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Predicting teachers' and students' reported mobile device use in STEM education: The role of behavioural intention and attitudes

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Institute of Education, Faculty of Social Sciences, University of Tartu, Estonia

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LIST OF ABBREVIATIONS

AIC – Akaike information criterion
AN – Anxiety
BI – Behavioural Intention
BIC – Bayesian information criterion
CFA – Confirmatory factor analysis
CFI – Comparative fit index
EE – Effort expectancy
ENJ – Enjoyment
OECD – Organisation for Economic Co-operation and Development
PU – Perceived usefulness
RMSEA – Root mean square error of approximation
SAMR – Substitution, augmentation, modification, and redefinition
SCT – Social cognitive theory
SE – Self-efficacy
SEM – Structural equation modelling
SI – Social influence
STEM – Science, technology, engineering, and mathematics
TAM – Technology Acceptance Model
TBP – Theory of Planned Behaviour
TLI – Tucker-Lewis index
TRA – Theory of Reasoned Action
UTAUT – The Unified Theory of Acceptance and Use of Technology

LIST OF ORIGINAL PUBLICATIONS

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Article II: Participating in the following stages: conceptualisation, adapting the measurement instruments, formulating the research questions, conducting the data analysis, writing the original manuscripts, and doing the rewrites based on reviewers' suggestions. Writing the paper as the main author in cooperation with co-authors.

Article III: Participating in the following stages: conceptualisation, adapting the measurement instruments, formulating the research questions, conducting the data analysis, writing the original manuscripts, and doing the rewrites based on reviewers' suggestions. Writing the paper as the main author in cooperation with co-authors.

Article IV: Participating in the following stages: conceptualisation, designing interview script, formulating the research questions, conducting four and analysing eight interviews, writing the original manuscripts, and doing the rewrites based on reviewers' suggestions. Writing the paper as the main author in cooperation with the co-author.

1. INTRODUCTION

Digital competency has become one of the worldwide learning goals in education as technology continues to be a natural and inseparable part of our everyday life. It has been shown that using technology in education helps to support student achievement (e.g. Cheung & Slavin, 2013; Sung et al., 2016), motivation (e.g. Connolly et al., 2012) as well as the acquisition of new skills (e.g. inquiry skills, Pedaste et al., 2012) and the implementation of contemporary learning approaches, e.g. supporting collaboration and self-regulation skills (Sung et al., 2016, Pedaste & Leijen, 2018). And yet, the frequency of technology use in an educational context before the COVID-19 pandemic and distant learning has been rather low (Pedaste et al., 2017; OECD, 2015). Bagon, Gačnik and Starcic (2018) showed that only *ca* 60% of students from grades 7–9 report using a computer for homework, whereas over 90% report listening to music and surfing the Internet. OECD studies have shown that almost all students in Estonia (from age 16) have access to the Internet (OECD, 2019a); however, use of technology in an educational context has been lower than average in OECD countries (OECD, 2015). The former may be associated with the accessibility of technology in schools, where it has historically been connected to computer labs and other stationary technological solutions. However, the frequency of mobile device use – devices with higher mobility like smartphones and tablets – in education has been suggested to be relatively low as well (Pedaste et al., 2017). Therefore, it is reasonable to say that accessibility of technology is not sufficient to guarantee the use of technology in education.

Research has shown that attitudes are key indicators as to whether technology, including mobile devices, are used (Abu-Al-Aish & Love, 2013; Gil-Flores et al., 2017; Venkatesh et al., 2003). Several models have been proposed to capture the most prevalent attitudes for predicting technology use, which have shown that the model fit varies depending on whose behaviour we are aiming to predict and in which context (e.g. Abu-Al-Aish & Love, 2013). Moreover, the vast majority of studies focuses on a limited set of attitudes presented in one theory, therefore discarding possibly prevalent attitudes. The former highlights the importance of including a variety of attitude factors when aiming to predict mobile device use in a new context and among a new group of participants.

Since the 1970s, researchers have looked at behavioural intention (BI) as a mediator between attitudes and behaviour (Ajzen, 1985a). However, the following research has shown that this might not be reasonable. In the second-order meta-analysis, Sheeran (2002) showed that intention accounts for only 28% of variance in behaviour. Furthermore, a more recent meta-analysis failed to confirm a relationship between BI and usage behaviour, as the relationship did not satisfactorily pass the fail-safe test (Taiwo & Downe, 2013), and later studies have suggested that the relationship between BI and use becomes insignificant when considering the direct relationship between other attitude factors and use (e.g. Šumak & Šorgo, 2016). In his critique, Bagozzi (2007) also noted that the singular link between BI and behaviour itself discounts other possible factors that may influence whether individuals act on their intentions. Furthermore, the majority of studies aiming to evaluate the experience of technology usage measures the frequency of the behaviour as a key indicator, additionally they use surveys (e.g. Al-Emran et al., 2018). However, this approach might leave us short on information regarding how technology is being used, which has guided researchers to look beyond frequency and aim to bring more variability and depth to the measures of technology use, evaluating various activities which relate to digital literacy or related literacies (Pedaste et al., 2017) and differentiating between traditional and innovative use of technology (Teo et al., 2017). Therefore, the mediating role of behavioural intention between attitudes and behaviour, as well as the variability in mobile device use, needs to be further explored.

1.1. Research focus

1.1.1. Focus on mobile devices

Studies focusing on the use of computers among students and teachers are widespread, while less is known about the acceptance and use of mobile devices (smartphones and tablets) in education. However, mobile devices have become a crucial part of technology for several reasons. On one hand, they represent the rapid change in the landscape of technology, having transformed from a luxury item into an everyday item within less than 10 years. On the other hand, they bring about several possibilities to change education (compared with computers) – as a result of increased mobility, technological support is accessible everywhere and at any time during educational activities, in addition to becoming increasingly affordable. Previous research, however, has suggested that the use of mobile devices for educational purposes has been rather low among students (e.g. Pedaste, et al., 2017). Nonetheless, research gives us reason to believe that smart devices could be beneficial in the educational set. A meta-analysis showed that mobile device use in the educational context supports the acquisition of learning goals, whereas the effect seems to be greatest in the fields of social studies ($g = .78$), science ($g = .57$) and computer and information technology ($g = .71$; Sung et al., 2016). The study also highlighted the higher supportive effect of handheld devices (*vs* computers), showing that mobile devices can be especially useful in supporting the implementation of contemporary learning approaches, e.g. collaboration and self-regulation skills, and thereby inducing higher learning outcomes. Schools play a crucial role in preparing students to use mobile devices for a variety of personal and educational purposes beyond entertainment and communication. In order to develop all aspects of digital literacy, mobile devices should be used purposefully in an educational context (Melhuish & Falloon, 2010).

In the Estonian educational context, systematic technological advancement began in 1997 when The Tiger Leap Programme was officially launched. The programme aimed to provide Estonian schools with information and communication technology (ICT) infrastructure and to support content creation and the acquisition of use skills (Runnel et al., 2009). In 2012, the next step was taken and ProgeTiger was introduced, aiming to improve the technological literacy and digital competency of teachers and students (Education Estonia, 2021). For this aim, the programme focused on integrating the activities of the following three fields into different subjects and extracurricular activities: engineering sciences; design and technology; and information and communications technology. Therefore, the enhancement of digital competency has been at the forefront of education in Estonia. However, looking more closely, we can see that there is more variety in the acceptance and use of technology in Estonian society, including in the educational context. As summarised by the OECD (2019a) in 'Skills Outlook', Estonia is in the top 25% of countries being evaluated on its provision of skills to benefit from digitalisation in the younger age group (16–29). In the provision of skills to older age groups, digital exposure and effective technology integration in education, Estonia falls around the median. When it comes to teachers' preparation and training, exposure to supporting digitalisation is on the lower side (OECD, 2019a). However, technology use outside of school for schoolwork in Estonia has been slightly higher than the OECD average (OECD, 2021).

1.1.2. Focus on STEM context in education

Present research focuses on mobile device use in science, technology, engineering, and mathematics (STEM) subjects. STEM subjects have been highlighted as a priority area in education by the European Commission (2012), stemming from the high demand of STEM-related skills and lack of workforce (European parlament et al., 2015). Over time, several reasons have been proposed to explain the shortcomings in STEM subjects in schools that might contribute to the lack of skills or workforce. Research has shown that students' motivation in STEM subjects declines rapidly from elementary to secondary school (Potvin & Hasni, 2014). This is elaborated by studies showing that students evaluate school science classes as not useful for their life or future (Osborne & Collins, 2001) and too abstract. Furthermore, studies have shown a positive relationship between STEM motivation and the choice of having a career in this field (Potvin & Hasni, 2014), implying that motivation in these subjects at the school level may be of high importance when it comes to choosing a STEM-related career in the future. This brings us to the question: what could support an increase in motivation in these subjects? Technology use in education has been shown to have a positive impact on achievement and motivation (Cheung & Slavin, 2013; Connolly et al., 2012), in addition to supporting the use of contemporary teaching methods, which have the potential to get more students interested and working in STEM fields. More specifically, the lack of motivation has been connected to the abstractness of STEM subjects (Gilbert, 2006), whereas technological solutions have been seen as useful in teaching abstract concepts (Li, 2007). A large body of research has shown the positive relationship between technology use and higher motivation in

STEM subjects (e.g. mathematics, Higgins et al., 2019; science and technology, Potvin & Hasni, 2014). Therefore, the use of mobile devices for educational purposes in STEM subjects has the potential to support student motivation and career aspirations in the STEM field. However, technology cannot fulfil its purpose if it is not used purposefully in education. Furthermore, STEM subjects seem to be rather underrepresented in studies aiming to predict learning using mobile devices, whereas only approximately 18% of studies covered in a meta-analysis were conducted in STEM-related subjects and around 14% covered primary or secondary school levels (Al-Emran et al., 2018). Therefore, it is important to study the effects of technology, e.g. mobile device, use for educational purposes in STEM subjects in and outside school.

Present research focuses on the Estonian basic school context, with students from the 6th and 9th grades and teachers who teach STEM subject classes for these grades. While the general structure of Estonian education has been laid out in the analysis of educational challenges (OECD, 2020, p. 23), in the context of STEM subjects, it is valuable to bring out that students in the 6th grade have two subjects connected to STEM: mathematics and science, the latter of which covers the main topics of biology and the basis for physics, geography and chemistry. In addition, some schools offer extra technology or computer classes; however, the current study focused mainly on mathematics and science for the 6th grade students. From the 9th grade, physics, biology, chemistry, and geography are introduced as separate subjects. These subjects have been the focus of the digital literacy initiative (ProgeTiger), whereas many schools also offer national optional curricula and the school's own subjects in technology education (Information Technology Foundation of Education (HITSA), n.d). Estonian students have been relatively high performers in PISA – in PISA 2018, Estonia was among the top performers in all three domains assessed (OECD, 2020). When it comes to the changes in learning and teaching that followed the COVID-19 pandemic, it has been brought out that three key tools likely facilitated the switch to online learning: school management platforms, digital resource banks and a team of educational technologists who enabled educational actors to mobilise resources familiar to them (OECD, 2020).

1.2. Aims of the dissertation

The overarching aim of this thesis is to better understand how attitudes and behavioural intention interact in predicting teachers' and students' mobile device use for educational purposes in the STEM context. To this end, the studies presented here contribute to the aim broadly in three stages. First, testing how relevant attitude factors interact to predict mobile device use in education for students and teachers. More specifically investigating attitude structures and the relationships between these for students (Article I) and teachers (Article II). Second, exploring the mediating role of behavioural intention between attitudes and usage behaviour and looking more closely at the behavioural aspects and interactions they have with the prevalent attitudes of students (Article I) and teachers (Article III). In addition, an original analysis is presented in the current thesis to help explore the relationship of attitudes, BI and usage behaviour in the example of students. Third, inspecting the relationships between behavioural intention, willingness and technology use further by exploring which groups of teachers can be distinguished based on attitudes towards technology and usage behaviour (Article IV).

Based on the aim, the following research questions are proposed:

1. Which factors of attitudes towards mobile devices in learning can be differentiated for students and teachers?
2. What are the relationships between these attitudes for students and teachers?
3. Which of the attitudes predicts BI and behaviour for students and teachers?
4. Which groups of teachers can be distinguished based on attitudes towards technology, perceived obstacles, and usage behaviour?

2. THEORETICAL BACKGROUND

In the following sections, the theoretical outline of the dissertation is presented. First, an overview of the relevant theories in predicting behaviour, e.g. technology use, and their developments is given. This is followed by a short synthesis of these theories and how teachers' attitudes have been used to aggregate available data and find meaningful groups of teachers. In the last part, an overview of the aims for measuring technology use in different formats is provided.

2.1. Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB)

The Theory of Reasoned Action was one of the first to postulate that individuals' behaviour can be predicted by the attitudes that person holds towards a particular action (Ajzen, 2012), and intention to perform said behaviour or Behavioural Intention (BI) is the immediate determinant of this (Ajzen, 1985). Therefore, reasoning is seen to proceed the action, which hints that behaviour is not just a reaction to the environment and resources available. Furthermore, BI is seen as the function of attitude towards the action and subjective norm (see definitions in Table 1). Attitude is seen as a combination of the belief about the consequences of behaviours and evaluation of the outcome. Subjective norm is the combination of normative beliefs and motivation to comply (see Figure 1). Distal factors, such as demographic characteristics or personality traits, are assumed to have no direct effect on behaviour. According to the TRA, external variables are related to behaviour if and only if they influence the beliefs that underlie the attitudinal or normative determinants of the behaviour.

In the Theory of Planned Behaviour (TPB), behavioural and normative belief arose as the sole determinants of attitude and subjective norm, respectively (Ajzen, 2012). Ajzen (1991) introduced perceived behavioural control (preceded by behavioural control) as a crucial variable in predicting both BI and later on also behaviour itself (Figure 1, Ajzen, 2011). Ajzen (2012) brings out that the conceptualisation of perceived behavioural control owes much to Albert Bandura's work on self-efficacy. Ajzen has emphasised that the relationship between BI and behaviour in the context of the TPB appears to not hold to the extent of that expected in the TRA (Ajzen, 2011). Ajzen argues that several factors can influence the relationship, one of the most important being perceived control. The author states (2011, p 1115), "whether intentions predict behaviour depends in part on whether the strength of the intention-behaviour relation is moderated by control over the behaviour".

The TBP has been shown to help predict teachers' behavioural intention when it comes to technology use (e.g. Teo, 2012; Teo et al., 2016), with attitudes, social norms and perceived behavioural control accounting for up to 71.7% of the variance for BI (Teo et al., 2016). The authors extended the original model by introducing some unaccounted relationships between variables based on the suggestions from the tested model. Furthermore, the authors highlighted the somewhat surprising result of the negative relationship between social norms and BI, concluding that the relationship between these two constructs might be more complex than proposed by the original theory. Attitudes towards technology use rose to be the highest predictor of BI, while being combined with perceived usefulness, perceived ease of use and technical support.

