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Validation of the Self-assessment Model of the Smart Schoolhouse

Marge KUSMIN, Mart LAANPERE

Tallinn University, School of Digital Technologies, Narva mnt. 25, Tallinn, Estonia

margek@tlu.ee, martl@tlu.ee

ORCID 0000-0003-0243-0234, ORCID 0000-0002-9853-9965

Abstract. In today's technology-enriched world, the demand for engineers continues to grow, while students' interest in natural sciences is on the decline. In order to spark students' interest in STEM subjects, we launched a project "Smart Schoolhouse by means of IoT" and involved schools from five different regions in our country, with whom we were testing the idea of Smart Schoolhouse (IoSS). The main idea of IoSS is to automatically collect various data from the Smart Home system, from physical and virtual learning environment and integrate this data with the digital footprints of learners' (on their own devices and online platforms) and use it for two different purposes: non-personalised data for learning processes and personalised data for learning analytics. We developed a Self-Assessment Model of the Smart Schoolhouse (SAMSS) to support schools to map their readiness of innovation before taking real steps to implement the IoSS, e.g. before to rebuild the Smart Home system.

In this article we give an overview of the validation process of a SAMSS with The Nominal Group Technique (NGT) where participated eight experts from different schools, school levels, and with different teaching experience. During validation, there where arised 22 ideas or proposals of change and all of them were discussed. At the section of results there are an overview of the self-assessment model supplemented with the proposed changes made during the validation process.

Keywords: SmartSchoohouse; Nominal Group Technique; Self-assessment model

1. Introduction

The opportunities offered by technology have changed our lives, our communication and behaviour, the demands on our skills and knowledge, they have created a more comfortable living environment or given us exciting challenges. It's extremely rapid development in recent decades, the versatility of the opportunities offered, the wide range of applications, and new requirements for positions and staff skills associated with technology will lead to changes in the workplace, a growing demand on the workforce, and new skills required by and of the employers, and the conditions under which they are acquired.

Changes taking place in society put pressure on schools who have to prepare students for their future life and positions some of which may not even exist yet (Bakhshi et al., 2017), (Z_punkt The Foresight Company, 2014). Although the schools have to be conservative enough to ensure the continuity of education, they are expected to be innovative and teach new knowledge, consolidate skills, and develop attitudes so that the graduates meet the ex-pectations of 21st century society. The OECD Learning Compass 2030 (OECD, 2018) explains eight of the main competencies of life-long learning and (Blikstein, 2018) explains that commercial world has a broad demand for workers to be creative, flexible, more efficient in the new global economy, and more able to understand the manu-facturing and business management workflow of the 21st century.

One of the key fields is STEM (Science, Technology, Engineering, Math) where major changes are taking place and graduates are expected to be much more competent than just a few years ago. Digital transformation of education can be difficult for schools in response to changing trends, so working groups have been set up in various regions to promote digital transformation initiatives and to suggest how schools can set their goals. In recent years, these working groups have highlighted IoT solutions (Bakhshi, et al., 2017), (Laanpere et al., 2020) along with artificial intelligence (Bakhshi et al., 2017), (Reinitz et al., 2022), (Pelletier et al., 2022), and big data (Bakhshi et al., 2017), (Reinitz et al., 2022), (Pelletier et al., 2022), (Laanpere et al., 2020) as important aspects in education. In addition to this overview, the latter underscores what teachers should teach to prepare students for the future needs of the labour market and the opportunities offered by the application of various technologies.

The research (Laanpere et al., 2020) shows that in order to raise interest and a desire for purposeful learning in the students, it is important to involve them in the learning process, where through active learning methods they can explore the environment around them, analyse different situations and data collected from these different situations. An important role is played by the personal connection with both the environments and the collected data, and the effect of all this in the learners, so that the acquisition, consolidation, use, etc. of knowledge takes place in an inclusive and motivating atmosphere for the learners. One such possibility to spark an interest in the learners is the implementation of the IoSS (Kusmin and Laanpere, 2022) in the learning process, to reduce the gap between labour market needs, and the knowledge, skills, and attitudes of graduates.

In this article, at first, we will provide an overview of the IoSS, the purpose of developing the SAMSS, and give an overview and summarise the process and the results of the validation of SAMSS using the NGT. Finally, we will give an overview of the self-assessment model supplemented with the proposed changes made during the validation process.

2. The idea of the Smart Schoolhouse

The IoSS, as it is shown in Figure 1, relies on three aspects: (1) A Smart House system in which, contrary to normal practice (where consumers do not need to know what data is collected and how this data is used to regulate everything), the collected data is available to students in a simple and convenient way so that these data could be used in the learning process, for example for research projects; (2) the second aspect is STEM learning, where these non-personalised data (the data collected from Smart Home system combined with anonymous data collected from the students by IoT devices, e.g. data collected from the learners' digital footprints) are used, and (3) the third aspect is the learning analytics, which allows the aforementioned data and, furthermore, personal data collected about each student to be used in order to anticipate weaknesses in the learning process, or to analyse the results of all or an individual learner.

To test the IoSS a project “Smart Schoolhouse by means of IoT” was launched. During this project (1) the schools were provided with IoT kits, (2) the usage of these IoT kits and data collected with them were tested in the teaching process, (3) suitable teaching materials were created, (4) a training was conducted so that the teachers could figure out different ways to use these IoT kits in teaching, and (5) data was collected to identify both the successes and setbacks of the usage of the IoT kits.

Although the implementation of the IoSS may seem quite simple, in reality, the situation turned out to be much more complicated than initially expected. To support schools in the implementation of the IoSS and to help them avoid unexpected situations that appeared during the testing of this idea in our project, we developed a SAMSS (Kusmin and Laanpere, 2022).

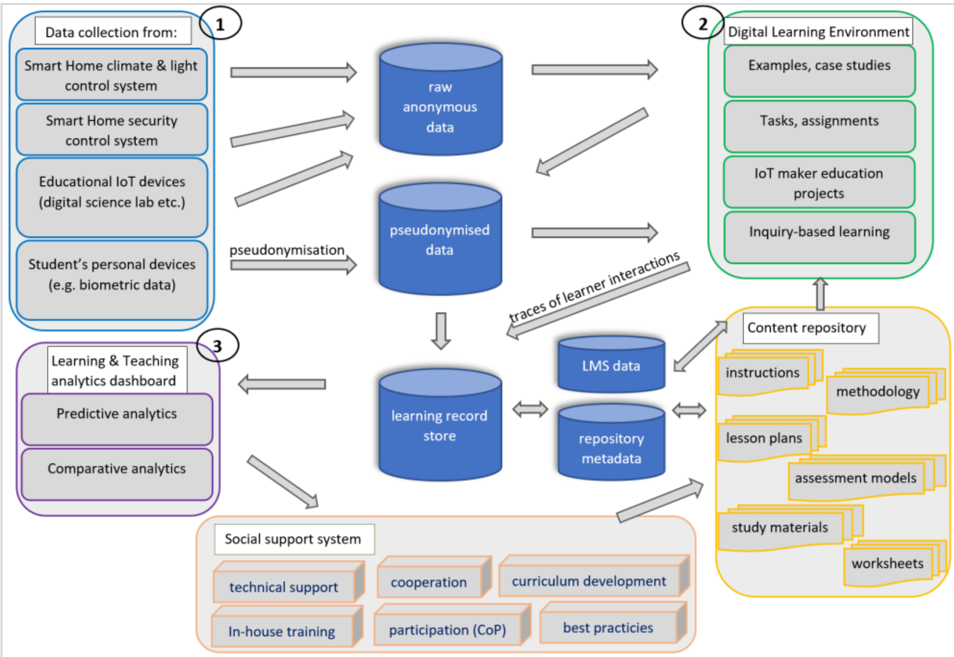

Figure 1. The data collection, handling, and use in a Smart Schoolhouse concept, and systems that support it.

