E-MINT: A Gamified App for Empowering Parents in Their Role as STEM Gatekeepers

Thomas Wernbacher¹, Sabine Zauchner², Natalie Denk¹, Alexander Pfeiffer¹, Simon Wimmer¹, Martin Hollinetz³, Jörg Hofstätter⁴ and Margit Ehardt-Schmiederer⁵ ¹Center for Applied Game Studies, Danube University, Krems, Austria ²MOVES, Vienna, Austria ³Otelo eGen, Vorchdorf, Austria ⁴ovos media, Vienna, Austria

⁵Offene Computer Gesellschaft, Vienna, Austria

<u>thomas.wernbacher@donau-uni.ac.at;</u> saza@moves.cc; natalie.denk@donau-uni.ac.at; <u>alexander.peiffer@donau-uni.ac.at</u>; simon.wimmer@donau-uni.ac.at; martin.hollinetz@oteloegen.at; jho@ovos.at; margit.ehardt-schmiederer@ocg.at

Abstract: When it comes to initiatives engaging children - especially girls - in STEM education or careers, parents are often a neglected group, despite being regarded as the most important gatekeepers in this field because they can have an impact very early on. They frequently feel under-informed and, as a result, lack the self-confidence to take on this role. The E-MINT project starts here and aims to motivate parents and equip them with the skills to serve as role models and mentors to their children. The Science Capital approach, a proven successful framework for creating awareness, fostering motivation and imparting knowledge in the context of science education, serves as the structural basis of the E-MINT app. This especially applies to the content and functionalities of the app, which is divided into four areas: "What you know". In this section, parents are encouraged to explore their own knowledge of STEM professions, gender stereotypes, career choices, educational pathways and future technologies. "How you think". In this part of the app, career aspirations, behaviour in different situations or thoughts about the future are told in short picture stories. "What you do". The app provides free access to virtual E-MINT Makerspaces. Parents can use the app to complete projects on 3D printing, environmental technology and upcycling at home. "Who you know". In this section of the app, parents are encouraged to use their own personal social network to improve their skills as STEM gatekeepers for their children. They are guided step by step through a social network analysis with the aim of visualising their personal STEM networks and finding ways to expand it. The presurvey showed parents to be well informed. Parents were most likely to lack information about new technologies and STEM education. In the post-survey, the usability of the app was rated as very good. The comparative survey on parents' STEM knowledge showed slight changes. Parents in the post-survey knew more about training opportunities for STEM professions, about the disproportion of men and women in technical professions and the importance of gender stereotypes for career decisions. Parents' views also changed slightly in the post-survey. Specifically, their attitudes towards computer games, which they now see as having more potential to increase children's digital curiosity, and they see computer games more as a gateway into technical professions.

Keywords: STEM, Gatekeepers, Science Capital, Nudging, Gamification, Maker Space, Gender

1. Introduction

Artificial intelligence and robotics have already found their way into our everyday lives, and technological innovations are developing at a previously unimaginable speed. In order to be able to participate in these developments, the German term "MINT"¹ (mathematics, informatics, natural sciences and technology) emerged as a field of study. Although professions in the MINT or STEM core areas of computer science and natural sciences promise a high degree of security when it comes to future employment opportunities, too few young students choose a career in this field. This is especially true for girls and young women. The many reasons for this have been well researched. Gender stereotypes still prevail in our society, and so, alongside the education sector, parents play the key role in getting their children interested in STEM professions.

E-MINT is dedicated to address this issue and to explore how parents can take on the role of coaches or mentors for their children in this area. The focus is on getting adults who have little or no connection to STEM fields excited about the topic. The aim is to help parents build the skills they need to be positive role models for their children.

¹ English: STEM

2. Science Capital

In order to understand the term "science capital", one must first explain the concepts of "capital", "habitus", and "environment" according to Pierre Bourdieu (Bordieu, 1983, 1986). "Capital" refers to the resources that an individual can draw on for his or her success in society (Claussen & Osborne, 2013). These include social capital, economic capital, cultural capital, and the higher-level symbolic capital (prestige). The more capital, the better cards one holds to act socially, while the value of the types of capital changes depending on the situation. "Habitus" refers to a person's entire appearance, from lifestyle to attitude to life. It is acquired in the course of growing up through social experiences, and forms our ideas of self-evident and impossible life situations. The "environment" is understood as the set of rules by which actions are taken, the conditions and relationships of an environment that determine the interplay of capital and habitus and recognise them as legitimate.