Table 1. Concepts and definitions used in different theories. Adaption of table presented in Article III

	Concept	Definition	Theory	Reference to definition
Attitude towards behaviour	Attitude towards the behaviour	"*Combination of behavioural beliefs and outcome evaluations, overall positive or negative feeling towards the act*"	TRA TPB TAM	(Ajzen, 2012, pp 441)
	Enjoyment or Hedonic motivation*	"*is defined as the fun or pleasure derived from using technology*"	UTAUT2	Venkatesh, Thong, & Xu, 2012, pp 161
	Playfulness*	"*the degree of cognitive spontaneity in microcomputer interactions*"	TAM3	Webster & Martocchio, 1992, p. 204; Venkatesh & Bala, 2008
	Anxiety	The degree to which an individual experiences negative feelings (e.g. fear, doubt) about using technology	SCT	(Compeau & Higgins, 1995)
	Behavioural belief	"*Person's subjective probability that performing a certain behaviour will produce a particular outcome*"	TRA TPB	(Ajzen, 2012, pp 440)
	Perceived ease of use	"*The degree to which the prospective user expects the target system to be free of effort*"	TAM TAM2	(Davis et al., 1989, pp 985)
	Effort expectancy	"*The degree of ease associated with the use of the system*"	UTAUT	(Venkatesh et al., 2003, pp 450)
	Outcome evaluation	"*The subjective value of the outcome*"	TRA	(Ajzen, 2012, pp 440)
	Perceived usefulness	"*The prospective user's subjective probability that using a specific application system will increase their job performance within an organisational context*"	TAM TAM2	(Davis et al., 1989, pp 985)

	Concept	Definition	Theory	Reference to definition
Attitude towards behaviour	Performance expectancy	"*the degree to which an individual believes that using the system will help them to attain gains in job performance*"	UTAUT	(Venkatesh et al., 2003, pp 447)
	Results demon-strability*	"*tangibility of the results of using the innovation*"	TAM2	Moore & Benbasat, 1991; pp 203; Venkatech & Davis, 2000;
	Price value*	"*consumers' cognitive trade-off between the perceived benefits of the applications and the monetary cost of using them*"	UTAUT2	Venkatesh, Thong, & Xu, 2012, pp 161
Social aspects	Subjective norm	"*Normative beliefs regarding different social references combined; total set of readily accessible normative beliefs concerning the expectations of important referents*"	TRA TPB	(Ajzen, 2012, pp 443)
	Normative belief	"*A person's subjective probability that a particular normative referent wants the person to perform a given behaviour*"	TRA TPB	(Ajzen, 2012, pp 441)
	Motivation to comply	"*Motivation to comply with important referents*"	TRA	(Ajzen, 2012, pp 441)
	Social influence	"*The degree to which an individual perceives that it is important to others that they should use a new system*"	UTAUT	(Venkatesh et al., 2003, pp 451)
	Facilitating conditions	"*The degree to which an individual believes that an organisational and technical infrastructure exists to support use of the system*"	UTAUT	(Venkatesh et al., 2003, pp 453)
	Image*	"*the degree to which use of an innovation is perceived to enhance one's status in one's social system*"	TAM2	Moore & Benbasat, 1991; pp 195; Venkatech & Davis, 2000

	Concept	Definition	Theory	Reference to definition
Perceived control	Control belief	"*Readily accessible about the presence of factors that may facilitate or impede performance of the behaviour*"	TPB	(Ajzen, 2012, pp 445)
Perceived control	Perceived behavioural control	"*The extent to which people believe that they can perform a given behaviour if they are inclined to do so*"	TPB	(Ajzen, 2012, pp 446)
Perceived control	Self-efficacy	Beliefs in one's capabilities to organise and execute the courses of action required to produce given attainments	SCT	(Bandura, 1997)
	Behavioural intention	"*Person's readiness to perform a behaviour. This readiness to act can be operationalised by asking whether people intend to engage in the behaviour, expect to engage in the behaviour, are planning to engage in the behaviour, will try to engage in the behaviour, and indeed, whether they are willing to engage in the behaviour*"	TRA TPB TAM UTAUT	(Ajzen, 2011, pp 1122)

* Note: Attitude factors that are mentioned under the respective theories, however, are not being further investigated in the current research.

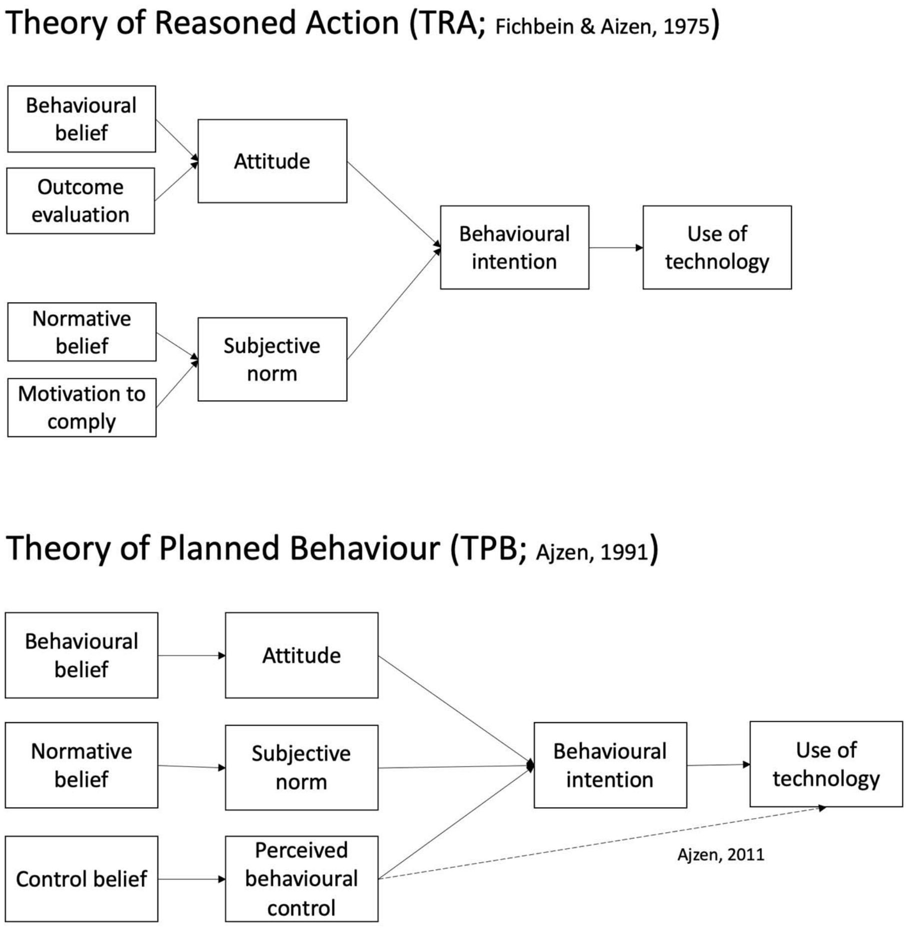

Figure 1. Visual representation of Theory of Reasoned Action and Theory of Planned Behaviour

2.2. Technology Acceptance Model (TAM) and extensions

The Technology Acceptance Model is one of the most widely used frameworks in the research of technology acceptance (Koul & Eydgahi, 2017). The model is an adaptation of the TRA for the user acceptance context (Davis et al., 1989), including with respect to the mediating role of behavioural intention between attitude and behaviour. The first version of the model was proposed and tested by Davis in 1989, showing that perceived usefulness and perceived ease of use predicted attitude towards technology, which in turn predicted intention to use technology, with the latter acting as a mediator between attitude and usage (see Figure 2, definitions in Table 1). During refinement of the model, self-efficacy was considered an important construct. However, Davis discarded self-efficacy from the variables with a reference to the need for it to be specific to the context; however, in the TAM, Davis saw acceptance as a general construct (Davis, 1989). In later work, Davis and colleagues (1989) claim that the self-efficacy paradigm does not offer a general measure that works in the context of technology acceptance. However, they bring out that self-efficacy could be seen as a part of ease of use, whereby the easier the system is to use, the higher self-efficacy should be (Davis et al., 1989). In empirical studies, Davis and colleagues tested the preliminary model and concluded that "attitude appears to mediate the effects of belief on intention even less then postulated by the TRA and the TAM" (Davis et al., 1989, pp 994). Therefore, the authors simplified the model by discarding the mediating role of attitude. Furthermore, based on empirical studies, authors highlighted perceived usefulness as a major determinant of BI, where perceived ease of use might have a direct relationship with BI or through the mediation of perceived usefulness (Davis et al., 1989). Any other factors are seen as external and, along the lines of the TRA and the TPB, expected to influence BI only indirectly through perceived usefulness and perceived ease of use (see Figure 2).

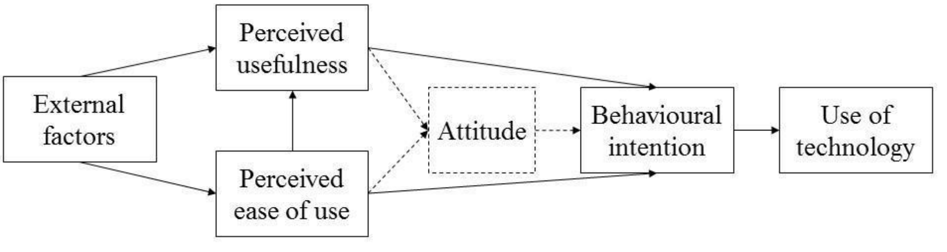

Figure 2. Visual representation of Technology Acceptance Model (TAM; Davis, 1989; Davis et al., 1989)

Several extensions to the model have since been proposed, where a set of variables have been tested to predict perceived usefulness and perceived ease of use (see Figure 3). In the TAM2, Venkatech and Davis (2000) focused on predicting perceived ease of use, proposing altogether five factors that could be potential predictors. In the development of the TAM3, Venkatesh and Bala (2008) tested both variables proposed in the TAM2 as well as proposed lists of variables to help predict perceived ease of use. Along the lines of the TRA, most of these factors have been expected to only influence BI through perceived usefulness or perceived ease of use. Only social influence (Venkatesh & Davis, 2000) and facilitating conditions (perceived external control, Venkatesh & Bala, 2008) have been allowed to predict BI directly as well.

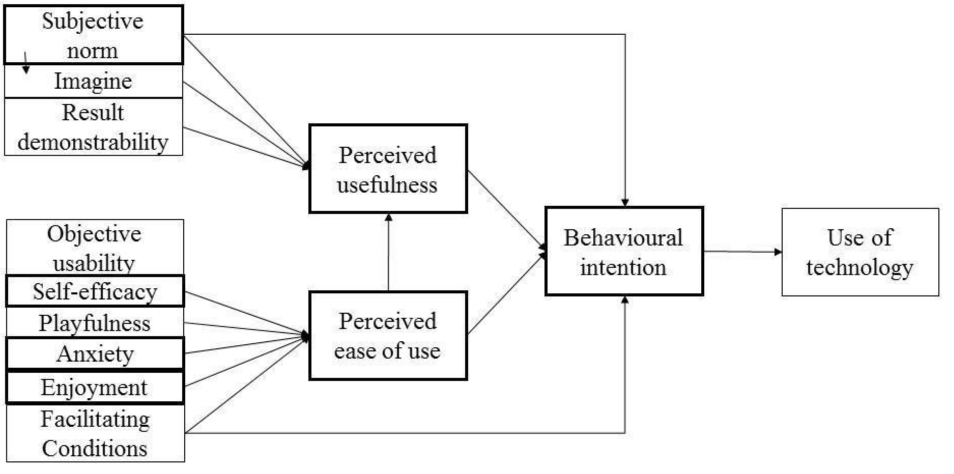

Figure 3. Visual representation of Technology Acceptance Model and its extensions (TAM2; Venkatech & Davis, 2000); TAM3, Venkatesh & Bala, 2008; mLearning (bold on the figure), Sánchez-Prieto, Hernández-García, García-Peñalvo, Chaparro-Peláez, & Olmos-Migueláñez, 2019)

The TAM model with its extensions has been extensively tested on teacher (Scherer et al., 2019) and student samples (Al-Emran et al., 2018) and has been shown in a meta-analysis to fit the data and help predict the behavioural intention and use of technology for both samples. However, the effects were shown to vary across studies, indicating possible context- or sample-specificity. For example, in the educational context, subjective norms played a larger role in teachers' perceptions of the usefulness of technology than in case of technology use in non-educational contexts (e.g. Scherer et al., 2019). In addition, Sherer and colleagues bring out the importance of variables in the extended versions, for example self-efficacy, concluding that the link between self-efficacy and TAM-core variables shows that the former might become a possible barrier or enabler for technology use or use intention in education. As the number of studies involving self-efficacy has been quite limited in the context of the TAM, the authors concluded that direct or indirect mechanisms leading up to this importance are still to be examined in greater detail. Furthermore, Pratama (2021) showed that the extended the TAM model predicted 72% of students' BI in the context of mLearning. The results highlighted the importance of perceived enjoyment as the highest predictor of BI, which led the author to conclude that when it comes to students' use of mobile devices, it may be reasonable to be guided by the "fun first, useful later" approach.

2.3. The Unified Theory of Acceptance and Use of Technology (UTAUT)

The UTAUT is based on eight models and theories that explain factors influencing the acceptance of technology (Venkatesh et al., 2003), including the TRA, TPB and TAM. Based on previous theories, authors have identified seven attitudes that should be investigated more closely: performance expectancy, effort expectancy, social influence and facilitating conditions, self-efficacy, anxiety and attitude towards technology or enjoyment (see Table 1 for definitions). However, authors hypothesised that the latter three of these factors will not have a direct effect on BI, which they partly supported with an empirical study (Venkatesh et al., 2003). Nonetheless, authors admit that caution is needed in adopting these results. In conclusion, four attitude factors were identified that have a direct effect on behavioural intention or technology use: performance expectancy, effort expectancy, social influence and facilitating conditions (see Figure 4).

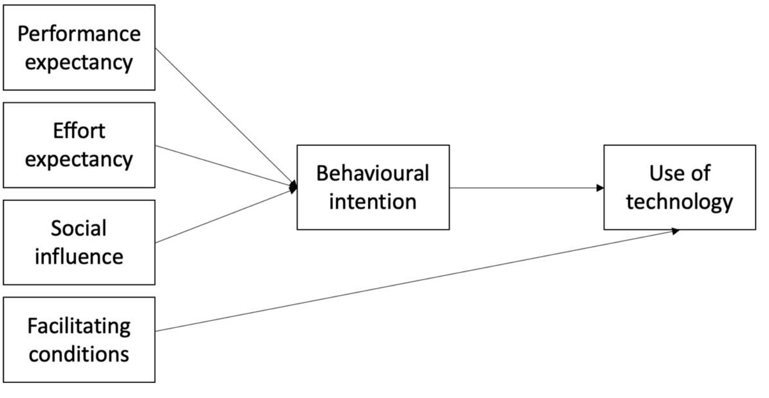

Figure 4. Visual representation of Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003)

The UTAUT also postulates that gender, age, user experience and voluntariness of use should be seen as possible moderators of relationship between attitude and BI. Voluntariness has been brought out in the TRA and the TPB as an influence on the model through individual characteristics (as self-efficacy) as well as external variables (as dependence on others; Ajzen, 1985a), whereas in the UTAUT, voluntariness is closely related to social influence (Venkatesh et al., 2003). In involuntary situations, social influence should be more related to perceptions of technology. In the UTAUT2, Venkatesh and colleagues (2012) took into consideration the possible differences between a consumer in the workplace and a consumer as a free agent, suggesting three variables that could help explain variance in BI and behaviour for the latter group: hedonic motivation (or enjoyment), price value and habit as predictors of BI (UTAUT2; Venkatesh et al., 2012). A variety of extensions to the model have since been proposed (Venkatesh et al., 2016).

However, the vast majority of these extensions has been tested in a workplace environment, therefore leaving us with a shortage of studies measuring attitudes towards mobile devices in educational settings (Venkatesh et al., 2016). Furthermore, the results of the factor structure for the UTAUT model have been rather diverse depending on the sample and goal at hand (Abu-Al-Aish & Love, 2013; Terzis & Economides, 2011).

2.4. Taking these theories together

From the list of attitudes covered by the previously described theories (see overview of attitudes in Table 1), the author of this thesis proposes three higher categories: attitudes towards behaviour, social aspects, and perceived control. This division follows the structure proposed by Ajzen in the TRA and the TPB, although expanded here with the aim of covering all relevant attitude factors proposed by theoretical models. The most prevalent attitudes in these categories and their interactions are illustrated on Figure 5. Behavioural factors (BI and behaviour) remain separate from the three categories. As seen in Table 1, several of these attitudes (within one category) have been proposed to reflect similar concepts as indicated in the definitions and items used to measure each factor. For example, perceived ease of use (TAM) and effort expectancy (UTAUT) both aim to reflect the perceived difficulty of using certain technological tools, whereas perceived usefulness and performance expectancy both look at the perception of the tool being useful in reaching a certain outcome. In the context of the TRA and the TPB, this concept goes along with behavioural belief and outcome evaluation, which reflect the probability of reaching the preferred outcome. Several of these theories, TRA, TPB, TAM, have looked at attitude as a separate factor for predicting behavioural intention. For the TAM, attitude was predicted to mediate the relationship between perceived ease of use, perceived usefulness, and behavioural intention. A similar factor was introduced to the extended UTAUT model, named hedonic motivation or enjoyment, which reflected the positive emotions associated with a behavioural act. In the context of mLearning, enjoyment has been highlighted as a valuable addition to the list of variables measured. Social aspects are covered by social influence, which focuses more on the evaluations of relevant others towards the behaviour and facilitating conditions as the infrastructural support. The former combines the social norm and normative belief aspect by focusing on the perception of others' influence on behaviour. Furthermore, studies have investigated the relationships between these attitudes beyond the mentioned theories. Scherer and colleagues (2015) looked at the relationship between usefulness and self-efficacy among teachers' technology use, showing that teachers who have higher self-efficacy tend to see technology as more useful for supporting teaching. Therefore, these attitudes are seen not only as individual contributors, but also as collaborators in predicting technology use.