3. A Self-assessment model of the Smart Schoolhouse

An integration of the IoSS requires significant educational innovation and implies a process of planning a change in at least three basic areas: pedagogical, technological, and organisational. So, to develop a SAMSS we used both (1) the list of relevant criteria which was based on the interviews carried out within the expert groups of the schools who participated in the project "Smart Schoolhouse by means of IoT", and (2) the analyses of different frameworks and models, used in the field of education.

After an initial quick overview of the models that support the creation of a framework for the IoSS we chose six models for a more in-depth study: DigiCompOrg and JISC frameworks, and SELFIE, MMEO, Digital Mirror, and TIM models. Additionally

56 models, 18 frameworks, and 4 matrices were examined in more detail with the aim of gaining input in writing down the descriptions of the criteria for the areas of the self-assessment model. Finally, 15 of them were selected to be taken into account when describing the areas and levels of the SAMSS. We took a 5-step development scale as the basis, where in order to reach from first level to second level, two complementary criteria had to be resolved or satisfied: one is that the proportion of the teachers and students involved increases, and the other is a depth of the change, meaning how and why these new things are being done.

The aim of creating a SAMSS for schools was to point out for different stakeholders the steps of how an ordinary school will grow into a Smart Schoolhouse, i.e. what are the steps, metrics, and activities that must be taken into account. There is, obviously, in addition to the technical solution, a need for more instructions and teaching materials. It is necessary to somehow include it all in the curricula, and at the management level it is also necessary to think about how to motivate and involve the teachers, and monitor the whole process, that is, to make informed decisions. This means that SAMSS also provides an opportunity to get an overview of the IoSS in order to set goals for shaping the vision and strategies. Furthermore, it offers schools the opportunity to determine their readiness for new challenges.

The self-assessment helps to find out the stage where a school is located in the SAMSS, in order to avoid situations where resources have been spent to create opportunities for applying the data collected by Smart Schoolhouse in the learning process, or acquired technique or technology, but there is no sufficient preparation and support mechanisms for implementing all this in the learning process, so the acquired technique or technology cannot be used, because there is either a lack of necessary preparation or the prerequisites for its use have not been met.

4. The chosen approach for validation of SAMSS

To increase the reliability of this model we used the Nominal Group Technique (NGT) to validate it. The NGT is a so-called structured group decision-making or consensus group method (Varga-Atkins et al., 2017), used in interviews (MacPhail, 2001) and for brainstorming (Lunenburg, 2011), (Abdullah and Islam, 2011), (Salajegheh et al., 2020), (Clive, 2012) to involve all the group members to elicit rational and creative opinions and to share their ideas, with the final aim of making a group decision. Lunenburg (Lunenburg, 2011) also highlights the following aspects of the advantages of making group decisions: (1) more knowledge and expertise is available to solve the problem, (2) a greater number of alternatives are examined, and (3) there is more commitment among group members to make the final decision work.

Group decision making is a very specific type of process – the exchange of ideas, the transmission of information, and the creation and guidance of experiences, involving personal interaction (Collison and Dunlap, 1978) – where a problem or situation is analysed, and alternatives are considered and evaluated to select a solution (Na and Park, 2018). In teamwork, especially in interviews, only the more eloquent participants are often heard and their ideas remain dominant. To give an opportunity to express their ideas for those group members who are more modest, with a quiet demeanour, too shy to express themselves (Varga-Atkins et al., 2017), or simply easily affected (Na and Park, 2018), the nominal group technique is often used. The aim of NGT is to achieve a group consensus based on the sum of individual viewpoints (Varga-Atkins et al., 2017) as it "is designed to receive input from all group members" (MacPhail, 2001). In using NGT it is possible to avoid the potential dominance of more vocal members over the quieter voices.

The NGT enables one to take into consideration the opinions of everyone in the group so it is possible to generate many ideas in a short time period (Na and Park, 2018). The collection of ideas generated as a result of this type of group work is likely to be more comprehensive than outcomes from less structured group discussions in which all members may not have actively participated (Collison and Dunlap, 1978). The individually generated responses are then clarified, reworded, grouped, and voted on, creating a list of ideas in the order that the participants deemed the most important. MacPhail (MacPhail, 2001) emphasises the ease of use of the NGT "because the researchers have to follow a series of predetermined steps, and these procedures are unlikely to differ significantly between groups, and the researcher's confidence in undertaking such a process is likely to be increased by avoiding the distractions of note-taking and tape-recording typical in other group interview formats." (MacPhail, 2001)

In the educational field, the NGT has been used for faculty development (Salajegheh et al., 2020), (Colon-Emeric et al., 2012) to map students learning (Chapple and Murphy, 1996), (Porter, 2013), (Tseng et al., 2006) and teaching (Chapple and Murphy, 1996) experiences, and their assessment (Varga-Atkins et al., 2017), (Grant et al., 2003) to evaluate curricula (Dobbie et al., 2004), (Davis et al., 1998) or a study model (Lancaster et al., 2002), (Whitelaw et al., 2016) and in other situations (Muridan et al., 2019), (Lunenburg, 2011), (Weng and Lin, 2014) where the experiences and opinions of experts can help set the direction or make consensual decisions which is why the NGT is used in the validation process of the self-assessment model.

Depending on the NGT moderator or facilitator it comprises four (MacPhail, 2001), (Salajegheh et al., 2020), (Clive, 2012), (Na and Park, 2018), five (Varga-Atkins et al., 2017), six (Lunenburg, 2011), (Abdullah and Islam, 2011) or nine (Collison and Dunlap, 1978) stages, which combine both individual and group work. All of these articles outline four common stages: (1) individual generation of ideas in silence, (2) round-robin recording, (3) explaining ideas and arranging wordings, and (4) ranking or voting. In some articles, the four main stages are divided into subsections (Preliminary vote, Additional discussion, Final vote (Lunenburg, 2011)) or additional stages are added (Definition of task; Establishment of timelines (Collison and Dunlap, 1978)). Although (MacPhail, 2001) emphasises that even though usually in-depth preparation is used to carry out the NGT, both in substance and in organisation, the preparatory part and the steps are often omitted from descriptions of the NGT. Therefore, we try to avoid it and provide an overview of all stages of the NGT.