The Science Capital approach as proposed by Archer (2015) (which measures and aims to increase a person's scientific capital) is based on Bourdieu's cultural theory, which compares everyday life to a game in which each person has different, transformable potentials, which arise from their sources of capital and can be used or transformed in exchange for others. The rules for such transformations are dictated by the environment. The Science Capital approach adapts Bourdieu's cultural theory to the needs of science education in the twenty-first century, emphasizing the importance of a person's self-efficacy in the scientific context (Area Knowledge), their attitudes and commitment (Area Attitudes), their own activities and activities of educators with content or practical relevance (Area Making), and their existing private or professional network (Area Networking).

In some environments, an individual's capital and habitus work well: they can play the game with ease. In others, their capital does not adapt to what is needed for the environment. Their habitus does not fit. They are less able to engage in something or their efforts are not valued as engagement. They cannot play the game or decide against doing so. Science Capital can be applied as an analytical tool (Archer et al., 2015) to better understand individual participation in scientific engagement. It helps to understand why some people are better equipped for science and some less. It also explains the different levels of well-being of people in STEM activities. Science Capital can be captured in several dimensions:

- Science Literacy: an individual's knowledge and understanding of STEM and how STEM works. This includes their confidence that they understand STEM.
- Science preferences: the extent to which an individual sees STEM as relevant in their own life.
- Symbolic knowledge about the transferability of STEM in the labour market (knowledge about the internal value and transfer of STEM qualifications).
- Consumption of science media (books, TV, online content).
- Participation in extracurricular contexts (e.g. visiting museums/zoos/aquariums/science Clubs).
- Knowing people (family, friends, peers and the wider community) who work in science jobs.
- Talking to others (friends, siblings, neighbours) about STEM in everyday life outside of school.
- Family, and especially parents, with STEM knowledge and qualifications.

By specifying these dimensions, Science Capital offers tools to foster a scientific habitus and develop capital across social, cultural, and symbolic STEM pathways. E-MINT integrates the innovative approach of Science Capital as a basic framework within the project methodology to better understand the broad target group of parents and their fields of action on the one hand, and to increase their degrees of freedom in supporting their children in STEM on the other.

3. Motivational Framework

3.1 Gamification

Playing is learning. And every child loves digital games. Today's children and young people grow up as so-called "digital natives" (Prensky, 2001) with digital media and use them in a natural way. The fact that the lives of generations Y & Z are digital and playful can be seen in gaming trends - 50% of under-25s are interested in e-sports, and every seventh Austrian regularly consumes game-related content via various channels such as Twitch (Jugend-Internet-Monitor, 2019). According to a study by GfK on behalf of ÖVUS, 5.3 million Austrians play digital video games. The average age is 35 years and the average time per week is about 10 hours. The games are played on PCs/MACs, smartphones, game consoles or tablets/handhelds. Digital games offer a wide range of challenges and opportunities, such as testing cognitive and motor skills.

Gamification builds on the use of game mechanics in naturally non-game contexts (Deterding, 2011). The goal is to specifically set desired behavioural impulses. This involves applying the motivational and feedback techniques that have been proven in games. Games provide clear goals (Hunicke et al. 2004; e.g. quests), they reward (Vorderer et al., 2004; e.g. badges, level-ups), they allow competition or cooperation with others (Yee, 2006; e.g. in the form of rankings, multiplayer elements) and they provide an interactive framework for different experiences and skills (Ivory & Kalyanaraman, 2007; Jansz, 2005;). The development of an emotional connection to the story, links to previous experiences, or the repetition of content in the story are all conducive to the transmission of learning content (Herbst 2014). Gamification has been successfully used in various application areas to promote participation, such as in the context of civic courage (Coronado & Vasquez, 2014), civic participation (Thiel & Lehner, 2015), e-learning (Barata et al., 2015) and e-government (Al-Yafi & El-Masri, 2016).