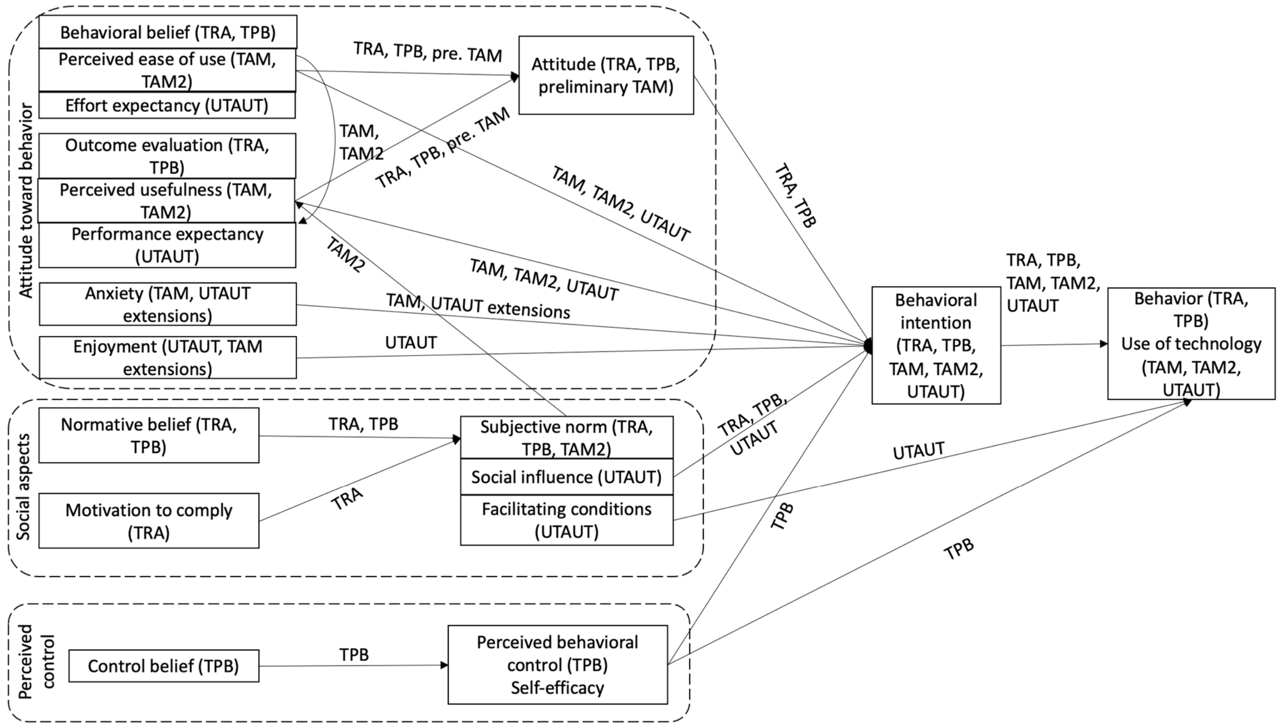

Figure 5. Theoretical model proposing three main categories of attitudinal factors and their sub-attitudinal factors. Arrows represent the direction of the relationships proposed and tested in the context of theories discussed in this thesis

*Note: TRA – Theory of Reasoned Action; TPB – Theory of Planned Behaviour; TAM – Technology Acceptance Model; UTAUT – Unified Theory of Acceptance and Use of Technology. For definitions and references, see Table 1.

Some researchers, such as Tsybulsky and Levin (2019), have proposed looking beyond individual attitudes and observing attitudes on a higher level, as a system of beliefs where it is important to understand not only the content of the beliefs, but also their interactions and different patterns of coexistence. The authors termed this system of beliefs as ‘worldview’, where they used Wilber’s (1995) three-dimensional construct to describe an approach to the digital worldview that comprises objective (how I relate to digital content), intersubjective (how I relate to others through digital means) and subjective dimensions (how I see myself represented in the digital world). This approach somewhat changes the focus of the subject from “how I perceive technology” to “how I see myself in relation to technology”. While the latter approach might bring new insights into the understanding of technology use, the vast body of research focusing on aiming to capture the individual attitudes and their roles in predicting technology use has to be a relevant path in this research.

More often than not, research aims to test models of attitudes that transcend the subject matter; to this end, the models have been tested on samples including a variety of teachers and students in several subject contexts. As Al-Emran and colleagues (2018) showed in a meta-analysis focusing on predicting learning using mobile devices, 41% of studies did not specify the subject context or were conducted in a mixed context. Similarly, Scherer and colleagues (2015) reported having teachers from STEM fields as well as humanities, languages and physical education. In other examples, the subject context of the participants has not been mentioned in the example of teachers (e.g. Teo, 2012; Teo et al., 2016) nor that of students (e.g. Pratama, 2021). Therefore, it could be expected that these attitude factors are meaningful in predicting mobile device use for students and teachers in the STEM context; however, a narrower context might bring some particular insights into how to enhance mobile device use in STEM education.

2.5. Predicting Behavioural Intention (BI) and technology use in education

2.5.1. Predicting BI or technology use

Throughout the previously introduced theories, BI is seen as the ‘gate’ between attitudes and behaviour, where attitudes can only influence behaviour through changing intention. However, it was emphasised early on that the relationship between BI and behaviour in the context of the TPB appears to fluctuate (Ajzen, 2011). Furthermore, it is noted that the singular link between BI and behaviour itself discounts other possible factors that may influence whether individuals act on their intentions (Bagozzi, 2007). However, as mentioned previously, later theories (since the TRA) and empirical studies have mostly taken the relationship between BI and behaviour in isolation, without accounting for possible direct links between attitudes and behaviours. Looking further from cross-sectional studies, the second order meta-analysis by Sheeran (2002) showed that intention accounts for only 28% of variance in behaviour. Low predictive values might be affected by the exclusion of direct relationships between attitude and behaviour. In recent years, studies conducted in the educational context, more precisely on teacher samples, have shown that it might be beneficial to take into consideration the direct relationship between attitude factors and usage itself. Šumak and Šorgo (2016) showed that the relationship between BI and use becomes insignificant when considering the direct relationship between other attitude factors and use. Scherer et al. (2020) went one step further, showing that attitude factors could be combined under one higher level factor and finding that this factor, technology acceptance, predicts technology use directly but not through willingness. Therefore, it is important to consider the direct links between attitude and behaviour as well as the relationships mediated by BI.

2.5.2. Measuring technology use

The first step in the line of predicting technology use is choosing an optimal way of gathering information about the behaviour of interest groups. The majority of studies aiming to evaluate the experience of technology usage measure the frequency of the behaviour as a key indicator, and also use surveys (e.g. Al-Emran et al., 2018). Moreover, a meta-analysis in the field of mobile learning describes that a quantitative approach (47.92%) is the most employed research design with a growing trend, followed by a mixed method (18.75%) and qualitative (14.58%; Chee et al., 2017). This might reflect the fact that the former is a cost effective way to gain insight into the behaviour of teachers and students, which provides sufficient information in the required format in order to aim to predict behaviour. However, this approach might leave us short on information on how technology is being used, as it could be argued that while we aim to understand the determinants of the behaviour, the specifics of the behaviour might become important. Therefore, researchers have aimed to bring more depth to the field, for example by evaluating the frequency of several activities related to digital literacy or associated literacy (e.g. content creation, communication, information search) for students (Pedaste et al., 2017) and teachers (e.g. Kippers et al., 2018; Hatlevik et al., 2010). Researchers have also aimed to differentiate between traditional and innovative use of technology for teaching, where the former reflects a more teacher-centric approach and the latter supports student-centric, technology-based learning (Teo et al., 2017). A similar model has been proposed by Zhao (2004), who in the context of teachers of social studies proposed a continuum where the characteristics of technology use are described primarily through the roles of teachers and students, with the two extremes of teacher-centric and student-centric. Building on the work by Zhao (2004), Karaseva and colleagues (2013) proposed based on their research that teachers of science and humanities might differ in how they use technology in their teaching; moreover, they concluded that humanities teachers' use of technology covered the full continuum, whereas technology use by science teachers was more on the teacher-centric side.

Puentedura (2006) proposed an SAMR framework to evaluate the educational use of technology with a focus on integration of the latter into the teaching-learning process. The framework consists of four hierarchically positioned levels; starting from the lowest: substitution, augmentation, modification, and redefinition. Crompton and Burke (2020) conducted a systematic review using SAMR, through which the authors empirically extended the framework and provided an overview of the usage cases for every level of the framework. The first two levels, collectively named enhancement, focus on substituting usual tasks with similar ones using technology (substitution) or adding some minimal function (augmentation), such as slides with embedded videos to illustrate a topic (Crompton & Burke, 2020). The next two levels are named transformative levels, as the technology used enables learning activities to be redefined up to the point where technology is necessary, as the activity would not be possible any other way, e.g. collaboratively solving problems or writing text. In the case of modification, technology enables significant task redesign (such as finding stars in the sky using augmented reality), whereas with redefinition, tech enables the creation of a new task that would not be possible without technological solutions (such as students recording experiments and editing them to illustrate the learning process). It is suggested that the use of technology at the higher levels might be associated with better learning outcomes, from an effect size of 0.029 at the substitution level to 1.563 at the redefinition level (Hamilton et al., 2016). However, Hamilton and colleagues are critical of interpreting these findings and bring out three challenges that SAMR faces, the second being 'rigid structure'. Hamilton and colleagues thereby challenge the notion of structuring the levels in a hierarchical way, where the higher levels are suggested as a more efficient way of using technology. The authors go further, challenging the examples used by Puentedura (2014), which rely on the study conducted by Pearson et al. (2005). In one of these examples, they challenge Puentedura's interpretation of the study extracted from the work of Pearson and colleagues (2005), which tested a tool to support reading comprehension, by testing out the tool with and without metacognitive prompts supporting a more adaptive reading strategy (Salomon et al., 1989). While Puentedura brought this study out as an example of technology use at the redefinition level, Hamilton and colleagues argue that "the findings (referring to the study by Salomon and colleagues) point to the positive impact of the metacognitive-like guidance with which students were provided, not the actual technology itself". In light of Crompton and Burke's (2020) extensions and elaborations on the SAMR framework, we could argue that those metacognitive prompts could be seen as the addition that takes the use of technology from the enhancement level to transformative. Here, the question is whether the use of these prompts is possible in a non-intrusive way without the help of technology. In the example of Salomon and colleagues (1989), technology seemed to be the means of enabling the use of these prompts in a cost effective and non-intrusive way as they were incorporated into the reading process.

3. METHODOLOGY

3.1. Procedure and participants

For Articles I, II, III and IV, data was collected in two parts as a part of the project ‘Smart technology and digital literacy in promoting a change in learning’.

For Articles I–III, the data was collected between March and May 2016. The following criteria were used to select the schools from which the sample group was drawn: general education (the sample group did not include schools with special education; use of Estonian as the basic teaching language; more than five students in the target classes (6th and 9th); and specific region (proportionally students from city, country side, bigger and smaller schools). Altogether 326 schools fit the criteria in Estonia in 2016. For both 6^{th} and 9^{th} grade, the schools were divided by area and number of students into three subgroups (schools of big cities, city schools, rural schools), of each of these a proportionate random selection was done among these schools, presenting us with 202 schools. As a first step, e-mails were sent to the heads of schools describing the study and inviting them to participate. Secondly, phone calls were made to schools that did not respond to the first reach out to remind them of the invitation, explain the study further and give the opportunity to respond to the invitation. In total, 147 schools participated in the study with a representative sample across Estonian schools.

Data for Article IV was gathered in spring 2020 during the COVID-19 pandemic lockdown (as a remark: the Republic of Estonia announced lockdown on the 12th of March and the period was officially over on the 17th of May 2020). Teachers were invited to participate in a voluntary study focusing on teacher experience and technology use during the COVID-19 pandemic. One-hour interviews were scheduled and conducted within the lockdown period (April to May 2020). All interviews were conducted via video conferencing systems Zoom or Microsoft Teams and were recorded at least in audio format (except for one video for which recording failed). As a precaution, written notes were taken during the interview. Oral consent to record the interview was asked from every participant as the first question and with the explanation that the recordings would be used only for achieving the aims of the study and stored on a physical hard drive, access to which is only granted to the authors of the current study. All interviews were conducted in Estonian and the relevant quotes from participants were translated into English for publishing.

3.1.1. Students

Article I focused on data gathered from students. In selected schools, an informed consent form was sent to all parents/guardians of 6^{th} and 9^{th} grade students, which consisted of the information about the study. Informed consent forms were also presented to students. Only those students their parents who both agreed to participation were enrolled in the study. Of previously described schools, 3521 students participated, of whom 2673 were enrolled in 6^{th} and 848 in 9^{th} grade. In total, 1824 girls and 1697 boys participated in the study. The average age of 6^{th}

grade students in our study was 12.7 years (*SD* = .63) and for 9th grade students 15.6 years (*SD* = .54).

3.1.2. Teachers

Articles II, III and IV focused on data gathered from teachers. For Articles II to III, we reached out to STEM subject teachers for 6th (mathematics and science) and 9th grade (mathematics, physics, chemistry, geography, and biology) through their schools, asking them to fill out an online questionnaire on a voluntary basis. In total, 377 STEM subject teachers participated in the study. Altogether, 178 mathematics teachers participated in our study, 155 of which reported teaching in 6th grade and 92 in 9th grade. Some of these teachers reported teaching mathematics in both grades. Altogether, 214 science teachers filled out the survey, of which 46 teach only 6th, 89 only 9th and 79 teachers teach in both 6th and 9th grade. Of the 168 teachers teaching science in 9th grade, 80 teach biology, 71 geography, 44 physics and 48 chemistry. In the study, school-level feedback was offered and therefore the age and gender of a teacher can be perceived as characteristics that make the anonymity of participants questionable, especially in the case of smaller schools where the number of STEM subject teachers can be low. Therefore, the gender and age of teachers were not asked so as to raise the level of anonymity of the teachers participating in the research.

For Article IV, all Estonian basic school STEM subject teachers were approached through the schools with the invitation to participate in a study. The participants were Estonian science, geography, physics, chemistry, and biology teachers who voluntarily agreed to share their experiences about teaching in distance learning/teaching conditions. In total, 13 teachers (see Table 2) accepted our call to participate in a one-on-one online interview with a preliminary duration of 60 minutes.

Table 2. Descriptions of participants (table originally presented in Article IV)

Participant (pseudonym)	Work experience as teacher	Subjects
Anna	3 years	Science and Geography
Kati	2 years	Science and Physics
Kristi	7 years	Science and Chemistry
Mati*	30 years	Physics
Karolin	10 years	Biology, Science
Maria	20 years	Biology
Timo	4 years	Science
Kristjan	64 years	Physics, Science
Triinu	16 years	Biology, Geography, Science
Veiko	20 years	Biology
Paul	17 years	Physics and Chemistry
Anne	34 years	Biology
Piret	35 years	Biology

*Note: For this teacher, the interview took place via Microsoft Teams and was not recorded.