In the light of given backgroung information and the previously outlined problems it is crucial to validate SAMSS. The questions defined for the study are:

- Are all core aspects present in the self-assessment model? Is anything missing or redundant?
- Have these aspects been logically organised and clearly described in both criteria and levels?
- Which existing validation approach is optimal for SAMSS, and how does it need to be adapted?
- What are the possibilities for validating the model in a pandemic situation?

In next sections, based on the recommendations of (Humphrey-Murto et al., 2017), we provide an overview of the implementation of the NGT adding in-depth explanations of what happened at the different stages to make the process clear and add credibility to it.

5. Methodology

The NGT method was chosen to validate the model over other open-ended methods, as it allows independent sharing of individual ideas, the finding of a common language based on them, and the selection of major ideas based on group consensus.

The aim of the NGT was to gather feedback and suggestions to improve the initial model, so that the web-based model being developed and tested in the next phase would use terms understandable to the teachers, reflect different aspects of the Smart Schoolhouse, have structurally correct content, and meet the requirements of the IoSS. In the NGT, we involved experienced teachers from different schools participating in the projects "Smart Schoolhouse by means of IoT" or "Maths Digital Learning Resources Project" who had previous experience in using mini-robots or IoT kits in their learning and teaching processes.

As the selection of participants for the consensus group methods requires careful consideration to ensure that the participants are knowledgeable, represent the area of inquiry, and have practical experience, the criteria to be met by the participants were defined before the invitations were sent out. As we wanted to receive constructive criticism, arguments, and suggestions for improving and replenishing the model, we only included those teachers who were interested in promoting the field. The first list of potential participants was created based on the following criteria: teachers who (1) had excelled in at least one project, either IoT or MR, (2) had at least five years of pedagogical experience, and that (3) the participants of the session would be divided into different types of schools.

Considering the fact that most teachers are already pressed for time and it may be difficult to find a mutually convenient moment for everyone involved with the NGT, an initial invitation was sent to a larger number of suitable candidates than was needed, more specifically to 18 teachers. As it was expected, finding a common time for the NGT sessions became difficult and finally only 8 teachers replied in the affirmative and participated in the session. Based on (Humphrey-Murto et al., 2017) there are typically 5–12 members involved when using the NGT, and adds that representation of multiple viewpoints and expertise is more important than the size of the group.

Table 1 provides an overview of the participants' teaching experience, gender, and the project in which they have made extensive use of either the IoT kits or mini-robots. The first column of the table shows the type of school the participants work at, which determines the age distribution of the learners. As it is shown in Table 1, (1) five of the participants were involved in the "Smart Schoolhouse by means of IoT" (Kusmin and Laanpere, 2022) project and three in the "Maths Digital Learning Resources Project" (Leoste et al., 2019); (2) two participants had more than five years of pedagogical experience, while six participants had more than ten years; (3) four taught Robotics; (4) six were teachers of STEM subjects and two were teachers of other (non-STEM) subjects; (5) three were male and five were female; (6) two worked in Upper secondary schools (students aged 14-18), two more in Secondary schools (students aged 7-18), and four worked in Lower secondary schools (students aged 7-14). As evidenced, the background of the participants was quite varied.

Table 1. An overview of the NGT participants.

School	Teaching subject	Technology experience	Teaching experience	Gender
USS[1]	History, Career studies, Project studies	IoT[4]	> 10	F
USS	Computer Science, Informatics	IoT, R[5]	> 10	M
LSS[2]	Informatics	IoT	> 10	M
SS[3]	Mechatronics and Robotics, Project studies	IoT, R	> 10	M
SS	English,	IoT	> 10	F
LSS	Maths, Informatics, Integrated STEM lessons	MR[6], R	> 10	F
LSS	Informatics	MR	> 5	F
LSS	Informatics, Robotics	MR, R	> 5	F

[1] USS - Upper secondary school
[2] LSS - Lower secondary school
[3] SS - Secondary school
[4] IoT – usage of IoT kits in the project “Smart Schoolhouse by means of IoT”
[5] R – robotics lessons
[6] MR – usage of mini-robots in the “Maths Digital Learning Resources Project”

Under normal circumstances, the model would have been validated within one long day, where there would have been coffee and food breaks between the different sessions to boost teamwork, build trust, and find a common language between the team members. Instead, due to the global situation, the teamwork organised for the further development and validation of the model had to be carried out online and it was divided into two meetings taking place two weeks apart. The need for the two meetings and a fairly long period between those meetings was due to a desire to gather in-depth feedback and suggestions to better improve the original SAMSS. Thus, the participants needed time to get acquainted with the model and to form their opinions. Both NGT sessions took place via the webinar software Zoom and were recorded. The Flow chart of steps carried out during the NGT sessions are visualised in Figure 2.

5.1. The first session

The aim of the first session, planned for 45 minutes, was to explain the objectives of the creation and use of the model, to provide some background information, and to introduce the model itself. Furthermore, all of the participants were asked to think within the next two weeks (between sessions in Figure 2) about what the IoT-based Smart Schoolhouse means to them and how they personally would model or manage its development.

The introductory session was conducted by a facilitator who, despite the fact that more than half (M = 62.5%) of the participants of the teamwork had also participated in the project "Smart Schoolhouse by means of IoT" and were familiar with the project background and with the needs of the creation of a SAMSS, gave a short introduction to all of the participants in the session. This was followed by a brief introduction of the areas, criteria, and explanations of the SAMSS, and a brief overview of the frameworks and pedagogical models, on which the self-assessment model is based. At the end of the first session, the participants were given a task to familiarise themselves with the model and later give their thoughts about it.

Before giving the participants the main question or statement of the NGT, the session facilitator encouraged them to think about the model, asking a series of questions to pay attention to when exploring and familiarising themselves with it. The main question was: "What is an IoT-based Smart Schoolhouse for you?" and "How to model and/or manage its development?"

