# “RemoteMentor” Evaluation of Interactions Between Teenage Girls, Remote Tutors, and Coding Activities in School Lessons

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**Abstract.** Research points at various factors for the low and even decreasing proportion of women in the IT sector in developed countries, e.g., psychological causes, social factors, or structural conditions. These possible explanations all have one thing in common: they recognize adolescence as the essential confidence-building phase in girls. Girls aged 12 to 15 years old seem to lose interest in computer science (CS). Providing mentors and female role models are two key elements to counteract gender stereotypes in CS. “RemoteMentor”, a joint Austrian research project brought these two approaches together and expanded them in the form of “remote tutoring”: female students aged 14 to 15 received one-on-one human support through smartphones for their coding project during their regular CS and arts lessons. The aim of the one year investigation was to analyse gender aspects in the tutoring process and the output of the collaborative coding project. This was done with group discussions, the evaluation of the online tutoring units and an analysis of the final games in regard to the applied Computational Thinking concepts. Results showed that the project was a promising approach to support and motivate at least a certain group of female students in coding.

**Keywords:** Remote tutoring · Gender analysis · CT skills · Coding project · Smartphones

## 1 Introduction

The underrepresentation of women in the field of information technology (IT) has been discussed in interdisciplinary research for decades. A gender-gap occurs


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in several STEM disciplines (science, technology, engineering, and mathematics), but it is most evident in the discipline of computer science (CS). The number of women in CS is very low and even declining in most developed countries [27]. Consequently, software engineering jobs are male-dominated, as shown by Eurostat's statistical data [7]. In Europe, 83% of the people working as Information and Communication Technology (ICT) specialists are male. This underrepresentation in terms of participation in the IT sector leads to inequalities and thus to disadvantages for women. Sapna Cheryan et al. [6] describe that stereotypes define the culture of the IT sector. Stereotypes work on two levels: on the one hand, they are descriptive (how is something) and on the other hand, they are prescriptive (how should something be). Examples of such stereotyped ideas of the IT sector would be the "male character" or a "chilly environment". For people working in IT, such stereotyped notions would include nerds or geeks who live socially isolated [6,13]. These ideas are more compatible with typical images of masculinity than femininíty. Young people usually engage in areas they feel "compatible" with, which is largely structured by the category of gender. If the profession does not fit the "traditional gender model", one is not as likely to pursue it or feels discriminated against by someone who does. To strengthen girls' confidence and interest, mentoring programs and appropriate role models are two key elements to introduce girls to technical subjects and to awaken their interest for CS [2,3,26]. Researchers are certain that girls' interest in IT changes early in their adolescence between the ages of 12 and 15 years old. For this reason, introducing female mentors from secondary school onwards is described as the most effective [18]. Another option that has proven to be particularly effective in increasing programming interest and motivation is to offer mentoring programs.

We combined these strategies and started the "RemoteMentor" project, a form of online mentoring which works by pairing university students with teenage girls between the ages of 13 and 15 years from two secondary schools in Graz. "RemoteMentor" was a one-year investigation that started in January 2018 with funding from NetIdee (Internet Foundation Austria). For this project, female students used the app Pocket Code and they got immediate help in real time from advanced users (i.e. remote tutoring). A sociological analysis investigated gender aspects in this remote tutoring process by conducting group discussions with 61 girls, analysing the transcripts of the online tutoring sessions. Additionally the final coding projects were evaluated from technical viewpoints and referred to important Computational Thinking (CT) concepts described by Jannette Wing [30]. The aim of the paper is twofold: First, we investigate differences in the teenage girls' tutoring experience by female and male tutors. The developed typology shows how the interactions between attitudes of the girls (i.e. active-passive) and the tutoring orientation (i.e. dictating or supporting) resulted in different tutoring styles (i.e., cooperative, directive, interactive, and authoritative). Second, these results were compared with the evaluations of the coding projects and showed the relationship between girls' types of attitudes and applied CT concepts of their final projects. This paper investigates the following research question: What influence do the following aspects have on the students' attitude towards programming or their final games: the tutoring orientation, the tutoring style of tutors, and the gender of the tutors?