3.2 Nudging

Nudging as a model of gently influencing human decisions originated in behavioral economics. Thaler and Sunstein (2008) define nudging in their seminal work as a positive intervention aimed at voluntary behavior change. These interventions, known as "nudges," have primarily been used in the field of health protection (Quigley, 2013). The concept of nudging is based on motivational psychology models and has obvious parallels to the gamification principle. In contrast to gamification, however, artificial goals and rewards give way to subtle decision-making strategies. Nudges increase the visibility of behavioral alternatives by informing, encouraging reflection, and promoting social exchange. Several studies have been conducted to demonstrate the impact of nudging on human behavior via legal regulations (Quigley, 2013; Vlaev et al., 2016), on health (Marteau et al., 2011; Hanks et al., 2012; Olstad et al., 2014), and on physical activity levels (Te Brömmelstroet, 2014), with results indicating a 10-30% increase in desired behaviors. There are to date, however, no known STEM-related articles or meta-analyses that show the effect size of nudging as an intervention.

In social research, there are repeated calls to draw on behavioural theories in order to reinforce positive effects on attitudes or behaviour by means of theory-based interventions. For our own research approach of voluntary, playful behavioural change or knowledge transfer in the course of E-MINT, the Transtheoretical Model (TTM) (Prochaska & Velicer, 1997; Prochaska & DiClemente, 2005) and nudge theory are particularly well suited. Nudges ultimately serve to gently motivate people to do things voluntarily that they would not have done or would not have done to the same extent without them. The great advantage of targeted nudging based on levels is that the respective nudges are tailored to the individual target group's level of motivation and knowledge:

- No Intention There is no intention to change the behaviour → informative and awareness-raising nudges (e.g. educational information on the topic of STEM professions, on prevalent stereotypes, on emerging technologies – "What you know");
- 2. Intention formation There is an intention to change behaviour → knowledge-conveying and reflective nudges (e.g. STEM success stories and insights into the attitudes of other users "How you think");
- Preparation The target behaviour is targeted, first steps have been taken → social and normative nudges (e.g. personal STEM role models made visible in the social network analysis – "Who you know");
- 4. Action Concrete actions are set in relation to the target \rightarrow virtual STEM makerspaces "What you do";
- 5. Maintenance The goal behaviour is to be maintained in the longer term \rightarrow stabilising and preventive nudges (e.g. representation of the individual learning progress through experience points).

4. Methodology

4.1 Research Material - the E-MINT App

The different sections of the E-MINT app were designed based on the Science Capital Framework. The theoretical foundation is reflected in a simplified version that deviates slightly from the original guiding theory. This applies to the menu structure, the available rubrics, content and functionalities of the app. The demonstrator was created using an already developed SaaS solution "ovos play". Since ovos play was developed as a micro-learning system, an implementation concept was created based on it to enable short and interactive storytelling packages. To ensure ease of use for the target group, care was taken to use a common user interface with simple navigation. Therefore, the most important pages, such as the home screen and access to the four main sections, were anchored in the main navigation.

4.1.1 Section I: "What you know"



Figure 1: Section within the app relating to STEM knowledge

Parents are encouraged to explore their own knowledge about STEM professions, gender stereotypes, career options, educational pathways, and future technologies in this section. E-MINT does not claim to be a career counselling tool or to test parents' knowledge in a quiz-like format. Rather, the goal is to pique people's interest. The app presents the areas of knowledge in the form of maps with an interactive, activating narrative. As a central gamification mechanic, experience points were given out depending on the amount of knowledge cards read by the respective user.

4.1.2 Section II: "How you think"





In everyday life, parents are frequently confronted with new challenges and questions, whether they are about their children's career goals, behaviour in various situations, or future plans. Because there is usually no clear "right" or "wrong," these usually provide plenty of discussion points for debate. In this section of the app, current events are told in the form of short picture stories. "What do you think about it?" is the question that follows each story. The results can then be compared to the results of all E-MINT users. In addition, expert advice on the subject is provided. The goal is to encourage parents to actively address their own attitudes while remaining aware of their role as gatekeepers.