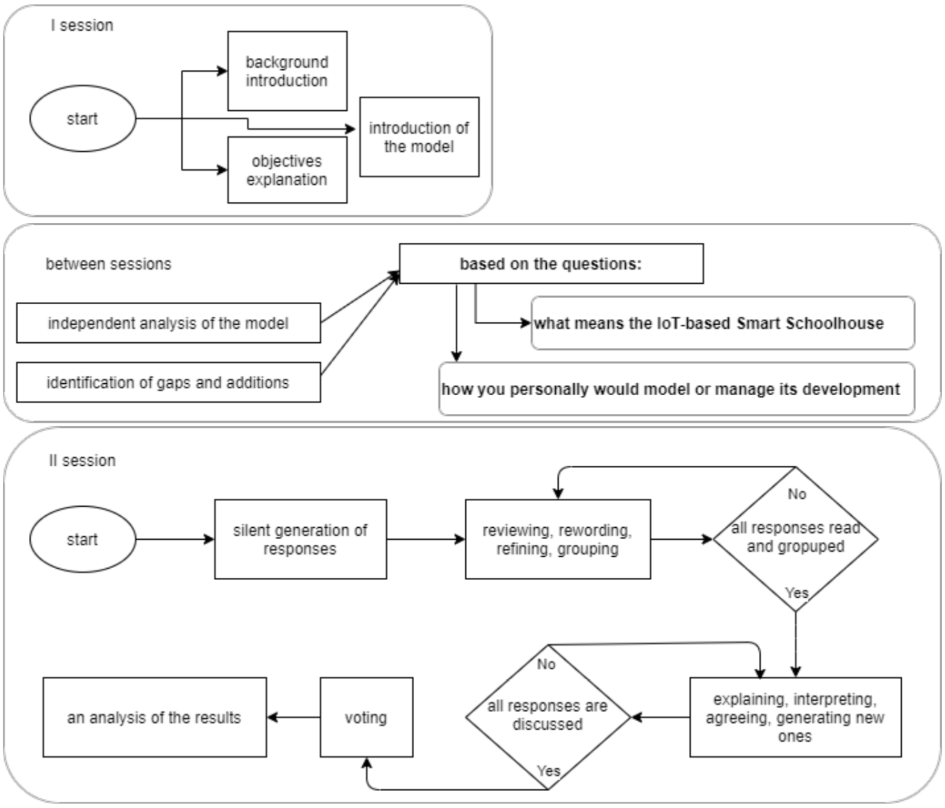

Figure 2. A flow chart of various steps in Nominal Group Technique carried out in the validation process of SAMSS.

5.2. The second session

After two weeks of individual familiarisation with the SAMSS, a second NGT session took place. The second session was scheduled to be 90 minutes long, meant to keep the participants focused on a sense of achievement over a specific period of time.

Again, the NGT session was conducted by a facilitator who briefly reiterated the topics covered in the previous meeting and explained the objectives, milestones, timeframes, and expected outcome of that meeting. As it is presented in Figure 1 the session was scheduled to have six stages: (1) writing down ideas independently and in silence, (2) Round-robin recording, i.e. reading and grouping these ideas, (3), Negotiating, clarifying, and rewording ideas, (4) Discussion of submitted ideas and adding ideas based on them, (5) voting on the ideas, and (6) setting these ideas in order according to votes received and discussion of the voting results.

Because the web-based brainstorming software Mural was used during the session it was necessary to share the link and code for the participants to enter into the environment and give them a brief overview of how to operate in the environment. When all of the participants had reached the online environment Mural, they were asked to write down their ideas and suggestions for improvement based on the main question of the NGT session in silence.

The first phase was an individual activity, silent writing of ideas. The participants were given 10 minutes to indi-vidually brainstorm and try to produce a qualitative list of their ideas, suggestions, and proposals for improvement of the model. This stage ensures that all members can contribute fully in an idea exchange (Collison and Dunlap, 1978) and allows a “fair participation of all participants" (Na and Park, 2018) both for those who are somewhat shy, too modest, or easily affected by more dominant voices, and for those who tend to be more influential, vocal, and impose their opinions on others. The next step was convergent thinking to bring together and look at the responses so that similar ideas and suggestions would form some kind of groups.

The second phase of NGT was round-robin recording, which is important in the context of a normal NGT session to ensure an opportunity for all participants to articulate their individually written ideas and suggestions, and continue to involve all participants. At this stage, a basic list of all responses is compiled, consisting of what everyone has written. Given the fact that by using Mural all the responses were visible at the very beginning already, we made a small change and asked everyone to read out their own ideas and, if others had similar thoughts, to group them. Reading their answers aloud is very important in teamwork in order to create the added value inherent in teamwork, where the other thoughts or ideas may spark a new one and lead to a very different but very important thought or idea. The content, merit, appropriateness, and relevance of these responses are not yet discussed at this stage. It can be said that the aim of this stage was to listen to other responses, to identify and collate items that are the same or similar. It was also possible to distinguish the groups of ideas with different colours.

The third phase of validation process was negotiating, clarifying, and rewording ideas. In the previous stage, all of the participants presented their responses, and similar ideas were grouped, but no questions were asked, nor were these responses explained, specified, or discussed, as that was not the point of that stage. Its aim was listening to participants' comments and explanations on their responses, and to review the wording of responses. With the permission of each author, these responses were then reworded and, if necessary, divided into several smaller ones so that they were suitable to be voted on at a later stage. At this and the next stage, especially in web-based NGT, the facilitator had a very important role to play. He had to give participants enough time, so they could explain and comment on their responses, however it was extremely critical to stay within the given timeframe despite the number of ideas generated.

The next phase engaged participants in discussion on submitted ideas and adding ideas based on them. Following clarification responses may at first be discussed before evaluating them. As it is suggested by Collison et. al. (Collison and Dunlap, 1978) "These items [responses] are best discussed if the group adheres to clarifying discussion format. Ask, “What does ….. mean?” rather than to state that an item does or does not belong on the list." This is the stage of NGT where during the discussion a so-called common knowledge (Wenger et al., 2011) is created, known, and valued in communities of practice, which is very difficult for non-members to access. The success of this phase is determined by the NGT facilitator's ability to create and maintain a positive atmosphere throughout the session, to ensure a mutual trust, openness, and support of the participants.

Voting as one of the stages of the NGT distinguishes it from conventional brainstorming and allows this method to be used as an assessment tool to prioritise responses (Varga-Atkins et al., 2017), (MacPhail, 2001), (Na and Park, 2018), find alternatives (Na and Park, 2018), identify areas needing attention or change (MacPhail, 2001). Varga-Atkins et. al. also points out “that the sequencing list created during the NGT voting phase makes the process scalable.” (Varga-Atkins et al., 2017). While in the first stage participants were asked to list all possible responses to a question or statement, and these responses were all clarified, reworded, discussed, supplemented, and grouped in subsequent stages, in the voting stage all participants were again given the opportunity to work individually to analyse the answers collected and discussed, and give them their votes.

All of the participants were given 14 votes to highlight the responses that were the most important in their eyes. Within the allotted time, 5 minutes in our NGT session, all participants were able to cast votes: (1) they had the opportunity to cast three votes to the most important response in their opinion and (2) 11 more votes to the responses that help make the SAMSS more understandable and relevant.

The validation process was finalised by discussion on the voting results. After the evaluation of the responses, there was some time for a discussion to find out "Are there any disagreements?", “Has something important been left out in the voting?” The facilitator also asked the participants for their opinion about which area of the model should be the first one when the implementation of the Smart Schoolhouse begins? All of the participants were given time for their closing remarks.