3.2. Instruments

3.2.1. Questionnaires

3.2.1.1. Attitudes towards mobile devices

Students

The attitude questionnaire related to the use of mobile devices was based on a questionnaire developed by Pruet and colleagues (2016), which consisted of 20 items. Based on the theoretical background (UTAUT), some additional items were added in order to measure Social Influence, Self-efficacy and Effort Expectancy (for more information see Article I). In the main study, the questionnaire consisted of 22 items:

- Self-efficacy was measured through 5 items, composite reliability: .873; the error variance of four items was allowed to correlate (between SE1 and SE2, SE4 and SE5)
- Social influence through 4 items, in the final solution one item was discarded due to high correlation with other factors (SI4: "*Teacher encourages me to use mobile device for learning*", composite reliability: .715
- Anxiety through 4 items, composite reliability: .771
- Effort expectancy through 2 items, composite reliability: .425
- Performance expectancy through 2 items, composite reliability: .681
- Attitude/enjoyment through 5 items, where the error variance of two items was allowed to correlate (between EN4 and EN2); in the final solution one item was discarded due to high correlation with other factors (EN3: "*It is boring to use mobile device for learning*"), composite reliability: .881

A short overview of samples, instruments and analysis for every research question is shown in Table 3.

Teachers

The teachers' attitude questionnaire was based on the questionnaire used by Papanastasiou and Angeli (2008). Based on the UTAUT and TAM models, we added items directly measuring effort expectancy (Venkatesh et al., 2003). Answers were gathered on a 5-point agreement scale (1 – disagree up to 5 – agree). The final questionnaire consisted of 32 items structured as follows (see Article II for further information):

- Self-efficacy was measured through 6 items, composite reliability: .897
- Social support through 6 items, composite reliability: .833

- Anxiety through 4 items; composite reliability: .739
- Performance expectancy through 5 items, composite reliability: .873
- Effort expectancy through 3 items, composite reliability: .651
- Attitude through 3 items; composite reliability: .869
- Facilitating conditions through 3 items, composite reliability: .864

3.2.1.2. Behavioural Intention and the use of mobile devices

Students

As conceptualised by Ajzen, BI is seen as a person's readiness to perform behaviour, which could be reached in several ways, one of which is to ask "*whether they are willing to engage in the behaviour*" (Ajzen, 2011, pp 1122, see also Table 1). Therefore, behavioural intention to use mobile devices was measured via one item (with a 5-point agreement scale; 1 – disagree up to 5 – agree): "*I am willing to use mobile devices for learning*".

For evaluating mobile device use, students answered questions related to how often they use mobile devices for information searches, communication, content creation and gaming in connection to learning while they were in school and while they were outside of school as well as how often they used mobile devices outside of school for other purposes. The activities were then grouped according to the nature and location of the activity – in school for learning, outside of school for learning, outside of school for other purposes. As the variance was low for other activities besides information search, we continued focusing on information search. Furthermore, as the primary focus of the present study was on mobile device activities with a direct educational purpose, we discarded the last group of activities (outside of school for other purposes) from the research. We first focused on how often students search for information to fulfil educational tasks using mobile devices, and second, how often they gather materials for the same purpose both inside (2 items) and outside (2 items) school.

Teachers

Teachers answered items concerning their behavioural intention to use mobile devices for teaching ("*I am willing to use mobile devices in my classes")* and the current use of mobile devices ("*How often do you use mobile devices in teaching?"*). For the first item, teachers were asked to give an answer on 5-point agreement scale (1 – disagree up to 5 – agree) and to the latter question on a 5-point frequency scale (1 – never; 2 – once or twice a term or less; 3 – once or twice a month; 4 – almost every class; 5 – every class).

3.2.2. Interviews

A pilot study was carried out in order to ensure the reliability and trustworthiness of the interview scheme. The pilot study was done with one STEM subject teacher and the interview questions were adjusted as needed. The main adjustments included the exclusion of interview questions that were evaluated as repetitive by the teacher in the pilot interview. Semi-structured interviews were used during the interviews, which provided flexibility and the possibility to broaden the scope of questions in accordance with the teachers' answers and allowed, in order to check the meaning of the answers given, the interviewer to ask reflective questions during the interview. Altogether the interview consisted of 10 questions. The interview questions were presented in two parts: first, an introduction and the main topic, focusing on how teachers perceived teaching in distance learning conditions; and second, technology use for teaching and its variation compared with prior experiences (see Appendix A). Four out of 13 interviews were carried out by one interviewer; however, recordings of the interviews provided the possibility to evaluate the nuances in interviewing style.

3.3. Data analysis

3.3.1. Quantitative data

Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM) were used for data analysis. The statistical program Mplus (Version 7; Muthen & Muthen, 1998–2015) was used for the previously mentioned analysis. CFA was used to test the attitude structure of students (Article I) and teachers (Article II). SEM was used to develop a model to predict students' (Article I) and teachers' BI to use mobile devices and usage itself (Article II and III). The model fit was evaluated using the following fit statistics and criteria proposed by Bowen and Guo (2012): root mean square error of approximation (RMSEA): close fit: $\leq .05$, reasonable fit: .05–.08, poor fit: $\geq .10$; comparative fit index (CFI): $\geq .95$; and Tucker-Lewis index (TLI): $\geq .95$. For the Akaike information criterion (AIC; Akaike, 1974) and the Bayesian information criterion (BIC; Schwartz, 1978), lower values demonstrate better fit.

3.3.2. Qualitative data

We used cross-case analysis to describe the similarities and differences between the cases. This enabled us to position these cases relative to one another on the target aspects. The relevant paragraphs of the interviews were transcribed and analysed using inductive and deductive content analysis based on the research questions. The confidentiality of the responses was secured using pseudonyms to represent each participant, keeping the recordings on a secure hard drive.

To increase the trustworthiness of the interpretation of the interviews, 4 out of 13 interviews were co-analysed by the author of this thesis with the co-author of Article IV and used as a reference for the independent analysis of the remaining interviews (Williams & Morrow, 2009). This allowed the researchers to have a reference point for the rest of the analyses and to reach a common understanding of the four target aspects. Any differences in coding were discussed and an agreement was reached.

As mentioned, in the interviews we focused on four aspects to subtract and describe meaningful groups of teachers. For three of these aspects, we used an inductive approach:

1) willingness to use technology
2) change in technology use from pre-COVID to distance learning
3) the perceived obstacles to technology use

For one aspect, variety in the use of technology corresponded with the levels described in the SAMR framework. We used a deductive approach, aiming to differentiate enhancement and the transformative level of technology use. On this aspect, we relied on the work of Crompton and Burke (2020), who have brought out examples of the two higher levels and sublevels as follows:

- Enhancement level: on the level of substitution, technology acts as a direct substitute for the tool with no functional change (e.g. reading an e-book); on the second level, augmentation, direct substitution is enhanced functionally (e.g. constellation map on your smartphone that tracks movement).
- Transformational level: the technology used enables learning activities to be redefined up to the point where technology is necessary, as the activity is not possible in any other way. In the case of modification, technology enables significant task redesign (such as finding stars in the sky using augmented reality), whereas with redefinition, tech enables the creation of a new task that would not be possible without technological solutions (such as students recording experiments and editing them to illustrate the learning process).

Table 3. Overview of sample instruments and analysis used to answer research questions

Research question	Article	Sample	Instrument	Analysis
Which factors of attitudes towards mobile devices in learning could be differentiated for students and teachers?	**Students** Article I + additional analysis **Teachers** Article II	**Students** N=3521 n(6th grade)=2673 n(9th grade)=848 **Teachers** N=377	**Students** ***Students' attitudes towards mobile devices for learning questionnaire*** – 22 items, 6 subscales (self-efficacy, social support, anxiety, effort expectancy, performance expectancy, attitude/enjoyment) **Teachers** ***Teachers' attitudes towards mobile devices in teaching questionnaire*** – 32 items, 7 subscales (self-efficacy, social support, anxiety, effort expectancy, performance expectancy, attitude/enjoyment, facilitating conditions)	CFA, composite reliability
What are the relationships between these attitudes for students and teachers?	**Students** Article I **Teachers** Article II		**Students** ***Students' attitudes towards mobile devices for learning questionnaire*** (short) – 4 subscales (self-efficacy, social support, anxiety, performance enjoyment) ***Behavioural Intention*** – "*I am willing to use mobile devices for learning*" **Teachers** ***Teachers' attitudes towards mobile devices in teaching questionnaire*** (short) – 5 subscales (self-efficacy, social support, anxiety, performance expectancy, facilitating conditions) ***Behavioural Intention*** – "*I am willing to use mobile devices in my classes*"	SEM

Research question	Article	Sample	Instrument	Analysis
Which of the attitudes predict BI and behaviour for students and teachers?	**Students** Article I + additional analysis **Teachers** Article III		**Students** ***Students' attitudes towards mobile devices for learning questionnaire*** *(short)* ***Behavioural Intention*** – "*I am willing to use mobile devices for learning*" ***Mobile device use*** **–** 2 items mobile device use for information search for learning at school and 2 items at home for learning **Teachers** ***Teachers' attitudes towards mobile devices in teaching questionnaire*** (short) ***Behavioural intention*** – "*I am willing to use mobile devices in my classes*" ***Mobile device use*** **–** *"How often do you use mobile devices in teaching?"*	SEM
Which groups of teachers can be distinguished based on attitudes towards technology and usage behaviour?	**Teachers** Article IV	N=13	***Semi-structured interview*** Altogether 10 questions, for the full interview script see Appendix A. Examples of questions in the interview: • What are you doing differently in your teaching compared with the period before distance learning? • What are the main goals of using technology in your lessons during distance learning? Give some examples.	Cross-case analysis, inductive and deductive content analysis

4. RESULTS

In the first subsection, we aim to answer the first two research questions focusing on attitude structures and the relationship between them for students and teachers. In the second subsection, we give an overview of the relationship between these attitudes, BI and mobile device use, answering the third research question. The results will be structured by students and teachers. In the third subsection, we aim to answer the fourth research question by bringing out groups of teachers based on their attitudes towards technology and usage behaviour.

4.1. Attitudes towards mobile devices

4.1.1. Students

In the student sample we looked into six attitude factors, leaving out facilitating conditions as infrastructural support is not directly within the scope of students – the accessibility of mobile devices at school has a more direct effect on teachers. For students, the support of teachers and other students might be more influential; this aspect is covered by the factor of social influence. Therefore, we tested model fit for attitude structure with six separate factors, which, however, was not satisfactory ($\chi^2(171) = 3611.19$, p=.00, RMSEA=.08, CFI=.91, TLI=.89). As brought out in Table 4, correlations between effort expectancy, enjoyment, perceived usefulness, and self-efficacy seem to be unreasonably high, which might suggest that these constructs could not be differentiated. The modification indices provided with the model suggest that items from perceived usefulness load to enjoyment factor with one effort expectancy item (EE1: "Using mobile devices makes studying easier"). Whereas the other effort expectancy item (EE2: "Using mobile devices for studying is difficult") loads with anxiety factor. Both items fit the description of the new factors and the changes were therefore acceptable.

Table 4. Pearson correlations between six attitude factors for student sample.

	Social influence	Effort expectancy	Enjoyment	Perceived usefulness	Self-efficacy	Anxiety
SI						
EE	.07(.03)**					
ENJ	.22(.02)**	1.09(.03)**				
PU	.18(.02)**	1.16(.33)**	.92(.01)**			
SE	.23(.02)**	1.05(.03)**	.76(.01)**	.79(.01)**		
AN	.03(.02)	–.94(.03)**	–.58(.02)**	–.42(.02)**	–.60(.02)**	

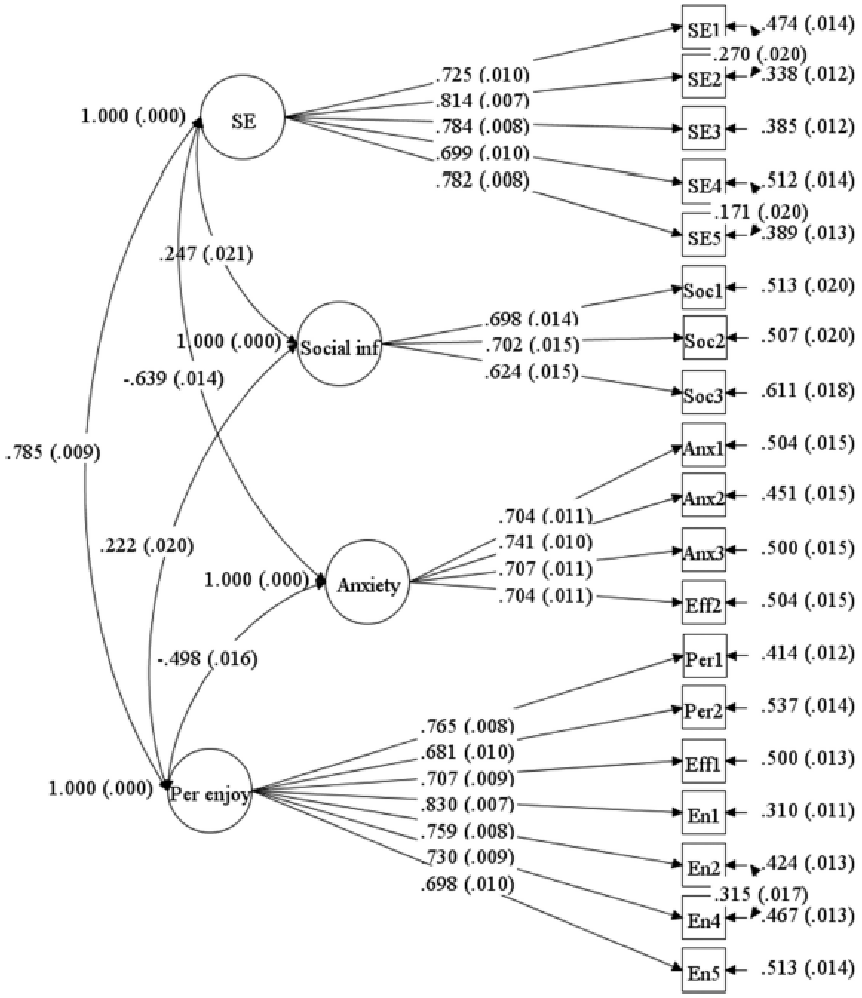

Figure 6. Structure of students' attitudes towards mobile devices for learning (results of confirmatory factor analysis, standardised model). All regression coefficients and correlations are significant at the level p<.01 (standard errors brought in parenthesis). SE – Self-efficacy; Social inf – Social Influence; Per enjoy – Performance enjoyment. First published in Article I

Based on the previous, we defined in Article I the model shown on Figure 6. Based on the model, we were able to differentiate four attitude factors: self-efficacy, social influence, anxiety and a new factor named performance enjoyment, which combines items from performance expectancy and enjoyment factor. A higher correlation could be seen between the self-efficacy and performance enjoyment factors (r=.79, p<.01), which shows that students who believe they can use mobile devices for learning find the use of mobile devices more useful and enjoyable. The next step in Article I showed that self-efficacy could be seen as a predictor for performance enjoyment, explaining 61.4% of variance in performance expectancy. Therefore, having higher self-efficacy raises the chances that particular students perceive mobile devices as useful and enjoyable for learning (see Figure 7). Furthermore, performance enjoyment, social influence and anxiety predict 42.8% of variance for BI, with performance enjoyment being the highest predictor. It is noteworthy that mobile device use in school and at home for educational purposes showed a rather high correlation (see Figure 7).