## 2 Theoretical Background

Gender and technology represent two constructed concepts that influence each other [29], see Sect. 2.1. In addition, stereotypes, social and institutional factors in the context of CS are used to analyse gender aspects, especially those of girls and young women, see Sect. 2.2. Subsequently, theoretical foundations of mentoring and especially of online mentoring, as well as a conceptual definition of mentoring and tutoring, will be discussed in Sect. 2.3. The game creation approach based on visual coding will be presented in Sect. 2.4.

### 2.1 Gender and Technology

Researchers of the 1980s and 1990s focused on differences in performance (e.g., in school subjects) and preferences (e.g., interests and hobbies) between genders [26]. The underrepresentation of women was connected with gender inequalities in their access, use and attitudes towards computers [1]. Solutions of this time included changing women's attitudes towards computers and technology to more "male" views. Research today does not see the solution in a need to change girls' and women's attitudes towards computers but emphasises the investigation of social influences such as stereotypes, associated power, and domination relationships in the IT sector [1]. Wendy Faulkner [9] states several reasons why it is necessary to include the category of gender in technology research. We would like to mention five reasons that are considered most important for this paper: (1) technology is gendered because the main players in this field are male, (2) there are clear gender differences in the division of labour in technical sectors, (3) technological artefacts have themselves a materially or symbolically gendered character, (4) in Western cultures, notions of the technical sector have predominantly male connotations, and (5) methods of working in the technical field can have a gender aspect. Feminist constructivist technology research argues that technology and gender should be understood as co-constructed and thus as mutually influencing each other [28].

### 2.2 CS, Stereotypes, Social and Institutional Factors

Stereotypes are among the most influential factors leading to gendered modes of behaviour [3]. Consequently, stereotypes in CS seem incompatible with the self-concept of adolescent girls [23]. This is described by the concept of "interests as identity regulation model" (IIRM) [19,20]. This concept describes the underrepresentation of girls and women in technical areas to this incompatibility of their gendered self-concept and the male connotation of STEM areas—and in particular the area of CS. According to the IIRM, young people choose school subjects and extracurricular activities on the basis of their idea of who they are or what they want to be in the future. Acknowledging or distancing oneself from engagement in certain areas is a way for young people to express and show their identity [19]. According to Kessels et al. [19], the category "gender" plays an important role in such decisions. The IIRM model can help to explain not only commitment but also non-commitment to certain areas. Thus it is well suited to break down gender aspects that have been shown in real-time online-mentoring during the project.

### 2.3 Mentoring, Online Support, and Tutoring

An established practice to support and encourage interest in programming among teenage girls are mentoring approaches. In regards to CS, girls can receive detailed information about possible professional fields, requirements for applicants, earning opportunities, etc. [10]. If female role models serve as mentors, they can break down stereotypes and girls can learn from their experiences [2,10]. Mentors can also strengthen their mentees with encouragement and confirmation, especially if they doubt their suitability for the IT sector [10]. According to Khare et al. [17], online mentoring offers many possibilities. By eliminating the factor of location, even people who may live in rural areas and for whom a copresent face-to-face meeting would not be feasible can benefit. Compared to analog mentoring, online mentoring is much cheaper, the use of resources is much lower, and it can be used more effectively. Despite these positive aspects, there are also some negative aspects or ethically problematic ones [8]. For instance, misunderstandings in communication, or questions of privacy and confidentiality. Another form of mentoring are tutoring approaches. Tutors help their tutees to achieve a specific goal or skill. This cooperation is usually very limited in time, but can nevertheless have a major impact on the person being supported, for example if a sense of achievement has an influence on later educational or professional ambitions. In the case of the "RemoteMentor" project we are dealing more likely with a tutoring concept. For the presentation of the results we will thus stick to "tutoring".