6. Results

As a result of the NGT, depicted in Figure 3, three main groups of topics emerged: (1) rewording (11 ideas), or rephrasing the idea while also expanding it (4 ideas), (2) ideas that provide meaningful addition to the model (8 ideas), and (3) general ideas, that support the understanding of the concept of Smart Schoolhouse (7 ideas): to use as suggestions or explanations of the SAMSS to different stakeholders.

During the first stage – Silent writing of ideas i.e. divergent thinking – 22 ideas were written down, many of which were noted only as keywords. In the next step - Negotiating, clarifying, and rewording ideas - these ideas were discussed, most of them reworded, and responses with keywords were supplemented by a full clause. This was repeated until each response was reviewed, understood by all group members, and appropriately worded for the voting stage. After this stage there were a total of 30 responses. Then it was time to discuss the responses to find a common language and understanding, followed by voting. This resulted in weighted values for ideas discussed and facilitated a comparison of model areas, criteria, levels, and descriptions. In total, the participants had 112 votes, of which only 57 were used.

As the voting was anonymous, it is not known who and why did not use all the votes given to them, however, six responses did not score any points at all. It can only be assumed that the suggestions for improving the model were marginal and according to the participants, these suggestions do not significantly increase the value of the model. The vote resulted in a list of 30 responses ranked according to the votes received: five responses receiving four points, seven responses receiving three points, a further four responses receiving two points, and eight of the remaining 14 each receiving one point.

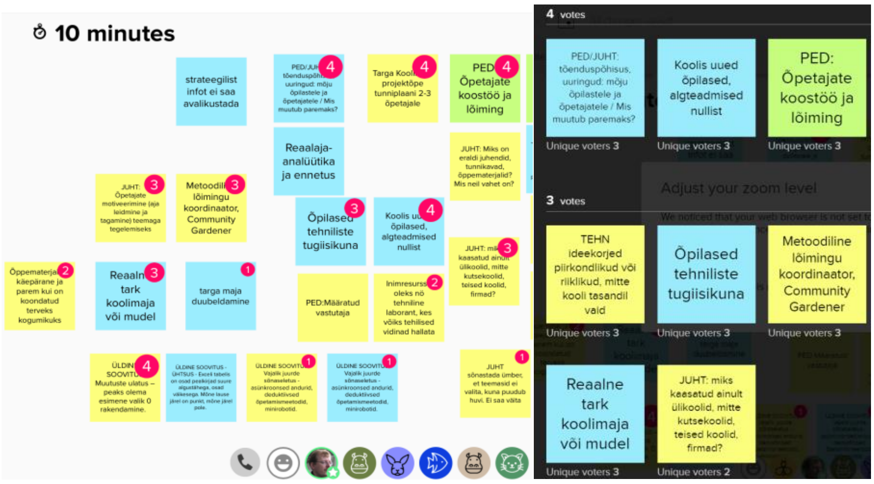

Figure 3. Data collection and voting in the NGT session, where red dots show the number of votes. The translations in English are in Appendix A.

The most valuable recommendations of the experts, used to improve the SAMSS, were as follows: 1) create a support group of students so that students can be used as support specialists in each class; 2) involve students in the stage of technology renewal and the budget planning; 3) in addition to the teachers' cooperation with universities, expand their cooperation with vocational schools, companies or the entire community, both within the country and abroad; 4) rephrase the criterion of integrated learning so that it is clearly understood that to support integration, the subjects to be integrated must be in the lesson plan at the same time.

Altogether, there were 19 changes made to the SAMSS, as an output of NGT, most of them were marginal in content but invaluable to make a SAMSS more understandable as helping to improve or supplement the wording or rephrasing. Overview of the improved Self-Assessment Model of Smart Schoolhouse is in Appendix B.

7. Discussion

In order to make sure that the SAMSS meets its goal, that it enables the analysis of the most important aspects supporting the IoSS, and is clearly formulated for users, it is essential to validate it. There are several methods that can be used to validate, or to determine the accuracy and reliability of the model's predictions. We used the NGT method. Eight experts with different backgrounds and teaching experience, who also had experience using mini-robots or IoT devices in their classroom, participated in the NGT session. Only participants, three out of eight had not participated in the project "Smart Schoolhouse by means of IoT" and therefore, did not have the same understanding of "what does a Smart Schoolhouse mean?". Furthermore, they did not have a "common language" on this subject with the other five experts. Looking back at the sample, it can be concluded from the results of the NGT session and the discussion that the involvement of these three experts, unrelated to the aforementioned project, turned out to be paramount and helped make the model much clearer. They gave many invaluable suggestions to reword or rephrase descriptions of different criteria. Also, it was very informative to observe how they interpreted the descriptions of the various criteria and gave a better understanding of how to explain the idea of Smart Schoolhouse to different stakeholders.

		episodic implementation	coordination	redesign of processes	commonisation of innovations	constant renewal
1.	**Technological innovation**					
1.1.	Basic hardware (core module)					
1.2.	IoT technology					
1.3.	Smart House solutions					
1.4.	Platform / software / app					
1.5.	Data, data warehouse					
2.	**Pedagogical innovation**					
2.1.	Technical instructions					
2.2.	Study materials (Worksheets, etc.)					
2.3.	Methodological materials (lesson plans, assessment models, etc.)					
2.4.	Technological competency of the teachers					
2.5.	Teaching methods (Methods of involving students, etc.)					
3.	**Change management**					
3.1.	In-house training					
3.2.	Technical support for teachers					
3.3.	Curriculum development					
3.4.	Cooperation at school level					
3.5.	Participation in communities of practice (at least on a national level)					

Figure 4. A self-assessment model: 3 areas, 5 criteria, and levels.
Summaries of the level descriptions are in Appendix B.

Although the NGT resulted in 19 changes to the SAMSS, the validation of the model provided considerably more necessary information than initially expected. The ideas collected during the NGT and their voting results are in Appendix A, and an overview of the upgraded model is in Appendix B. Since not all ideas were taken into account when supplementing the model, it is important to explain this part separately. As already stated above, it was possible to group the 30 presented ideas into three: ideas that (1) needed a better formulation, (2) complemented the model, or (3) helped clarify the nature of the Smart Schoolhouse.

The ideas that were implemented into the model can be split into three categories: (1) support services (n=4), (2) data protection (n=2), and (3) motivation (n=2). Since additional solutions for providing support services were pre-sented in four different ways (in Appendix A ideas no. 16-19 / 8 votes), it was obviously important for experts. Therefore, in the model, we reviewed all the descriptions related to support (technological support, pedagogical support, manuals, methodological materials, as well as teachers' cooperation and sharing of knowledge and experi-ence) and organised and supplemented the wording. To experts, it was also important to emphasise secure and ethical use of personal data in accordance with the terms of the GDPR. Two ideas (no 22-23 / 4 votes) were about motivating teachers. There is no separate aspect of motivation in the SAMSS, but in the discussion it was agreed that it is not a priority if the subjects to be integrated are added to the lesson plan at the same time so that the teachers can better cooperate and plan their time. Hopefully, this helps to reduce the drop in motivation.

