the Amazon Alexa Skill. As the launch of the Skill and the learning game is done with just three words at home in the living room, children can improve their Skills whenever they want in very small sessions. The algorithm in the background validates the answers and trains the child in a very individual way. With the story of baking a cake and the short duration of one session, children are motivated to calculate the amount of ingredients and finish the game. We strongly recommend the use of game-based learning in combination with interesting new technologies. By increasing the use of the TU Graz Maths Trainer, the algorithm will be trained and improved. Common mistakes or weaknesses will be analyzed and integrated into the algorithm which leads to a much better learning curve. We think that this is the way to guide children in a playful way through their education.

[1] Parts of this chapter have been published in:

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