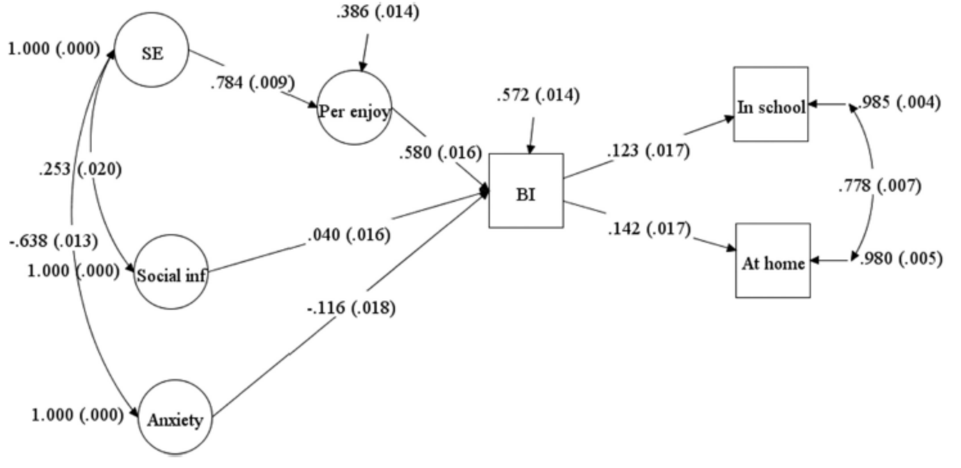

Figure 7. The model prediction of students' Behavioural Intention (BI) and mobile device use in school and outside school for learning (at home) via attitudes towards mobile devices (Self-efficacy (SE), Social Influence (Social inf), Anxiety and Performance enjoyment (Per enjoy)). Standardised Solution; N = 3527. All regression coefficients are significant at the level p<.01; $\chi^2(199) = 2753.61$, p<.01, RMSEA = .06, CFI = 0.94, TLI = 0.93).

First published in Article I.

4.1.2. Teachers

In the teacher sample, we included all seven attitude factors highlighted based on relevant theories. The CFA model showed reasonable fit based on RMSEA; however, both CFI and TLI indices were lower than recommended ($\chi^2(381)$= 923.47, p<.00, RMSEA=.061, CFI=.92, TLI=.91). Looking more closely at the model, we can see that the correlations between a few factors are higher than would be considered reasonable (see Table 5), which influences the model fit as these factors cannot be differentiated in the model. Specifically, effort expectancy, attitude towards technology use and performance expectancy all had correlations higher than .85, which indicates that the independence of those factors is questionable. This implies that teachers may perceive mobile device usefulness in terms of how much effort it takes to use them and how much they like using it. Based on previous studies showing performance expectancy to be the highest predictor of BI of these three, we continued with the former.

Table 5. Correlations between teachers' mobile device attitude factors, CFA Model 1

	Self-efficacy (1)	Social influence (2)	Anxiety (3)	Performance expectancy (4)	Effort expectancy (5)	Attitude towards technology use (6)	Facilitating conditions (7)
(1)	(.897)						
(2)	.615(.030)*	(.833)					
(3)	–.774(.030)*	–.348(.057)*	(.739)				
(4)	.577(.041)*	.441(.052)*	–.546(.048)*	(.873)			
(5)	–.797(.040)*	–.448(.063)*	.864(.040)*	–.866(.037)*	(.651)		
(6)	.754(.030)*	.492(.049)*	–.743(.035)*	.925(.018)*	–.922(.034)*	(.869)	
(7)	.344 (.052)*	.713(.037)*	–.094(.060)^{ns}	.190(.058)*	–.148(.068)*	.196(.057)*	(.864)

Note: * $p<.001$, ns – not significant. Composite reliability values on the diagonal.

Therefore, in the next steps in Article II, we continued with five attitude factors: self-efficacy, social influence, anxiety, performance expectancy, and facilitating conditions. Correlations between these factors are presented in Table 6. Two pairs of factors have relatively higher correlations (self-efficacy and anxiety, social influence and facilitating conditions); however, these are not so high that we would need to discard these factors as independent ones. As will be discussed later, higher correlations between these constructs are expected based on previous studies.

Table 6. Correlations between factors for the second model and composite reliability for factors (on the diagonal), see also Article II

	Self-efficacy (1)	Social influence (2)	Anxiety (3)	Performance expectancy (4)	Facilitating conditions (5)
(1)	(.897)				
(2)	.536 (.047)*	(.833)			
(3)	–.788 (.030)*	–.258 (.062)*	(.739)		
(4)	.577 (.041)*	.390 (.055)*	–.444 (.052)	(.873)	
(5)	.344 (.052)*	.753 (.036)*	–.090 (.061)ns	.192 (.057)*	(.864)

Note: * p<.001; ns – not significant. Composite reliability values on the diagonal.

In Article II, we showed that social influence and facilitating conditions could be brought together under a higher order factor, which we named social aspects (see Figure 8). It is noteworthy that social influence has more weight in the higher level construct. Taken together, social aspects predict teachers' attitudes towards mobile device use for teaching. Furthermore, social aspects predict a major part of variance in self-efficacy. This gives reason to believe that the belief of being capable of using mobile devices in the classroom is very closely related to the existence of social and infrastructural support for this activity. For anxiety, the relationship with social aspects is strong and negative – less social support is related to higher anxiety. Performance expectancy is also positively related to social aspects, which shows that having this support raises the likelihood of teachers perceiving mobile devices as useful for teaching. In this model, we saw that anxiety, performance expectancy and self-efficacy all contributed directly to predicting the variance for BI.

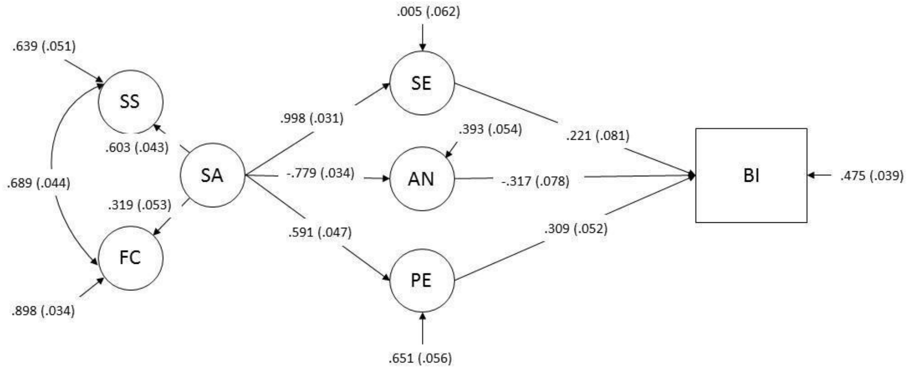

Figure 8. Predicting teacher behavioural intention to use mobile devices for teaching through teachers' attitudes (self-efficacy (SE), anxiety (AN) and performance expectancy (PE)) and these through perceived social aspects (SA) (social influence (SS) and facilitating conditions (FC)). All solid lines represent statistically significant paths (p<.001).

First published in Article II

4.2. Predicting BI and mobile device use

4.2.1. Students

For students, two models were tested: for Model_S 1 in Article I, BI mediated the relationship between attitude and mobile device use (see also Figure 7), and for Model_S 2, a direct relationship between attitude and usage behaviour was assumed (Figure 9; see fit indices in Table 7). The results show that each model could be found to have a reasonable fit separately. In Model_S 1, performance enjoyment, social influence and anxiety directly explained approximately 43% of the variance for BI, which in turn explained 2% of the variance for use in school and 2% of the use of mobile devices for learning at home, respectively. It is noteworthy that mobile device use both in school and at home for learning are strongly correlated. In Model_S 1, attitudes predicted 22% of mobile device use in school and approximately 17% of use at home for learning purposes. When attitudes were allowed to have a direct relationship with usage, BI did not contribute to predicting mobile device use in school or outside school. Upon comparison, Model_S 2 is preferred given that it has higher values for CFI and TLI and lower values for RMSEA, AIC and BIC. As the models are nested, we conducted a chi-square difference test to evaluate whether the difference between models was significant. The results indicated that the two models are significantly different, with $\Delta\chi 2=607{,}5$; $\Delta df=6$; $p<.001$, with Model_S 2 being preferable.

Table 7. Fit indices for the tested models for students (S marks models for student sample)

	χ2 (df)	RMSEA	CFI	TLI	AIC	BIC	Ad BIC	R2 for BI	R2 for use in school	R2 for use at home
Model_S 1	2753.6 (199)	.06	.94	.93	192465	192934	192692	.428	.015	.020
Model_S 2	2146.1 (193)	.05	.95	.94	191870	192376	192115	.427	.219	.167

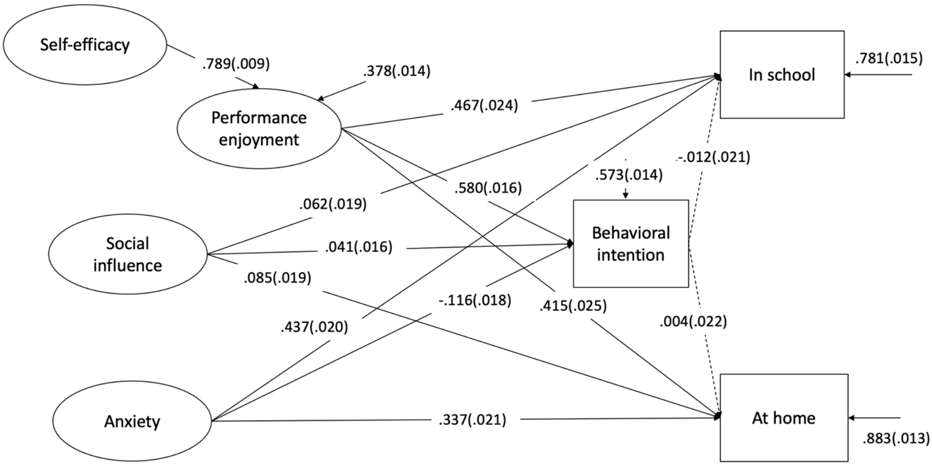

Figure 9. Model_S 2 predicting students' BI and mobile device use in learning via attitudes towards mobile devices. Standardized Solution; N = 3527. For model fit indices see Table 7

4.2.2. Teachers

In Article III, two models were tested to predict teachers' mobile device use for teaching. In Model_T 1, BI was seen as a mediating variable and Model_T 2 attitude factors were allowed to predict use directly. Both models had a satisfactory model fit (see Table 8), with Model_T 1 accounting for 35% and Model 2 accounting for 46% of the variance for usage behaviour. Model_T 2 is preferred given that it has higher values for CFI and TLI and lower values for RMSEA, AIC and BIC, as well as based on the chi-square difference test, which indicated that the two models are significantly different, with $\Delta\chi2$=66,7; Δdf=4; $p<.001$.

Table 8. Fit indices for the tested models for teachers (T marks models for teacher sample, adapted from Article III)

	χ^2 (df)	RMSEA	CFI	TLI	AIC	BIC	R^2 for BI	R^2 for use
Model_T 1	693.2 (281)	.062	.925	.913	23413	23791	.536	.348
Model_T 2	626.5 (277)	.058	.936	.925	23355	23748	.543	.467

It is noteworthy that Model_T 2 explains 12% more variance in behaviour, with self-efficacy and social influence contributing to the prediction of behaviour directly in addition to the mediation of BI. Self-efficacy predicts both behavioural intention and behaviour itself; teachers with higher self-efficacy are more prone to have higher behavioural intention and to use mobile devices more often in teaching. The relationship between social influence and BI remains insignificant, although in Model_T 2 we can see that social influence positively predicts behaviour. Anxiety and performance expectancy appear to predict behaviour through BI in both models. Facilitating conditions predicted behaviour positively in the first model; however, taking into consideration their direct relationship with other attitude factors, facilitating conditions do not appear to predict either behaviour or BI. Accounting for direct relationships between all attitude factors and behaviour lowers the predictive power of behavioural intention to behaviour, which suggests that relying on the mediating relationship of BI alone might not be reasonable.

4.3. Teachers' groups based on attitudes and technology use

As we could see that teachers' attitudes predicted the frequency of mobile device use for teaching, the pandemic presented a unique situation in which we were able to study teachers with varying attitudes towards and habits around technology use while teaching solely at a distance, making the use of technology (to a different extent) essential. These descriptions provided valuable insight into the connection between willingness to use technology and technology use as well as perceived obstacles for the groups of teachers. Based on teachers' descriptions of their experiences with technology before and during the pandemic, we distinguished three teacher groups (the positioning of teachers in these groups is illustrated in Figure 10). Between these groups, we noticed some differences in perceived obstacles emerge, which provided insight into the teachers' perceptions of technology in the educational context (see Table 9). In order to keep the following chapters descriptive of the groups and their differences, it is important to bring out that a few obstacles were mentioned by teachers in all three groups (see Table 9 for overview): problems with infrastructure (e.g. hardware accessibility by students, Internet connection), providing immediate feedback to students and students' digital skills. In the case of the former, the teachers' environment started to play a role, as in some cases all students had tablets to use provided by the school, whereas others reported that regardless of the expectation that everyone has access to tools, this might not be the case.

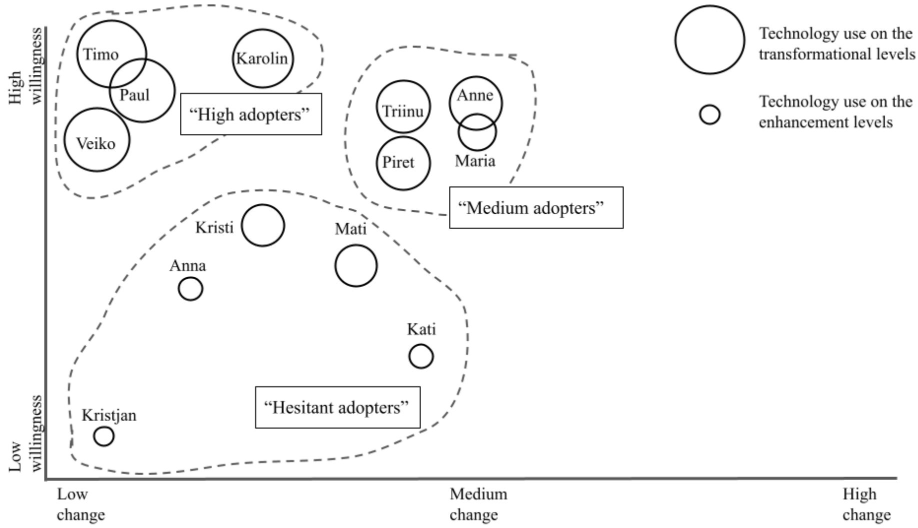

Figure 10. Teachers' relative position on three aspects: willingness to use technology for teaching, change in technology use (compared with pre-COVID-19) and variety of technology use. Adapted from Article IV

Table 9. Perceived obstacles by group

Group	Shared obstacles		Distinctive obstacles
Group A: (Timo, Karolin, Paul, Veiko)			Limitations of technological solutions Too many solutions in use in parallel
Group B: (Triinu, Anne, Maria, Piret)	Problems with infrastructure Problems with giving immediate feedback Students' digital skills	Time-consuming for the teacher Students' study skills	Difficulties with external learning materials
Group C: Kristjan, Kati, Anna, Mati, Kristi)			Difficulties with technological solutions Teachers' attitudes and beliefs

Note: First published in Article IV.

4.3.1. High adopters

Teachers in this group could be described through relatively high levels of willingness towards technology use in teaching and relatively low change in technology use from teaching in the classroom to distance learning during the pandemic. As one teacher brought out, “The use of technology [in the classroom] was rising [before lockdown]; however, now it is absolute,” and at the same time, “A teacher in a state of emergency is still a teacher” (Timo). In this group, the descriptions of technology use cases clearly reflected the transformational level, describing how technology use helped them and students perform tasks that would not have been possible without the support of technological solutions. In the example of Karolin, “With the worksheets in Wiser, they can check themselves if they are correct. With the workbooks, this doesn’t happen, maybe they wait until the teacher collects [the workbooks]… and then get to know [the right answers], but now they get [them] right away.” As mentioned previously, teachers in this group brought out three obstacles to technology use for teaching: infrastructure, immediate feedback, and students’ digital skills. However, in contrast to the following groups of teachers, the teachers in group A mentioned more resources for overcoming these obstacles. As one teacher illustrated, “I have chosen environments where I know that they have acquired [the skills] already” (Timo). In addition, teachers in this group mentioned that they find the limitations with certain technological solutions. One teacher stressed that in some cases it was challenging for him to keep track of which technological tool he had to use with students, as schools use a variety of options, e.g. for learning management systems.

In summary, teachers in this group reflected relatively high willingness to use technology for teaching and reported technology use on a transformational level.