### 2.4 Block-Based and Visual Coding

In the last decade, a number of block-based visual programming tools, e.g., the Scratch environment [24], have been introduced with the purpose of helping children and teenagers to have an easier time when first practicing programming. For our project we used the app Pocket Code, an app developed at TU Graz as part of the Open and Free Source Software (FOSS) project Catrobat. Pocket Code is a visual programming language environment that allows the creation of games, stories, animations, and many types of other apps directly on phones or tablets, thereby teaching fundamental programming skills. Drag and drop interfaces particularly make a lot of sense on smartphones, as users prefer using their fingers for dragging and dropping graphical elements on the multi-touch screen in almost all apps, even when entering text on "swipe"-type keyboards. To allow remote sessions via Pocket Code we use a second app with the name "Zoom".

The Zoom app (zoom.us) allows users to host a meeting, invite others, speak and chat with them, share the screen, and use a pen feature for highlighting.

## 3 Methods

To explore RemoteMentor as an approach to support young girls in their programming we explore the attitudes of the girls in relation to the tutoring style of their tutors and compared them with the CT concepts applied in their final programming projects.

### 3.1 Participants and Activity Design

The project was conducted at two academic high schools in Graz (Austria) in with a total of 113 students (61 girls, 52 boys). The age of the project participants was between 13 and 15 years. The classes consisted of boys and girls, however, with regard to the research interest, only the data of the girls has been examined for this paper. The students used the app Pocket Code in six to eight double units (=90 min) in a weekly interval. In unit 1 students solved a tutorial which included the basis functionalities of Pocket Code (messages, sensors, etc.). During unit 2 students created their ideas by using storyboards (a framework to support concepts they will need for programming). In units 3 and 4, students received support from a total of 16 (8 female, 10 male) different female and male remote tutors (more experienced users of the app, mostly university students from TU Graz). Tutors were allocated randomly among the students. Every female participant had one session with a male and one with a female tutor to be able to compare tutoring experiences with both male and female tutors. During a 30 to 40-min session, the students called a tutor and shared their screen with them via the app ZOOM to show their scripts and ask for advice, improvements, or further ideas, see Fig. 1.

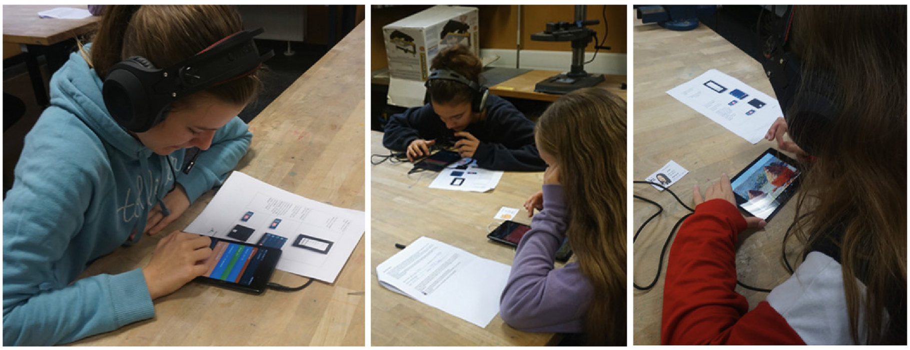

**Fig. 1.** Tutoring Session with headphones, Pocket Code, and the Zoom app.

The first survey phase started in May and continued until June 2018. In two secondary schools in Graz, real-time tutoring was offered as part of their regular CS lessons. In this first survey phase, four group discussions were held with 14 teenage girls and 27 transcripts of tutoring units were generated. The second survey phase started in October and continued until November 2018. Tutoring units were offered at the same two schools but this time during arts lessons. Students chose famous paintings and created interactive memes out of them through animations and games. Figure 2 shows some screenshots of the final artefacts. In this second survey, eight group discussions were conducted with 47 female students and 104 transcripts of tutoring units were generated. The research was approved by both universities' institutional ethical review panel prior to commencement. Following permission from the school and teacher to conduct the research, legal guardians of the students were informed of the research. Participants used nicknames in the group discussions and for their games.