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4.1.3 Section III: "What you do"



Figure 3: Section within the app relating to Maker Spaces

One of the primary goals of E-MINT is to give parents access to making tools. The app allows users to gain free access to virtual E-MINT Makerspaces. Parents can use the app to develop projects at home in the areas of making (3D printing), environmental technology (air quality, particulate matter), and upcycling (using and improving existing materials). The original project plan was to run the Makerspaces on-site, but due to the COVID 19 pandemic we decided to use the virtual makerspaces format in the final E-MINT product after successfully testing it.

Parents who participate in the virtual Makerspaces receive an "E-MINT Makerspace Package" containing equipment and materials for implementation. This can be used for a limited time and is then returned, or it can be purchased and kept in the family. Parents can already take the first steps toward using the tools themselves, guided by the app. They receive additional explanations and introductions to the topics, as well as opportunities for questions and discussions, during a joint online workshop using a video conferencing tool. This combination of online learning, app-supported tutorials, and individual experimentation allows for self-directed and self-regulated learning.





Figure 4: Section within the app relating to personal STEM networks

Parents are encouraged to use their own personal social network to improve their skills as STEM gatekeepers for their children in this section of the app. They are guided through a network analysis step by step with the goal of visualizing their personal STEM network and identifying potential starting points for its expansion. Furthermore, parents are encouraged to share their experiences and knowledge, for example, through social media networks. This section of the app was designed as a DIY social network for fostering the development of entrepreneurship in the context of future education as well as business opportunities.

4.2 Research Design

The research design of the E-MINT project is based on a user-centred design approach, in which potential users were the focus of the conception and development of the app from the very beginning (cf. needs analysis). This also applies to the evaluation of the E-MINT app, in which both formative and summative evaluation methods were used. The formative evaluation was carried out with two focus groups that took place on 1 and 2 December 2020, i.e. at a time when the E-MINT app was already available in a beta version. Before the focus groups, the participants were asked to test the E-MINT app to the extent that they could form a concrete picture of it.

For the summative evaluation of the pilot test, a pre-test, post-test design was used. The aim was to test the E-MINT app under real-life usage conditions, i.e. to make it available to parents over a period of 3 months to gather their individual experiences of using it. The pre-survey took place between 23 February and 01 April 2021. The post-survey took place between 01 and 14 July 2021.

4.3 Sample

Questionnaires were used for the pre- and post-tests. In addition to the demographic data of the participants, their knowledge about STEM and their attitudes towards STEM and technology were collected in the pre-test. The post-test built upon these areas and supplemented them with the aspect of usability, a general assessment of the app and its content levels, which are based on the science capital approach (knowledge, attitudes, network, making). A total of 109 responses (69 female, 38 male, 1 diverse, 1 n/a) were received for the pre-survey, and 42 parents (30 female, 12 male) participated in the post-survey - mainly in the age categories from 30 to 50 years.

5. Findings

The pre-survey of the pilot test showed parents to be well informed. The most common need for information was about new technologies and STEM education.



Figure 5: Usability rating of the E-MINT app (N=42; 1 = "fully agree", 5 = "do not agree at all")

A five-point Likert scale was used to evaluate the usability of the E-MINT app. In particular, the need for assistance in using the app was clearly rejected with a mean value of 4.28, and the parents surveyed also tended to disagree with the question about whether they had to deal with it intensively before using it. The app is not considered to be difficult to use (M=3.78) and the menu structure is not considered to be too complex (M=3.58). Parents did not have any safety concerns in this survey (M=1.78). The general use of the app (M=2.22), the integration of the individual areas of the app (M=2.14) and the question of comprehensibility for other users (M=2.33) were also rated rather well. On average, the parents can imagine using the app regularly with a value of 2.50.