4.3.2. Medium adopters

As with group A, Group B could be described through relatively high levels of willingness towards technology use in teaching and technology use cases that reflected the transformational level (in some cases leaning towards enhancement level, more precisely modification). Where this group started to clearly differentiate from the previous group was in the change in technology use, where teachers described a moderate increase in use. It is important to bring out that the change was not extreme but more noticeable than in the descriptions of group A. As one teacher described, “I was a frequent user before the crisis and I can say that it has increased during the current situation” (Piret), whereas another teacher perceived the change to be more widespread: “Everything had to be redone/adapted to the digital version” (Maria).

This group shared two additional perceived obstacles with the following group of teachers: first, how learning to use new solutions and creating study materials was rather time-consuming for the teacher, and second, referring to obstacles beyond technological difficulties, pointing out student study skills and how working independently was difficult and took more time. As one teacher illustrated, “The biggest difficulty is that [students] lack the skills to work on their own with the textbook” (Kristjan). However, from this group of teachers, unique perceived obstacles that were not mentioned by the other groups arose. Teachers reported having difficulties with materials constructed by someone outside the school, such as quizzes provided by environmental institutions.

4.3.3. Hesitant adopters

In group C, teachers had larger variability in the levels of willingness towards technology use; however this stayed between medium and low relative to the other two groups. As one teacher reflected on this hesitation, “I have never been hostile (towards technology), but now it was a bit more difficult …” (Anna). Similarly, there was more variance in the change in technology use for this group. However, this aspect becomes even more meaningful when taken with the level of technology integration. We were able to see how teachers with lower levels of willingness described technology integration that stayed on the enhancement level, substitution for the smaller cycles on Figure 1 or modification for slightly bigger cycles. Even though all of the teachers described a change in technology usage, for some teachers the change was more related to technology than for others. Kristjan shared his experience relying on similar tasks in the classroom, however giving the instructions and receiving the answers in a more remote way: “/…/ I give instructions on which pages to go through, to which questions to pay extra attention to /… /”. Whereas other teachers in this group described a slightly different relationship with technology by expressing that they had the chance to keep using the technological solutions they already knew: “There is not much difference when it comes to the environments I use” (Anna).

When it comes to obstacles, teachers reflected on some obstacles that were shared with other groups, such as time-consumption: “I know there are so many interesting things, but I haven’t had the time to make them work for me and haven’t had that now either” (Kristi). However, these teachers also reflected on two unique obstacles: difficulties with technological solutions and attitudes or beliefs towards technology. As for the former, teachers described a variety of difficulties from Internet capabilities to the impact of long hours behind the computer. The latter was a more elusive obstacle, as teachers themselves did not mention these explicitly; however, based on their descriptions of their experiences and the principles guiding them in making choices and finding solutions, a clear theme emerged. These attitudes which emerged as non-digital solutions were viewed as preferable, as one teacher described, “I held the position (before COVID-19) that as technology is used in many subjects anyway, in science classes we do ‘real things’” (Kati). Some did not see the value in adding technological solutions to the teaching practice, in the words of one teacher:

> "I have thought (about using Zoom) but the system that I use . . . I am happy and students are happy . . ." (Kristjan).

In this case, the teacher hinted at willingness to use technological solutions, but the lack of clear added value to their practice or clear usefulness seemed to be a determinant obstacle.

5. DISCUSSION

The overarching aim of this thesis is to better understand how attitudes and behavioural intention interact in predicting teachers' and students' mobile device use for educational purposes in a STEM context. This aim was reached broadly in three stages: first, investigating attitude structures and the relationships between these for students and STEM subject teachers; second, looking more closely at behavioural intention, reported mobile device use and their interactions with the prevalent attitudes for students and teachers; and third, to explore which groups of teachers can be distinguished based on attitudes towards technology and usage behaviour. In the following section, the results of all three subsections are discussed in connection with theoretical standpoints and previous empirical findings. In the last sections, scientific and practical implications as well as the limitations of the study and directions for further research are addressed.

5.1. Attitudes towards mobile devices for students and teachers

5.1.1. Attitude towards behaviour

Looking into the factor structures of students and teachers, we can see several similarities. First of all, it seems that for both samples, performance expectancy, effort expectancy and general attitude/enjoyment are highly related concepts. This is more clearly seen in the teacher sample, where these factors showed separate satisfactory reliability; however, correlations between these were over .80. In the student sample, performance expectancy and enjoyment results are a bit clearer, showing that these factors might be seen as one construct. These results follow the study conducted by Pratama (2021), showing perceived enjoyment as the highest predictor of BI. Furthermore, similarly high correlations have been shown to emerge between attitude factors in previous teacher samples (Scherer et al., 2015). Second, anxiety is shown to be negatively correlated with other attitudes for both students and teachers. Moreover, anxiety rises as a significant predictor of BI, with higher anxiety predicting lower levels of behavioural intention to use mobile devices in learning or teaching. For both samples, these results advocate narrowing the number of attitude factors measured, more specifically questioning the need to measure performance expectancy, effort expectancy and general attitude/enjoyment as three separate and independent factors for students and teachers. This is somewhat controversial to the attitude factors proposed in the TAM and the UTAUT, as both of these theories emphasised the role of these attitudes separately in predicting BI (Davis et al., 1989, Venkatesh et al., 2003). However, this might be explained by the inclusion or exclusion of other attitude factors and their potential relationships in the model. The original TAM model only considered the three attitude factors under discussion here (Davis et al., 1989) and later observed only a limited relationship between perceived usefulness (Venkatesh & Bala, 2008), perceived ease of use and other attitude factors, looking at the relationship of e.g. self-efficacy, anxiety and perceived ease of use or subjective norms and perceived usefulness in the context of mLearning (Sánchez-Prieto et al., 2019). Nonetheless, studies based on the TAM have shown that combining some of the factors may be reasonable, as Holden and Rada (2011) found a factor combined by performance expectancy (usability) and effort expectancy (perceived ease of use) helped predict teachers' general attitude towards technology use at a higher level. Contrary to the previous, we considered all attitude factors included in the study as potential predictors of BI directly, thereby testing the factor structure which gave a basis for exploring the number of factors in the model further. Our results also follow the results of a large meta-analytic study conducted by Scherer and colleagues (2020) with a similar baseline of testing the factor structure, showing that attitude factors among teachers could be combined under one higher level factor. Even though factors from other subcategories such as anxiety show a high correlation with other attitude factors like self-efficacy, for teachers ($r = -.788$) and for students ($r = -.639$), these correlations in our study were not high enough to consider merging the factors. As expected, lower anxiety predicted higher BI to use mobile devices for both teachers and students. Therefore, there might not be a basis for distinguishing between the evaluation of how useful, how easy to use and how enjoyable mobile device use is considered in the educational context. And this seems to apply to teachers and students alike.

5.1.2. Social aspects

When it comes to relationships between attitude factors under social aspects, somewhat different trends emerge for students and teachers. Interestingly, social influence and facilitating conditions did not directly predict BI for teachers (Article II). This was a rather surprising discovery, as social support has been found to be an important barrier to consider when implementing mobile devices in education (e.g. Sánchez-Prieto et al., 2019). Based on previous studies suggesting that instead of having a direct influence on technology use, school readiness (facilitating conditions) may play an important role in fostering teachers' attitudes that support technology use (González-Sanmamed et al., 2017), we took a step further and investigated the potential indirect relationship between social aspects and other attitude factors in the teacher sample. Our study confirmed the results of González-Sanmamed and colleagues (2017), showing that attitudes taken as social aspects predicted teachers' self-efficacy, anxiety and performance expectancy, which in turn predicted BI. In accordance with our study, previous research has shown that the correlation between social influence and facilitating conditions is stronger in the sample of teachers (in samples of teachers: $r = .36$ by Baydas & Goktas, 2017; $r = .32$ by Teo & Noyes, 2014, in other samples: $r = .22$; Venkatesh et al., 2003), which indicates that for teachers, these social aspects may have joint variance. Social context predicting 61% of anxiety and 35% of performance expectancy, for self-efficacy, no variance was left unexplained in this model. This advocates social and instrumental support having a strong role in the development of other attitudes and may help to support teachers in using mobile devices for teaching. Furthermore, this follows previous studies showing that school-level support and infrastructure had a stronger relationship with teachers' attitudes than with usage behaviour (Petko et al., 2018).

On the other hand, for students, social support directly predicted BI; however, its role in explaining the variance for BI seems rather modest. The correlation of social influence with other variables seems to be small (self-efficacy and performance enjoyment) or insignificant (anxiety). A meta-analysis by Al-Emran and colleagues (2018) has shown that studies at the primary school level have not been prevalent in this field; furthermore, several studies using the TAM as basis have taken into consideration social aspects as well; however, studies at the primary level that would do so are lacking. For high school students, Nikou and Economides (2017) found that social influence and facilitating conditions predicted, modestly but positively, performance expectancy and perceived ease of use, respectively. However, in the latter study, the direct relationship between social aspects and BI was not investigated. Results from a larger-scale study by Wang, Wu and Wang (2009) suggest, however, that the relationship between social aspects and BI might not be statistically significant in the younger population when it comes to predicting willingness towards mLearning. Even though previous authors focused on the adult sample, this proposes that social influence may play a smaller role in predicting mobile device use for students at the younger levels. Therefore, social aspects perceived on an individual level seems to be a relevant factor for teachers in predicting BI; however, at the student level, social aspects might have a modest relationship with BI as well as with other attitude factors.

5.1.3. Perceived control

For students, self-efficacy was shown to predict more than half (61.4%) of the variance for performance enjoyment – students who believed that they are able to use mobile devices for learning were more likely to perceive the use of the devices as purposeful and enjoyable in the educational context. Similar tendencies have been found in the teacher sample, as Sherer and colleagues (2015) showed that teachers who had higher self-efficacy in using technology for teaching also reported technology to be more useful in that context. Furthermore, this supports the choices made in the development of the UTAUT, where the authors hypothesised that self-efficacy for one will not have a direct effect on BI (Venkatesh et al., 2003); however, our results show that self-efficacy might still be a valuable addition to the model, helping to understand the development of other relevant attitudes for students. For teachers, self-efficacy along with performance expectancy and anxiety predicted 52% of the variance in teachers' willingness to use mobile devices in teaching. This is comparable to and, in some cases, even slightly higher than, the predicting power of the TAM (40% to 52%, Davis et al., 1989; Venkatesh & Bala, 2008) and the UTAUT (40% to 74%, Teo & Noyes, 2014; Venkatesh et al., 2003). Based on regression coefficients, we could see that the level contribution for each factor was relatively similar. For both samples, we found significant negative correlation between self-efficacy and anxiety, which is expected and correlates with previous studies where researchers have also found negative correlations between these constructs: from low ($r = –.16$ for science teachers by Efe et al., 2016) and moderate ($r = –.35$ for a general sample by Venkatesh et al., 2003) to high ($r = –.52$ for teachers and students by Simsek, 2011). Therefore, we can say that students and teachers who have higher beliefs in their ability to use mobile devices for educational purposes feel less anxiety towards this activity. In between self-efficacy playing an important role in predicting other attitudes and BI and having correlations with other relevant attitudes, it is reasonable to say that self-efficacy has a central role in mobile device use for educational purposes for both students and teachers. These results advocate the inclusion of self-efficacy as a central set of factors to be considered when aiming to understand the mobile device use of teachers or students, encouraging them to consider adding self-efficacy to the list of attitude factors. This supports the trends observed by Al-Emran and colleagues (2018), showing in a meta-analysis that over 50% of studies using the TAM to understand mLearning used external factors to expand the model and increase the model's explanatory power, in addition to expansions of the TAM suggesting the importance of the inclusion of self-efficacy (e.g. Sánchez-Prieto et al., 2019).

5.2. Predicting BI and mobile device use for students and teachers

Both teacher and student sample results showed that models where attitude factors are allowed to predict mobile device use directly predict a higher percentage of variability in usage behaviour and are preferable based on model fit indices. In the teacher sample, a mediated model explained 35% and a direct model explained 46% of the variance of usage behaviour. In the student sample, with a model that used BI as a mediating variable, only 2% of the variance for the use in school and 2% of the use of mobile devices for learning at home was explained. In the direct model, attitudes predicted 22% of mobile device use in school and approximately 17% of use at home for learning purposes. These results expand on previous findings (Šumak & Šorgo, 2016) by showing that allowing all of the attitude factors to have direct relationships with usage behaviour can help predict the variance of usage behaviour more accurately. Further, these results help shed some light on the possible reasons for the low predictive values of BI on behaviour in the second order meta-analysis by Sheeran (2002), suggesting that allowing the direct link between attitude factors and usage might raise the model's predictive value. This has been suggested previously by Šumak and Šorgo (2016) in studies focusing on teachers; however, current research shows that this applies to student samples as well.

We could see two attitude factors emerging as having a higher impact; these, however, differed for teachers and students. First, as with previous studies on teacher samples that emphasised the importance of self-efficacy in predicting technology use in education (Sánchez-Prieto et al., 2016; Scherer et al., 2015), this study found self-efficacy to be one of the strongest predictors of mobile device use in teachers. Among students, we could clearly see the self-efficacy role as well; however, as described previously, self-efficacy highly predicted performance enjoyment, which in turn was one of the highest predictors, alongside anxiety, for both mobile device use at home as well as in school.

Second, while for teachers, social influence showed a high supportive role in mobile device use, for students, this factor had very low predictive power. It is noteworthy that support from colleagues may not have a significant effect on willingness to use mobile devices but directly predicts teachers' behaviour. This supports previous studies among teachers, which show that teacher collaboration in using technology in education is one of the highest predictors of actual use of technology (Gil-Flores et al., 2017). Furthermore, these results may help explain the outcomes of previous studies, e.g. where Kreijns and colleagues (2013) showed that when compared to other attitudinal factors, social norms made a modest contribution to predicting BI. Based on results from the current thesis, this might be due to the fact that social support is more strongly related to behaviour and less to willingness/BI.

Somewhat surprisingly, facilitating conditions did not predict either BI or usage behaviour in the teacher sample. Similarly to previous studies (Šumak & Šorgo, 2016), in the model with BI mediating attitudes and usage behaviour, facilitating conditions did help to predict variability in usage behaviour. However, when taking into consideration the potential predictive power of other attitude factors, facilitating conditions did not add anything. We can conclude that while access to technology is an obvious prerequisite to using technology in teaching, the amount of infrastructure does not seem to add to the frequency of classroom use.

Present studies showed that for both students and teachers, taking into consideration the direct relationship between attitude and behavioural intention, the percentage of variability explained in mobile device usage will rise. It is noteworthy that for teachers, this percentage is higher. This might be because of teachers' higher autonomy, therefore their own attitudes towards mobile devices and willingness to use them may become one of the factors that influences the behaviour of students, culminating in the lower variability explained by student attitudes towards mobile devices.

5.3. Teachers' groups based on attitudes and technology use

The results from the large scale cross-sectional study showed us that behavioural intention might not play as relevant a role in predicting behavioural variability in mobile device use for students and teachers as has been previously suggested. The pandemic presented a unique situation where we could study teachers with varying attitudes towards and habits around technology use in a situation where teaching was possible solely through the medium of technological solutions. Based on teachers' descriptions of their experiences of using technology, three groups of teachers were found, which in several aspects resembled groups found in previous studies:

- *High adopters* were characterised by high willingness, low change, and technology use on a transformational level. We can see that this group of teachers resembles the "conscientious participants" in the research by Tsybulsky and Levin (2019), where teachers described seeing more opportunities and less difficulties in using new technology.
- *Medium adopters* were characterised by relatively medium to high willingness, medium change, and technology use on a transformational level, with some exceptions between augmentation and modification. Similarly to a group in the Tsybulsky and Levin (2019) study, teachers reflected a desire to be more able to use technology, however saw difficulties in engaging with the technology for teaching.
- *Hesitant adopters* were characterised by low willingness, low to medium change and technology use on an enhancement level. Named in Tsybulsky and Levin (2019) study group "outside observers", this group reported the lowest level of engagement in technology in teaching, also expressing low levels of interaction, interest, or trust in digital solutions.