Figure 5. A radar diagram characterising the readiness of the school to implement the Smart Schoolhouse concept. Translations of these criteria are given in Figure 4 and summary of self-assessment model in Appendix B.

From general ideas, that support the understanding of the concept of the Smart Schoolhouse, the suggestion (no 25 / 0 votes) to move base hardware strategy from the Technological innovation area into the Change management area was completely left. In several criteria, the third level (process redesign) includes strategy development, which is why placing this one description, without the descriptions given in previous and subsequent levels, in another area is not possible. As this idea was left without votes, it can be assumed that it was considered irrelevant. The rest of the ideas (no 26-30), although they cannot be used to complete the model, are noteworthy and can be used in the cover letter of SAMSS.

The attention to the need for a comprehensive cover letter was also drawn out as a concern of an expert: A participant in the "Math Digital Learning Resources Project" (Leoste et al., 2019) who did not have previous experience and knowledge of the project "Smart Schoolhouse by means of IoT" regretted that their school did not have an opportunity to participate in the project. She thought that the concept of the Smart Schoolhouse is very good but admitted that at first, she imagined that, unfortunately, it was only an opportunity for, more likely, larger schools, as smaller schools cannot even afford a robotics teacher or tutor, let alone a challenge as big as the concept of the Smart Schoolhouse. Participating in the analysis of the SAMSS changed her views and showed her that according to the Smart Schoolhouse concept, the aim is rather to involve non-computer science teachers in the use of IoT tools. After implementing the changes resulting from the validation in SAMSS, in order to make it more widespread, an online environment was created so that any school could analyse their readiness to implement IoSS and set goals for the future.

After the validation and improvements of SAMSS, an online environment was made available to any school interested in the Smart Schoolhouse for self-assessment. This online environment is created on the same principles as a platform named Digital Mirror (Ruiz-Calleja et al., 2019) known to Estonian teachers and other educational staff. In this new online environment, each of the schools involved can choose 15 options that best describe the current situation of that school out of 75 descriptions divided into three areas as shown in Figure 4 (1. Technological Innovation, 2. Pedagogical Innovation and 3. Change Management). Each of these three areas consist of five criteria which are further described across five more levels.

To carry out the self-assessment a team of 2-3 teachers, an IT specialist or an educational technologist and someone from the management is selected. It is crucial that all stakeholders would be represented and involved. At first, everyone completes an individual, evidence-based assessment, and it is followed by a team consolidation of assessments.

The results are visualised as a radar diagram, Figure 5, characterising the school readiness in different development areas to implement the Smart Schoolhouse concept. The most important aspect of the online environment is that the schools themselves collect the evidence to analyse their current situation. All answers, assessments, and evidence will remain for the school's own use, to compare de-velopment and trends after a year, two, three, etc. Also, it is possible to determine the goals of the development activity (which level does the school wish to reach in each criteria, etc.) and describe the measures to achieve these goals (budget, financier, responsible persons, etc.). A comprehensive framework for the development of Smart Schoolhouse is created from all the development measures, which the school can rely on in the following years.

8. Conclusion, limitations, and the future works

By using either smart home solutions or the IoT technology to collect data about their surroundings and them-selves, and integrating this data into the learning process, students will be able to find solutions to real life problems which will help involve them more in the whole learning process and might raise their interest towards STEM subjects. For this purpose, we presented the IoSS and developed a self-assessment model for schools (SAMSS), so that they may analyse whether they are ready to launch the IoSS.

The NGT were used to validate the SAMSS and collect improvement proposals, so that the web-based model being developed and tested in the next phase would use terms understandable to the teachers, reflect different aspects of the Smart Schoolhouse, have structurally correct content, and meet the requirements of the IoSS. With eight experts, we were looking for answers to the question: „What is an IoT-based Smart Schoolhouse and how to model and/or manage its development?", to support the formation of new ideas to help improve the SAMSS. In conducting the NGT we relied on the recommendations given by (Humphrey-Murto et al., 2017) which, based on various sources, gives recommendations for demonstrating methodological rigour for consensus group methods, to add credibility to the research process and ensuing results.

The validation process involved experts who participated in educational robotics projects, either in (1) the "Smart Schoolhouse by means of IoT" (Kusmin and Laanpere, 2022) or (2) the "Maths Digital Learning Resources Project" (Leoste et al., 2019) as they had experience in both the opportunities and the challenges of implementing IoT or using (mini) robots in teaching.

Due to the ongoing situation in the world, the teamwork organised for the further development and validation of the model took place online. We used Zoom software to communicate, share a screen showing Mural that was used to gather all the notes together in one place, discuss our thoughts on them, and to vote on the individually generated ideas.

There were 7 steps in the NGT: (1) a short introduction of the background and the needs of the development of the model was given; (2) a silent generation of ideas, where the participants were initially asked to list all possible responses to the main question individually; (3) Round-robin recording of ideas, where criticism was not allowed but clarification was encouraged; (4) clarification, rewording, and grouping – responses were grouped so that they were unambiguous and could be voted on; (5) a group discussion to find a common language and clarify all of the responses; (6) voting – once the group had agreed on a clear meaning for all of the ideas, each person anonymously voted by giving three points to the most important response and one point to the next 11 responses; and (7) discussion of voting results. The sessions followed the requirement of (MacPhail, 2001) to ensure internal validity by being unobtrusive and honest with its participants, involving the participants at all stages of the process, supported by the presence of a facilitator throughout the NGT procedures. The focus group sessions with experts were professionally facilitated, recorded, and transcribed.

Similarly to (Collison and Dunlap, 1978), the participants in the NGT sessions of the SAMSS, "evaluated the process positively in terms of the amount of productive effort that results within the time specified and items of the ease with which diverse ideas can be discussed and evaluated with minimal personal conflict" (Collison and Dunlap, 1978).

It is important for us to show how we guaranteed the validity of the validation of the self-assessment model and looked for aspects needing improvement. So, in using and describing the NGT method, we tried to avoid the situations pointed out by (Humphrey-Murto et al., 2017) and followed the suggestions given by them. They guide researchers "toward a comprehensive description and justification of the steps taken in their study, ensuring that the results of the research are as credible and as useful as possible" (Humphrey-Murto et al., 2017). Although we tried to ensure the reliability of the validation of the self-assessment model, it is necessary to point out some of its limitations.

MacPhail has declared (MacPhail, 2001) that the reliability of NGT could be demonstrated by repeating the NGT again with the same group members and obtaining the same results. In our situation, however, the exact same results will most likely not be achieved again. It is quite possible that the participation in the NGT sessions influenced the experts' understanding of the IoSS, which is why the same questions and discussions will no longer arise. As a result, some of the changes that were made in SAMSS may not be made when the NGT session is held again because the questions asked by the participants in the first NGT might not arise again.