Figure 6: Comparison of STEM knowledge between the pre-test (N=109) and post-test (N=42); 1 = "fully agree", 5 = "do not agree at all"

The comparative survey analysing the impact on parents' STEM knowledge shows slight changes. Parents in the post-survey know better about training opportunities for STEM professions, about the disproportion of men and women in technical professions and the importance of gender stereotypes for career decisions, about coding and that creativity is required in technical professions. They can imagine more about future professions and know that the core STEM professions are well paid. In detail, the comparison between the two surveys showed the following results: The comparison of the pre-survey with the post-survey tends to show a very slight to slight (statistically non-significant) increase in STEM knowledge among parents. The evaluation of the statement "I know about new technologies" remains the same. With a value of 0.33, the question "I know about STEM training opportunities" shows the highest increase. Only the statement that there will be no professions without digital skills in the future is interestingly less agreed with by parents in the post-survey than in the pre-survey (0.09). This does not seem logical; one explanation could relate to the selection of occupations in the "views" area, an section within the app where personal views on technical career paths were reflected upon.



Figure 7: Comparison of STEM attitudes between the pre-test (N=109) and post-test (N=42); 1 = "fully agree", 5 = "do not agree at all"

Parents' views also changed slightly when comparing the results of the pre-survey with the post-survey. Specifically, their attitudes towards computer games, which they now see as having more potential to increase children's digital curiosity. They also see computer games more as a gateway into technical professions. A slight increase in agreement can be seen for the statement that gender stereotypes are already developing in babies. In detail, the comparison between the two surveys showed the following results:

There were no or minimal changes in the statements that were already strongly agreed with in the previous survey, namely that schools should increasingly promote STEM skills and that girls are just as talented as boys for technical professions. Parents' views on computer games have changed slightly. They agree by a value of 0.23 that children's digital curiosity can increase through computer games and with a value of 0.25 more strongly with the statement that computer games can be a gateway to technical professions. With a value of 0.18, this also applies to the statement that gender stereotypes are already being established in infants. The biggest change, of more than half a point (0.62), occurred in parents' understanding of hacking as a criminal activity. While parents were indifferent to the statement that hacking is a criminal activity in the pre-survey (M=2.82), they tended to disagree with it in the post-survey. This again probably has to do with the story in the views section about the e-sportswoman and her participation in hackathons.

6. Conclusion

The evaluation was guided by the science capital domains of knowledge, attitudes, experiences and resources (Archer et al., 2015; DeWitt, Archer & Mau, 2016), which were used to structure the content of the app. Evaluation also focused on the usability of the app on a technical level and in relation to its content. While there were still slight problems with technical use in the pilot study, which could be solved quickly and easily, the structure and navigation in the map decks were perceived as intuitive and easy to use. Likewise, the low-threshold character of the content - easily comprehensible - was referred to positively.

The area of knowledge was also well received by parents. It became apparent that the participants in the pilot study saw themselves as very well informed about the importance of STEM already and in the future. This does not correspond to the typical parent in the current literature (McClure et al. 2017), but can probably be explained by the high level of education of the participants in the pilot study. Only their knowledge about training opportunities for STEM professions and the significance of gender stereotypes for the choice of technical professions proved to be expandable. The area of perceptions is assessed similarly. The parents already assume that there are no differences in aptitude between girls and boys in technology and are confident that they can actively support their children - even in a subject that is not accessible to them at first. This is also slightly in contrast to the literature (Milagrosa et al. 2012), which shows that parents are often not aware of their essential role on the one hand and often do not have the knowledge of how to support their children in the STEM field. The parents who have taken advantage of the virtual makerspace have an extremely positive perception of this offer, which has enabled 3D printing and fine dust measurement in the lockdown in their own living room. The organisation, the instructions in the app and the workshop leaders were all rated particularly highly by the parents.

7. Future Research

A major limitation in generalising this evaluation is that the participants in the evaluation cannot be regarded as representative. Three quarters of the parents have a university degree or a degree from a university of applied sciences, which explains their high level of knowledge in STEM, but does not enable transferability of the present study to other educational contexts. Also, the ratio of 2/3 women and 1/3 men in the pre-survey (3/4 women,1/4 men in the post-survey) may reflect societal stereotypes of tasks for children in the educational context, especially in lockdowns (e.g. Beigewurm, 2020) but seems to be clearly improvable especially with regard to the model functions of parents. Therefore, in order to anchor the project sustainably and broadly, other target groups should be included in further evaluations.

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