These results and differences between the groups of teachers provide three higher level insights into understanding the relationship between willingness, attitude, and behaviour in the context of technology use in education. First, all of the teachers used technology and mobile devices for teaching daily; however, willingness varied across participants, as illustrated in the short descriptions seen previously (see also Figure 10). Therefore, focusing solely on the frequency of mobile device use and willingness would likely result in a lack of observed relationship between these variables. However, looking at the descriptions of teachers' technology use and willingness, we can see a trend emerging where teachers with higher willingness report using technology on a transformational level, whereas teachers with relatively lower willingness on an enhancement level. These nuances might get lost in survey-based research, which has shown to be prevalent in the field of predicting mobile device use (Chee et al., 2017). These results echo the results from Tao and colleagues (2017), showing that models predicting behavioural intention to use technology on a traditional and innovative level differ; moreover, while perceived ease of use predicted BI on a traditional level, it did not for the innovative level. Authors also showed that previous experience seemed to be a significant positive predictor for BI in the case of innovative technology use, however not in the model predicting BI on a traditional level. On the other hand, these results somewhat contradict the results by Karaseva and colleagues (2013), who concluded in their research that science teachers' technology use was more teacher-centric and less versatile then for humanities teachers. Our results showed a high variety of use cases among STEM teachers, which could be seen across the continuum used by Karaseva and colleagues (2013). In summary, these results emphasise the need for variability in data collection methods in order to understand the interaction between willingness and mobile device use more thoroughly, beyond the frequency of behaviour.

Second, willingness and its relationship to other attitudes might be more multifaceted than previously suggested by Ajzen: "(BI) can be operationalised by asking whether ... they are willing to engage in the behaviour" (Ajzen, 2011, pp 1122). This is most seen in the descriptions of teachers among the *Hesitant Adopters*, who reflected teachers' beliefs as one possible obstacle to technology use. Here, teachers reflected hesitance in respect of the added value from the use of technology in teaching or viewing non-digital solutions as preferable, while also bringing out that they have thought about or have been open to technology use in teaching. In these cases, teachers might agree that they are willing to use technology; however, this might not be realised in their behaviour, as attitude based obstacles directly affect potential behaviour, not only through willingness. As mentioned, one of these obstacles might be the question of usefulness, which is related to the study by Karaseva and colleagues (2018) showing that the usefulness of technology may mean different things for teachers depending on their goal orientation. Therefore, for teachers whose goal is to "do real things in the classroom", technology might not seem a viable tool for teaching.

Third, we observed how all of the teachers reported having obstacles to the process of teaching while using technology. However, the types of obstacles reported and the potential to overcome these varied between groups. As in the example of *High Adopters*, more resources to overcome these obstacles were reported and therefore not limiting on the adoption of technology in teaching. These results echo the findings in the field of self-efficacy, showing that people's beliefs in their ability to successfully act can contribute greatly to the realisation of a certain behaviour, which was also proposed by Ajzen (2011) in the context of the TPB and as an addition to the TAM in later studies (Sánchez-Prieto et al., 2017), showing that including self-efficacy in the model helps increase predictive power. Scherer and colleagues (2015) showed that teachers with higher self-efficacy tend to report less obstacles to technology use in teaching and vice versa. Furthermore, this aligns with the results from the large-scale studies presented in this thesis in both teacher and student samples, showing the significant role of self-efficacy in the prediction of mobile device use for educational purposes. Results from the qualitative study add to this, showing that high self-efficacy does not necessarily reflect the absence of obstacles, but the potential to solve them.

5.4. Limitations and further research

First, the studies presented in this thesis focused on predicting teachers' current willingness and mobile device use in order to see which attitudes help us better understand these aspects in cross-section. Even though this approach has shown to be common in technology acceptance research (Al-Emran et al., 2015), future studies could test the present models on longitudinal data to confirm whether attitudes predict future behaviour to the same extent.

Second, due to ethical reasons, teachers' age or gender was not asked; therefore, these variables were not included in the models. Based on the TALIS survey, the average age of Estonian teachers is 49, which is the third-highest average age of teachers across participating countries (following Georgia and Lithuania; OECD, 2019). Thus, the majority of teachers in Estonia graduated from university at a time when technology use in the classroom was not yet common, as technology was not yet widely available. Along similar lines, Scherer and colleagues (2015) found that age was positively correlated with reporting obstacles to the use of technology in teaching. Therefore, teachers' age might be an insightful variable to consider in predicting mobile device use in education, and future studies could take this into consideration and test the model fit on different age and experience groups.

Third, as indicated, information on teachers' and students' behaviour was gathered through self-report questionnaires, which, despite being a widely used method (e.g. for students Al-Emran, 2018), may introduce bias due to social desirability. However, based on the distribution of teachers' reported mobile device use (on average less than once a month), we could see that teachers self-reported use was in coherence with the expected use rate. However, as the 5-point scale proposed a rather limited range of answers, for the teachers, the step on the scale from 'once or twice in a month' (for 3) to 'almost every class' (for 4) might have posed a challenge in answering. Even though this aspect was not raised by the teachers in the pilot group for this questionnaire, this might have limited the variability in the data by guiding teachers to choose between pre-proposed options. The qualitative approach provided the opportunity to gather richer descriptions of teachers' behaviour, therefore expanding the available data from 'how often' to 'in which ways'. Nonetheless, future studies may test the model fit for data, which includes observational data for frequency and levels/examples of teachers' mobile device use in the classroom.

Further research could aim to test the models proposed in this research in comparison with different subject teachers and students in a variable subject context. Even though we can see how these results build upon studies done in various subject contexts, these results do represent the STEM context, which might translate and expand mobile device use research in education generally; however, this assumption should be tested by future research.

5.5. Conclusions

The overarching aim of this thesis was to better understand how attitudes and behavioural intentions interact in predicting teachers' and students' mobile device use for educational purposes in a STEM context. The following summary of the main conclusions follows the three stages in which this aim was reached.

First, investigating attitude structures and the relationships between these for students and teachers in a STEM context. For both samples, performance expectancy, effort expectancy and general attitude/enjoyment seem to be highly related concepts. This is more clearly seen in the teacher sample, where these factors showed separate satisfactory reliability; however, correlations between these were over .80. In the student sample, performance expectancy and enjoyment results are a bit clearer, showing that these factors might be seen as one construct. When it comes to relationships between attitude factors under social aspects, somewhat different trends emerge for students and teachers. Interestingly, social influence and facilitating conditions did not directly predict BI for teachers, but through the mediation of other attitudes. Taken together, social influence and facilitating conditions predicted, however, 61% of variance for anxiety and 35% for performance expectancy. For self-efficacy, no variance was left unexplained in this model. This advocates social and instrumental support having a strong role in the development of other attitudes and may help to support teachers in using mobile devices in teaching. On the other hand, for students' social support directly predicted BI; however, its role in explaining the variance for BI seems rather modest. Therefore, social aspects seem to be a relevant factor for teachers in predicting attitude towards mobile devices in teaching; however, on a student level, social aspects might have a modest relationship with BI as well as with other attitude factors. Furthermore, the results from this thesis advocate the inclusion of self-efficacy as an essential attitude factor when aiming to understand the mobile device use of teachers and students, encouraging researchers to consider adding self-efficacy to the list of attitude factors measured. For teachers, self-efficacy along with performance expectancy and anxiety predicted 52% of the variance in teachers' willingness to use mobile devices in teaching. For students, self-efficacy was shown to predict more than half (61.4%) of the variance for performance enjoyment – students who believe that they are able to use mobile devices for learning were more likely to perceive the use of the devices as purposeful and enjoyable in the educational context.

Second, the relationship between behavioural intention, reported mobile device use and their interactions with the prevalent attitudes for students and teachers. The results showed, for both the teacher and the student sample, that models where attitude factors are allowed to predict mobile device use directly predicted a higher percentage of variability in usage behaviour and were preferable based on model fit indices. In the teacher sample, the mediated model and direct model explained 35% and 46% of the variance for usage behaviour, respectively. In the student sample, the model that used BI as a mediating variable predicted only 2% of the variance for the use in school and 2% of the use of mobile devices for learning at home. In the direct model, attitudes predicted 22% of mobile device use in school and approximately 17% of use at home for learning purposes. Furthermore, for students, BI seemed to lose its predictive power when the direct relationship between attitude and mobile device use was introduced.

Third, exploring which groups of teachers can be distinguished based on attitude towards technology and usage behaviour and what we can learn about technology use from their descriptions of technology use during distant learning at the beginning of the COVID-19 pandemic. The pandemic presented a unique situation where we were able to study teachers with varying attitudes towards and habits around technology use in a situation where teaching was possible solely through the medium of technological solutions. Based on teachers' descriptions of their experiences with technology use, three groups of teachers were found:

- *High adopters* were characterised by high willingness, low change and technology use on a transformational level (in which technology use enables one to redefine learning activities up to the point where technology is necessary, as the activity would not be possible in any other way).
- *Medium adopters* were characterised by relatively medium to high willingness, medium change and technology use on a transformational level, in some exceptions between augmentation (the use of technology adds some minimal function) and modification (the use of technology enables significant task redesign).
- *Hesitant adopters* were characterised by low willingness, low to medium change and technology use on an enhancement level (focus on substituting usual tasks with similar ones using technology or adding some minimal function).

Looking into the descriptions of all three groups of teachers, three higher level learnings can be highlighted.

1. While all of the teachers used technology and mobile devices for teaching daily, willingness varied among participants. Looking into the descriptions of teachers' technology use and willingness, we see a trend emerging where teachers with higher willingness report using technology on a transformational level, whereas teachers with relatively lower willingness on an enhancement level.
2. In the group of *Hesitant adopters*, teachers reflected hesitance in the added value from the use of technology for teaching or viewing non-digital solutions as preferable, while also bringing out that they have thought about or have been open to technology use in teaching. In these cases, teachers might agree that they are willing to use technology; however, this might not be realised in the behaviour, as attitude-based obstacles directly affect the potential behaviour, not only through willingness. Therefore, for teachers whose goal is to "do real things in the classroom", technology might not seem a viable tool for teaching.

3. *High Adopters* reported more resources to overcome potential obstacles and therefore did not perceive obstacles to inhibit the adoption of technology in teaching. These results echo the findings in the field of self-efficacy, showing that people's beliefs in their ability to successfully act can contribute greatly to the realisation of a certain behaviour. Furthermore, this aligns with the results of the large-scale studies presented in this thesis in both teacher and student samples, showing the significant role of self-efficacy in the prediction of mobile device use for educational purposes. The results of the qualitative study add to this, showing that high self-efficacy does not necessarily reflect the absence of obstacles, but the potential to solve them.

5.6. Implications

This doctoral thesis has several scientific and practical implications regarding research in the area of predicting and understanding mobile device use by teachers and students in the educational context, more specifically in STEM education.

5.6.1. Scientific implications

1. The results from the current research show that the widely relied on mediating role of BI between attitude and behaviour might behave as a bottleneck in predicting mobile device use for educational purposes. For both the teacher and the student sample, the results showed that models where attitude factors are allowed to predict mobile device use directly as well as indirectly predict a higher percentage of variability in usage behaviour as well as are preferable based on model fit.
2. The results showed that self-efficacy plays an important role in predicting other central attitudes, BI and the existence of correlations with other relevant attitudes. It is reasonable to say that self-efficacy has a central role in mobile device use for educational purposes for both students and teachers.
3. The current results add to the field of predicting mobile device use for teaching and learning in a STEM context by illustrating that teachers describe technology use in teaching from substituting usual learning tasks to transforming the learning in ways that are not possible without technology. This highlights the importance of looking beyond the frequency of the behaviour, which might help gain new insights into the complex relationship between BI, attitude and usage behaviour itself.

5.6.2. Practical implications

1. When aiming to support mobile device implementation among STEM teachers, it would be more useful to focus on enhancing support from colleagues and trust in one's abilities rather than emphasise structural support for using mobile devices. Using this information, interventions and professional development courses should be developed that focus on supporting teachers' self-efficacy and social support for mobile device use. The aim should be to develop a system that, in addition to endorsing teachers' willingness to use technology, supports the actualisation of said intent into behaviour.
2. For supporting students' mobile device use for learning, the key seems to be in enjoyment and self-efficacy. First of all, students' enjoyment evaluations were so highly related to the usefulness evaluations of mobile device use that we could not take them as separate attitude factors. This implies that in order for students to perceive mobile devices as useful for learning, it must include positive emotions and experiences. Taking a step back, the result showed that students' belief in their own ability to use mobile devices predicted how prone students were to see them as enjoyable and useful. Therefore, it would be beneficial for educators and educational technology innovators to address the questions of how enjoyable it is to use technological solutions for learning and how much confidence-building students might need before believing in their ability to use them for learning.
3. Based on this study, we can argue that for teachers, it is not enough to create useful, easy-to-use and enjoyable technological solutions, we must also work with teachers to support their self-efficacy and relieve the anxiety that comes with using technological tools in education. For this, social context may be crucial.
4. This thesis proposed an answer to the question of which attitudes predict mobile device use in education for teachers and students. We could see how we were able to predict higher levels of mobile device use variability for the teacher sample, which might be connected to the higher levels of autonomy for teachers when it comes to choosing the means of learning in and, as a proxy, outside the classroom, therefore culminating in the difference in how much variability in behaviour is predicted by individuals' attitude towards said behaviour. This suggests that the key to increasing students' mobile device use for educational purposes, might be in supporting teachers' attitudes and thereby their mobile device use in teaching, through which students will have positive models for mobile device use in learning. This in turn might raise students' mobile device use in learning both in and outside school, as our results showed a strong correlation between mobile device use in and outside school for students.

SUMMARY IN ESTONIAN

Käitumiskavatsuse ja hoiakute roll õpetaja ja õpilase raporteeritud nutiseadmekasutuse prognoosimisel STEM-hariduses

Digipädevuste arendamine on muutunud üheks prioriteetseks õpieesmärgiks olukorras, kus tehnoloogia täidab meie elus üha tähtsamat osa. Uuringud on näidanud, et tehnoloogia kasutamine hariduses võimaldab toetada nii õpilaste õppeedukust (nt Sung *et al.*, 2016), motivatsiooni (nt Connolly *et al.*, 2012), uute oskuste omandamist (*inquiry skills*, nt Pedaste *et al.*, 2012) kui ka nüüdisaegsete õpikäsituste rakendamist, sh koostöö- ja eneseregulatsioonioskusi (Pedaste & Leijen, 2018; Sung *et al.*, 2016). Siiski võib märgata, et tehnoloogia kasutamine hariduslikel eesmärkidel on jäänud madalale või mõõdukale tasemele (nt Pedaste *et al.*, 2017), kusjuures on näidatud, et vaid umbes 60% õpilastest kasutab arvutit kodutööde tegemiseks, samas kui 90% õpilastest kasutab seda muusika kuulamiseks või internetis surfamiseks (Bagon, Gačnik, & Starcic, 2018). Seega ei ole tehnoloogia olemasolu piisav eeldus selleks, et tagada tehnoloogia kasutamine hariduslikel eesmärkidel.