In addition to the aforementioned NGT steps, at the end of the session an analysis of the results was carried out to find out the participants' attitude towards the results, to see whether in their opinion all the crucial responses were marked and nothing important was missed. Experts participating in the NGT sessions had to imagine the imple-mentation of IoSS in their schools, as at the moment there isn’t a model-school to rely on. This means that the second limitation may arise from the novelty of the subject.

This, however, comes with another limitation. We tried to find experts with different educational backgrounds who are aware of using IoT kits or mini-robots in STEM learning, but again, we have to realise that the subject is quite novel and there aren't as many experts to NGT involved as we would have wanted. Although, according to (Humphrey-Murto et al., 2017), more important than the number of participating experts is their multiple viewpoints, expertise, perspectives, and knowledge, there may still arise a problem with generalisation of results. Even though we have a concern about the generalisation of the results of external validity, the credibility of the NGT in this study was ensured through the selection of only the most pertinent participants of varied backgrounds, the individual general-isation of ideas, and having the option to vote for any of the responses.

The reliability of the responses given by participants in an NGT can be assessed to a greater extent than the re-sponses given in the group interviews or during brainstorming (Na and Park, 2018). This is because by obtaining the responses each participant had written down, working together as a team, these responses were clarified, reworded, discussed, and finally, all of these responses were voted on individually. This resulted in weighted values for ideas discussed, and facilitated a comparison of model areas, criteria, levels, and descriptions, and making improvements to the model.

The use of the web-based software Mural that participants could join without having a user account ensured the anonymity of participants in the NGT sessions. Only the participants' own explanations and comments allowed others to anticipate their background, but this was their conscious choice that could have been avoided if they had wished to do so.

As a next step, after the validation of the SAMSS, an online self-assessment environment was created and tested. Now, we can offer more schools the opportunity to analyse their readiness to implement IoSS. The obtained results provide different opportunities for comparison studies of schools.

Appendix A

Results of NGT sessions:
grouped ideas and suggestions with the number of voters and votes.

no	group	idea or suggestion	voters	votes
1	rephrasing and expanding the idea	involve the students in renewing the technology and budget planning	2	2
2	rephrasing and expanding the idea	expansion of the participants in the idea collection (how to use digital tools)	2	2
3	rephrasing and expanding the idea	brainstorming regional or national, not just at the school level	3	3
4	rephrasing and expanding the idea	to include vocational schools, other schools, companies, etc. in the cooperation in addition to universities	2	3
5	rewording	adding a Smart Schoolhouse project based learning for 2-3 teachers to lesson plan	2	4
6	rewording	data collection centrally	1	1
7	rewording	Smart Schoolbag - a collection of apps, taking into account the development of technology	1	1
8	rewording	real-time analytics and prevention	0	0
9	rewording	to rephrase that topics are not chosen because there is no interest, that cannot be said	1	1
10	rewording	wording - initials, periods, etc	0	0
11	rewording	real Smart Schoolhouse or model	3	3
12	rewording	smart house doubling	1	1
13	rewording	study materials to be gathered into a collection	2	2
14	rewording	why are there separate manuals, lesson plans, and study materials?	0	0
15	rewording	cooperation and creativity of the teachers	3	4
16	meaningful addition	involve the students as technology support persons	3	3
17	meaningful addition	methodical integration coordinator, Community Gardener	3	3
18	meaningful addition	human resource: technical laboratory assistant who manages IoT devices	2	2
19	meaningful addition	designated person in charge of organising integrated lessons	0	0
20	general idea: data protection	strategic information cannot be disclosed	0	0
21	general idea: data protection	data protection	3	3

22	general idea: motivation	motivating teachers (finding and securing time) to deal with the topic	3	3
23	general idea: motivation	time factor: there is not enough time and it has to be taken at the expense of other things	1	1
24	general idea	Lack of funding (e.g. funding in school and on the municipalities' level, writing a project)	1	1
25	general idea	base hardware strategy from the Technology innovation area into the Change management area	0	0
26	general idea: cover letter	every autumn there are new students at school, knowledge from scratch	3	4
27	general idea: cover letter	evidence-based research: implications for students and teachers - What is changing for the better?	3	4
28	general idea: cover letter	scope of change - 0-level should be the first choice in implementation	2	4
29	general idea: cover letter	add explanation: asynchronous sensors, deductive teaching methods, mini-robots	1	1
30	general idea: cover letter	add explanation: deductive teaching methods, mini-robots	1	1

Appendix B

A self-assessment model summary:
3 areas, 5 criteria in each, and summative descriptions of levels.

1.	Techno-logical innovation	episodic implementation	coordination	process redesign	commonisation of innovations	constant renewal
1.1.	Basic hardware (core module)	Basic hardware (core module) describes the readiness of the technology from the possibilities of using asynchronous sensors to their intended use, and finally the impact of their use on teaching and learning will be analysed.				
1.2.	IoT technology	IoT technology criterion - described from a situation where mini-robots and different sensor kits are available at school, but they are rarely applied in the learning process, to a situation where, with the involvement of community, design contests are taking place to collect ideas for the potential use of the IoT in learning process; how is the monitoring of the use of IoT technology implementation organised; the development and improvement of the established strategic documents to guide the usage of the IoT technology.				
1.3.	Smart House solutions	Smart House solutions - From a situation where a school has at least an elementary Smart House solution (e.g. ventilation and / or heating system) to a situation where there is a strategy on how to use the data collected from Smart Home-system similarly to the data collected with IoT kits. And finally, the Smart House management and data collection platform is integrated with LRS, to use the non-personalised (row) data in the learning process and personalised data for the learning analytics.				
1.4.	Platform / software / app	Platform / software / app - From a solution that allows a one-time use and visualisation of data (according to device conditions, i.e. in different environments or devices) to the use of LRS, where data collected at different times is stored and managed, which in turn is related to e-learning environment and Smart Schoolhouse solution, allowing, with related software or applications, to filter and export the necessary (personalised, non-personalised) data according to user rights.				
1.5.	Data, data warehouse	Data, data warehouse - The description starts with a learning process that uses one-time data (currently being collected) depending on the capabilities of the IoT technology to a situation where, according to the Data Protection Act, non-personalised data collected into the LRS (mini-robots, IoT kits, Smart House solution) is used to enrich the learning process and cooperation with other schools that have joined the Smart Schoolhouse concept, and personalised data to analyse the learning process and visualise results.				
2.	Pedagogical innovation	episodic implementation	coordination	process redesign	commonisation of innovations	constant renewal

2.1.	Technical instructions	Technical instructions - From the lack of technical guidelines up to their coordinated creation process where the learners are involved according to the 4C (Consumption, Creation, Curation, Connection) framework
2.2.	Study materials (Worksheets, etc.)	Study materials - At lower levels, situations are described where learning materials created by others (worksheets, guides, instructional videos, etc.) are used by or adapted for the target group in order to purposefully apply the use of mini-robots, IoT tools, or Smart House data in the learning process. At the next levels, there are explanations where the co-creation and further development of learning materials that support the use of digital tools (integrated learning) is a part of teaching, i.e. a regulated and continuous process according to the 4C / ID Task - centred instructional design model in first levels, and ASSURE model in higher levels. The concept of the Smart Schoolhouse puts the learner at the centre of the learning process, which means that they are involved in the development of teaching materials and guides according to the "Levels of Co-Authorship taxonomy that defines seven levels of engagement by learners’". In addition, at the last level of this criterion, attention needs to be paid to the cooperation with research institutions and companies and Communities of Practice.
2.3.	Methodological materials (lesson plans, assessment models, etc.)	Methodological materials - Although this criterion describes, similarly to others, situations at the first levels, where from time to time the use of methodological materials made up by others to the use of conscious and self-created materials, the main emphasis of the criterion is on the trialogical approach to learning. For example a description of the base level: teachers use lesson plans based on a trialogical approach to learning created by others to apply technology in the learning process. The essence of the trialogical approach to learning is the involvement of learners in the knowledge creation. This means taking into account the levels of learner involvement when preparing lessons and choosing teaching methods and learning activities, the aims of which are to give learners the responsibility for learning. The VT&LM model can be used to prepare lessons, as well as the entire curriculum.
2.4.	Technological competency of the teachers (TPACK)	Technological competency of the teachers - This criterion pays attention to the skills of the teachers, which include excellent subject knowledge, pedagogical knowledge, and experience, as well as the ability to use technology purposefully. The first stage describes a situation where a school has one or a few very good initiators, to a situation where the teachers are constantly improving their teaching practices in order to create a stronger connection between the learning content and the pedagogical techniques and technologies used to deliver it. The descriptions of this criterion are based on the TPACK model. At the highest level, there are only those schools whose teachers share their experiences of teaching practices in the region, nationally, or internationally.
2.5	Pedagogical innovation	Teaching methods - In the criterion, we emphasised the use of inductive teaching methods that involve the learners. The learners are guided to use technology in a meaningful way in order to connect new information with previous knowledge. There are different frameworks

		(PFL) and approaches (Learning-by-Doing and Maker Movement) to support the choice of methods. In addition to the above we also brought out collaborations with universities to develop new teaching methods that support the use of technology (IoT, Smart Home Data) in learner-centred teaching to bridge the gap between practice and theory.				
3.	Change management	episodic imple-mentation	coordination	process redesign	commonisation of innovations	constant renewal
3.1.	In-house training	In-house training - As a beginner exploratory teacher, participation in the trainings that support the teacher inquiry into students learning (TISL model) is meant to help the teacher to support the monitoring of the learners' progress and the evidence-based modification of learning process. For the effective use of technology in the learning process there are two frameworks developed by UNESCO: ICT Competency Framework for Teachers (ICT-CFT) and ICT Competency Standards for Teachers'" (ICT-CST). Which can be used as a support mechanism by the teachers for self-improvement, or for the development of in-house training. As experienced exploratory teachers share their experiences, it is possible to rely on the Knowledge Appropriation Model (KAM) to explain the adaptation of the Smart Schoolhouse concept and to contribute to the adoption of positive changes throughout the organisation. Within this criterion the cooperation with universities to develop research methods that give support and guide the teachers in their self-development, and enable them to make evidence-based decisions in the learner-centred learning process is described.				
3.2.	Technical support for teachers	Technical support for teachers - The lowest level starts with the lack of technological support, where individual teachers who are more impressed with the possibilities of using technology in the learning process try to cope with it on their own. This is followed by levels where there is more technological support, starting with either an IT specialist, a robotics teacher, or a support team made up of students, to a technological support and mentoring system, the latter of which is reflected in strategic documents and has been proven to work the best.				
3.3.	Curriculum development (integration of subjects)	Curriculum development - To implement the Smart Schoolhouse concept, it is important that the school timetable supports the integration of subjects so that the teachers have the opportunity to integrate several subjects in the same classroom to use the IoT technology or Smart House Data in the learning process. The description of the levels starts with cooperation between some more interested teachers with an aim of integrating subjects for the purposeful use of a digital tool. In the higher-level description it is pointed out that the teachers share their experiences of working together on finding new integrations and to integrate technology into teaching in a targeted way with their colleagues. The integration of subjects is supported by the PK model for STEM education (translated as The didactics of inquiry based learning), which is part of a STEM framework composed by the Government of Flanders.				

3.4.	Research and creative work	Research and creative work that integrates subjects - In this criterion, we focus on technology-based research and creativity work that is created in the integration of subjects and focuses on the day-to-day problems surrounding the students. The first level description emphasises that technology-based research and creativity work is very seldom chosen because students have no interest in it or the school does not have the capacity to supervise them. On the following levels, however, it has already been indicated that schools have guidelines for guiding and evaluating creative work to the extent that, in cooperation with students and the community, exciting topics can be sought out, followed by a research or creative work on that topic either individually or in teams, and finally, the experiences received from this process are shared. This criterion is supported by the CRCD (Collect - Relate - Create - Donate) framework.
3.5.	Cooperation and Participation in communities of practice (at least on a national level)	Participation in communities of practice (at least on a national level) - At the first levels of the criterion, there is a low activity of teachers in both co-operation and in participation in communities of practice. Step by step, i.e. at the next levels, the teachers become more active and they are developing lesson plans and learning materials in cooperation for their integrated subjects. Cooperation is also taking place with companies and research institutions in order to implement IoT kits and Smart Schoolhouse data in a better way into the learning process. The experience gained is shared both in school and more widely. The principles of both cooperation and knowledge creation and sharing are described in the SECI model.

List of Abbreviations

IoSS - the idea of Smart Schoolhouse
SAMSS - the Self-Assessment Model of the Smart Schoolhouse
NGT - The Nominal Group Technique
STEM - Science, Technology, Engineering, Math
IoT - Internet of Things
GDPR - General Data Protection Regulation

Abbreviations in Appendix A

TPACK - Technological Pedagogical Content Knowledge Framework
ICT-CFT - ICT Competency Framework for Teachers
ICT-CST - ICT Competency Standards for Teachers
KAM - Knowledge Appropriation Model
TISL model - The teacher inquiry into students learning
PK - Pedagogical Knowledge
SECI model - Socialization, Externalization, Combination, and Internalization
VT&LM model - The Victorian Teaching and Learning Model
4C / ID - Four-Component Instructional Design (4C/ID
ASSURE model - Analyze Learners; State Standards and Objectives; Select Strategies, Technology, Media, and Materials; Utilize Technology, Media, and Materials; Require Learner Participation; Evaluate and Revise
4C model - Consumption, Creation, Curation, Connection
LRS - Learning Record Store
CRCD model - Collect - Relate - Create - Donate
DigiCompOrg - The Digital Competence Framework of 7 key elements and 15 subelements
JISC model - model created by The United Kingdom digital, data and technology agency
SELFIE tool - Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies
MMEO model - The Maturity Model of Digital Transformation
TIM - The Technology Integration Matrix

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