Varasemad uuringud on näidanud, et hoiakutel on põhiroll selles, kas tehnoloogiat kasutatakse või mitte (Gil-Flores, Rodríguez-Santero, & Torres-Gordillo, 2017; Venkatesh, Morris, Davis, & Davis, 2003). Alates Ajzenist (1985) ja planeeritud käitumise teooriast (TPB) on uurijad toetunud põhimõttele, et hoiakud prognoosivad käitumiskavatsust ning seeläbi ka käitumist. Tehnoloogia aktsepteerimise mudeli (TAM) alusel on rõhku pandud eelkõige tajutud kasulikkuse ja kasutuskeerukuse hinnangute prognoosimisvõimele, mis vastavalt peegeldavad inimese usku, et tehnoloogia kasutus toetab tema tulemuslikkust (Davis *et al.*, 1989, lk 985) ning tehnoloogia kasutusega seotud subjektiivset hinnangut kasutuse lihtsusele (Davis *et al.*, 1989, lk 985). Hilisematest uuringutest on ilmnenud, et TAMi laiendamine võib aidata suurendada prognoosimisvõimet. Näiteks on välja pakutud, et nutiseadmetega õppimise kontekstis võiks lisada mudelisse enesetõhususe (inimese usk enda võimekusse käitumist edukalt juhtida; Bandura, 1997, Sánchez-Prieto *et al.*, 2019) ning ärevuse (negatiivsete emotsioonide kogemise määr tehnoloogia kasutamise kontekstis; Compeau & Higgins, 1995). Mainitud hoiakuid on hinnatud ka TBP raames, kuid mõnevõrra üllatavalt on TAMi kontekstis vaadeldud hoiakute rolli vaid tajutud kasulikkuse ja kasutuskeerukuse hinnangute prognoosimisel (Sánchez-Prieto *et al.*, 2019). Lähtudes ühendatud tehnoloogia aktsepteerimise ja kasutamise teooriast (UTAUT), on Venkatesh ja tema kolleegid testinud erinevate hoiakute prognoosimisvõimet, arvestades viimases mudelis vaid hoiakuid, millel oli otsemõju käitumiskavatsuse prognoosimisele. Erandi moodustas instrumentaalne toetus, mille puhul oodati otsest seost tehnoloogia kasutusega. Peale kasutuskeerukuse ja tajutud kasulikkuse hinnangute on käsitletud ka planeeritud käitumise teooriast tuttava sotsiaalse mõju seost käitumiskavatsusega. Sotsiaalset mõju on defineeritud kui inimese hinnangut sellele, kuivõrd oluliseks peavad ümbritsevad inimesed tehnoloogia kasutamist. (Venkatesh *et al.*, 2003)

Hilisematest uuringutest on selgunud, et käitumise prognoosimine läbi käitumiskavatsuse ei pruugi olla põhjendatud. Šumak ja Šorgo (2016) on näidanud, et käitumiskavatsuse ja käitumise vaheline seos muutub statistiliselt ebaoluliseks, kui lubada hoiakutel otse prognoosida käitumist ennast. Sarnaselt on Scherer koos kolleegidega (2020) välja toonud, et kõiki eraldiseisvaid hoiakulisi tegureid iseloomustab kõrgema taseme faktor ning see prognoosib tehnoloogia kasutamist, kuid mitte käitumiskavatsuse variatiivsust.

Toetudes eespool välja toodud uuringutele, vaadeldakse doktoritöös tehnoloogia ja täpsemalt nutiseadmete kasutamisega seotud hoiakuid kolme laiema kategooria all: üldised hoiakud (hoiak nutiseadmete suhtes, kasutuskeerukuse ja tajutud kasulikkuse hinnangud), sotsiaalsed panustajad (sotsiaalne mõju ja infrastruktuurne toetus) ning tajutud kontroll (enesetõhusus).

Nutiseadmete kasutuse hindamisel on laialdaselt levinud kvantitatiivne uurimisviis (47,9%, Chee *et al.*, 2017). Enamasti kasutatakse küsimustikke, et saada ülevaade käitumise sagedusest (nt Al-Emran, Mezhuyev, & Kamaludin, 2018). See on kulutõhus andmete kogumise viis, kuid jätab sagedasti vastamata küsimusele, kuidas tehnoloogiat kasutatakse. Uurijad on pakkunud välja lähenemisviise, kuidas hinnata tehnoloogia kasutuse variatiivsust. Näiteks tuginedes Puentedura (2006) loodud SAMRile (asendamine, augmentatsioon, kohandamine, redefineerimine), koostasid Crompton ja Burke (2020) süstemaatilise ülevaateuuringu, milles laiendasid mudelit ning tõid iga taseme juurde näiteid.

- Täiustamise tasemed
  - Asendamine: tavategevus asendatakse sama tegevusega tehnoloogia vahendusel, nt õpiku lugemine e-lugerist
  - Augmentatsioon või laiendamine: tehnoloogia abil lisatakse esialgsele tegevusele minimaalne funktsionaalsus, nt video lisamine ettekandele, et illustreerida teemat

- Ümberkujundavad tasemed
  - Kohandamine: ülesannet muudetakse tehnoloogia abil märkimisväärselt, nt tähtkujude vaatlemine virtuaalreaalsuses
  - Redefineerimine: tehnoloogia abil luuakse uus ülesanne, mis ei oleks tehnoloogiata võimalik, nt õpilased salvestavad eksperimendi tulemused ning muudavad salvestist, et illustreerida õpiprotsessi.

Kokkuvõtvalt võib öelda, et kuigi hoiakute rolli nutiseadmete kasutamise prognoosimisel on laialdaselt uuritud ning selle tähtsus on leidnud kinnitust, jääb siiski küsimus, millised hoiakud ja mil määral aitavad prognoosida käitumist ning mis osa täidavad käitumiskavatsused selle seose vahendamisel. Lisaks on oluline arvestada, et seoste uurimiseks on kasutatud sageli küsimustikel põhinevaid uuringuid, mis ei pruugi võimaldada hinnata nutiseadme kasutust laiemalt kui sageduse põhjal.

Toetudes eelnevale, on doktoritöö eesmärk mõista hoiakute ja käitumiskavatsuse seost õpetajate ja õpilaste nutiseadmekasutuse prognoosimisel STEM-hariduse kontekstis. Eesmärgist lähtudes on sõnastatud neli uurimisküsimust.

1. Milliseid nutiseadmete kasutamisega seotud hoiakute faktoreid on võimalik õpilaste ja õpetajate valimi põhjal eristada?
2. Millised seosed ilmnevad õpilaste ja õpetajate valimi põhjal hoiakute vahel?
3. Millised hoiakud prognoosivad õpilaste ja õpetajate käitumiskavatsust ja kasutuskäitumist?
4. Milliseid õpetajate rühmi on võimalik eristada, toetudes nende hoiakutele nutiseadmete kasutuse suhtes, tajutud takistustele ning harjumustele kasutada nutiseadmeid õppetöös?

Andmeid koguti projekti „Nutikad tehnoloogiad ja digitaalne kirjaoskus õppimiskäsituse muutmisel“ raames kahes osas. Esimeses uuringus (märts–mai 2016) osales 3521 õpilast ning 377 STEM-ainete õpetajat. Osalenud õpilastest 2673 õppisid 6. ja 848 õpilast 9. klassis. Keskmine vanus 6. klassi õpilastel oli 12,7 aastat (*SD* = 0,63) ja 9. klassi õpilastel 15,6 aastat (*SD* = 0,54). Õpilaste hoiakuid hinnati küsimustikuga, mis koosnes 20 väitest ning tugines Prueti ja tema kolleegide (2016) tööle. Õpilastel paluti hinnata, kuivõrd nad kasutavad nutiseadmeid koolis ja kodus õppe eesmärgil infootsinguks, kommunikatsiooniks, sisuloomeks ning mängimiseks. Õpetajate hoiakuid nutiseadmete suhtes õpetamise kontekstis uuriti küsimustikuga, mis koosnes 32 väitest (kohandatud Papanastasiou & Angeli, 2008 järgi). Nutiseadmete kasutamise sageduse hindamiseks paluti õpetajatel vastata küsimusele „Kui sageli kasutad nutiseadmeid õpetamisel?“. Teises uuringus (aprill–mai 2020, COVID-19 eriolukorra ajal) viidi 13 STEM-aine õpetajaga läbi poolstruktureeritud intervjuu, mis koosnes 10 põhiküsimusest, millega uuriti õpetajate kogemusi tehnoloogiaga eriolukorra ajal toimunud õppetöös. Kogutud andmete analüüsimiseks kasutati kinnitavat faktoranalüüsi ja strukturaalvõrrandite mudeleid (vastamine 1.–3. uurimisküsimusele) ning induktiivset ja deduktiivset sisuanalüüsi (vastamine 4. uurimisküsimusele).

Vastusena esimesele kahele uurimisküsimusele ilmnes, et nii õpetajate kui ka õpilaste valimi korral ei pruugi kasulikkuse, tajutud kasutuskeerukuse ning üldine hoiak nutiseadmete kasutamise suhtes selgelt eristuda. Sellele on osutatud ka varasemates uuringutes, kus on leitud tugevaid korrelatsioone mitme hoiakufaktori vahel (nt Scherer *et al.*, 2015). Käesoleva doktoritöö tulemus on aga mõnevõrra vastuoluline TAMi ja UTAUTi kontekstis, kus eeldatakse, et nii hinnang tehnoloogia kasulikkusele kui ka kasutuse lihtsusele aitavad prognoosida käitumiskavatsust (Venkatesh & Bala, 2008). Doktoritöö tulemused viitavad, et nii õpilaste kui ka õpetajate valimi korral ei pruugi hinnangud kasulikkusele ning kasutuskeerukusele selgelt eristuda, kuid sarnaselt varasemate uuringutega prognoosib kasulikkuse hinnang nii õpilaste kui ka õpetajate käitumiskavatsust.

Eeltoodule lisaks on tähelepanuväärne sotsiaalse toetuse roll käitumiskavatsuse ennustamisel. Õpetajatel prognoosis sotsiaalne toetus käitumiskavatsust teiste hoiakute (enesetõhususe, ärevuse ja kasulikkuse hinnangute) kaudu. See toetab Petko ja tema kolleegide (2018) tulemusi, mille kohaselt on sotsiaalne ja infrastruktuurne toetus tugevamalt seotud õpetajate hoiakutega tehnoloogia suhtes kui tehnoloogia kasutussagedusega. Õpilastel prognoosis sotsiaalne mõju otse käitumiskavatsust, kuid seos oli pigem nõrk. Wang jt (2009) on näidanud, et sotsiaalse mõju seos mobiilsete tehnoloogiatega õppimise kontekstis tundub olevat nõrgem noorematel. Kokkuvõttes paistab sotsiaalne toetus olevat mõjukam õpetajate valimi korral, kus see võib mängida rolli teiste hoiakute kujundajana.

Nii õpetajate kui ka õpilaste käitumiskavatsust prognoosib ka enesetõhusus, mistõttu on vaja hinnata enesetõhusust nutiseadmete kasutuse prognoosimisel. Sellele vajadusele on viidanud mitmed uuringud, kus on nähtud vajadust TAMi ja UTAUTi raames arvestada ka enesetõhususe hinnanguid (nt Sánchez-Prieto *et al.*, 2019).

Vastusena kolmandale uurimisküsimusele selgus, et nii õpetajate kui ka õpilaste puhul on eelistatud/soovituslik arvestada hoiakute otsest seost käitumisega – vastupidiselt TPB, TAMi ja UTAUTi mudelis soovitatud vahendatud seosele. Õpetajate valimi korral prognoosis mudel, kus käitumiskavatsus vahendas hoiakute ja käitumise seost, 35% nutiseadmete kasutuse variatiivsusest, samas kui otseseid seoseid lubav mudel prognoosis 46% käitumise variatiivsusest. Õpilaste valimil prognoosis vahendav mudel 2% ning otseseid seoseid lubav mudel 22% (nutiseadme kasutus koolis) ja 17% (nutiseadme kasutus kodus õppe eesmärgil) variatiivsusest. Eelnev toetab nii Šumaki ja Šorgo (2016) kui Sheerani (2002) välja toodut, mille kohaselt on õpetajate hoiakud tehnoloogia suhtes seotud käitumise variatiivsusega otse, mitte vaid käitumiskavatsuse vahendava mõju kaudu. Töö tulemused näitavad, et sama tendents esineb ka õpilaste valimi korral.

COVID-19-ga seotud eriolukorra ajal läbi viidud intervjuud võimaldasid mõista õpetajate kogemusi nutiseadmete kasutamisel, nende hoiakuid ning valmisolekut kasutada nutiseadmeid olukorras, kus õppetöö toimub distantsilt ning suures osas tehnoloogiliste lahenduste vahendusel. Vastusena neljandale uurimisküsimusele eristus kolm õpetajate rühma: 1) aktiivsed kasutajad (suur valmisolek, väike muutus kasutuses, tehnoloogia kasutamine ümberkujundaval tasemel), 2) keskmised kasutajad (keskmine-suur valmisolek, keskmine muutus kasutuses, tehnoloogia kasutamine ümberkujundaval tasemel) ja 3) kõhklevad kasutajad (väike-keskmine valmisolek, väike-keskmine muutus kasutuses, tehnoloogia kasutamine täiustamise tasemel). Esile kerkis tendents, kus suurema valmisolekuga (käitumiskavatsusega) õpetajad kirjeldasid tehnoloogia kasutust pigem ümberkujundaval tasemel. See teadmine ei tuleks aga esile, kui keskenduda vaid sageduse hinnangutele, nagu seda on sageli tehtud (Chee *et al.*, 2017). Õpetajate kirjeldused aitasid mõista hoiakute, käitumiskavatsuse ja käitumise seoseid. Kõhklevate kasutajate kirjeldused näitasid, et õpetaja hoiakud, täpsemalt kõhklused tehnoloogia kasulikkuse suhtes, võivad mõjutada otsesemalt tehnoloogia kasutust. Seega, õpetajad, kelle eesmärk on teha tunnis n-ö elulisi asju, ei pruugi tajuda tehnoloogiat kui asjakohast tööriista õpetamiseks. Samuti tuli õpetajate intervjuudest esile enesetõhususe keskne roll. Selline uurimistulemus toetab varasemate uurimuste omi, kus enesetõhusus on olnud mudelite oluline laiendus (Sánchez-Prieto *et al.*, 2017). Praegune uuring viitabki, et suur enesetõhusus ei pruugi peegeldada tehnoloogia kasutusega seotud takistuste puudumist, vaid pigem usku nendega toime tulla.

Doktoritöö tulemuste põhjal saab anda soovitusi nii edasiseks uurimistööks nutiseadmete kasutamise prognoosimisel hariduse kontekstis kui ka praktikutele ja koolijuhtidele, kes soovivad mõista ja/või toetada õpetajate ja õpilaste nutiseadmekasutust hariduslikel eesmärkidel. Nutiseadmekasutuse uurimisel on soovitatav arvestada hoiakute võimalikku otsest seost kasutuskäitumisega ning võimalusel testida nii käitumiskavatsuse poolt vahendatud kui ka muutujatevahelisi seoseid arvestavaid mudeleid. Peale sageduse võib väärtuslik olla ka tehnoloogia kasutuse näidete uurimine, et paremini mõista hoiakute, käitumiskavatsuse ja nutiseadmete kasutuse seoseid. Praktikutel ja koolijuhtidel, kes soovivad toetada õpetajate ja õpilaste nutiseadmekasutust hariduslikel eesmärkidel, on soovituslik silmas pidada, et kasulike, kergesti kasutatavate ja meeldivate lahenduste pakkumisest ei pruugi piisata, vaid oluliseks võib kujuneda õpetajatele sotsiaalse toe pakkumine, samuti selle kaudu nutiseadmetega õpetamise enesetõhususe suurendamine. Eelnev toetab käitumiskavatsuse kõrval ka nutiseadmete kasutust, seega ei jää nutiseadmete hariduslik rakendatavus üksnes kavatsuseks: sotsiaalse toe pakkumise ja enesetõhususe suurendamise kaudu on võimalik toetada ka kavatsuse realiseerumist käitumisena.

APPENDICES

Appendix A. Interview schema for semi-structured interview used in Article IV

A. Descriptive questions:

1. What does it mean to be a teacher in distance learning conditions?
2. What are you doing differently in your teaching compared with the period before the distance learning?
3. What has been the biggest change in preparing lessons, in conducting lessons and in giving feedback to students?

B. Technology use in teaching:

1. What role does technology play in your current lessons? How does this differ from what it was before?
2. What kind of technology do you usually apply to your lessons?
3. What are the main goals of using technology in your lessons during distance learning? Give some examples.
    a. What are the main obstacles to using technology in distance learning conditions?
    b. What is positive about using technology in distance learning conditions?
    c. Does distance learning change your attitude towards technology?
4. What were the main goals of using technology in your lessons before distance learning?

Background

1. Age
2. Years taught
3. Subject(s) taught

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S281 Arvuti õpiprogrammide kasutamise metoodika ja pedagoogika; S260 Psühholoogia

Publikatsioonid

Adov, L., & Mäeots, M. (2021). What Can We Learn about Science Teachers' Technology Use during the COVID-19 Pandemic? *Education Sciences*, *11*(6), 255. doi:10.3390/educsci11060255

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