**Fig. 2.** Gaming artefacts during the RemoteMentor project.

### 3.2 Data Collection Process

Non-participant observations were conducted in both the programming and tutoring phases. The purpose of the observations was merely exploratory and therefore not conducted in a systematic way to develop a guideline for the group discussions. We held a total of 12 group discussions lasting 45 min each with 61 teenage girls. The girls were subdivided into smaller-groups of two to eight students to be able to adequately reconstruct individual stand points and the formation and exchange of opinions within the group setting [11]. The interview guide consisted of 16 questions derived from the literature review on girls/women in computing and from the non-participant observations. The topics included views on programming, their experience of and satisfaction with their work on the project and the tutoring they received, assessment of their own programming skills, and perspectives on female role models in the IT sector. All online tutoring sessions were audio recorded and transcribed into a text file by the tutors themselves for budgetary reasons. There were a total of 131 transcripts, of which 8 had to be excluded for poor quality. The remaining 123 transcripts were included in the evaluation. All completed gaming apps were uploaded to the Catrobat Sharing page (https://share.catrob.at/). A total of 111 games were uploaded, and 60 of them were created by girls. The projects were analysed by using a Computational Thinking (CT) skills matrix, applied by the open source software Dr. Scratch [21]. CT fosters the idea that young people who are introduced to CS, learn more than just programming but apply several higher thinking skills [30]. To successfully implement their own programming solutions, students had to apply different programming concepts, such as loops and conditions, as well as practices, such as abstraction and debugging [16]. Dr. Scratch is an analytical tool that evaluates Scratch projects. Since both, the Scratch environment and Pocket Code uses a very similar visual block-based programming language, these analysis could be easily adopted for our tool. Fundamental CT concepts which are analysed comprise [25]:

- Abstraction and problem decomposition: breaking down a problem into smaller ones (e.g., use more than one script/object)
- Parallelism: focussing the thinking process in more than one direction (e.g., several scripts are triggered by the same events)
- Logical thinking: include decision actions or logical operators (e.g., if-else)
- Synchronization: ability to understand complex information and synchronize code (e.g., by wait actions)
- Flow control: to create plans for known/unknown events (e..g, iterations)
- Interactivity: to include feedback for users or user actions (e.g., mouse click)
- Data representation: e.g., operations on variables and lists.

The redefined matrix for analysing Pocket Code projects is described in the next section.

### 3.3 Data Analysis

Three kinds of data were the subject of our analysis: (1) the transcripts of the group discussions, (2) the transcripts of the tutoring sessions, and (3) the programmed games. Different methods of data analysis were applied. The transcripts of the group discussions were coded according to constructivist grounded theory [5] and the transcripts of the tutoring sessions were subjected to a summative content analysis [14]. The artefacts of learning, the programmed games, were evaluated according to applied CT concepts following the analysis of the open source software Dr. Scratch [21].

Following the principles of the constructivist grounded theory methodology [5], the use of the different techniques of data analysis and the combination of the different data types followed an iterative logic and resulted in theoretical concepts. We started the process of data analysis by "initial coding", and coded the transcript line-by line in order to identify relevant issues and aspects. In a second step we used the technique of "focused coding" to systematically develop and ground our central categories that had already emerged in the first analysis sessions (different types of girls and tutoring). In the final step of "theoretical coding" we related the codes to our core categories, different types of girl's attitudes to programming as well as the different tutoring orientations, and styles in order to develop our theoretical concept. The development of this theoretical concept was nourished and strengthened by the analysis of the transcripts of the tutoring sessions by a summative content analysis which focused on linguistic and communicative aspects of the tutor and tutee interactions.

The goal of the analysis of the transcripts of the tutoring units was to investigate whether the male and female tutors structured their assistance differently or preferred different linguistic means and also whether the girls' participation would be different depending on their tutor's sex. We conducted a summative content analysis, that combines the counting of frequencies (of words or content) with their contextual interpretation [14]. The context here consisted in linguistic means that we defined, adopting an older method of studying language use in same-sex and mixed-sex dyads developed by Mulac et al. [22]. It allowed us to break the transcripts into coded segments, whose pattern in the given mentoring unit pointed to its overall structure. All transcripts were coded and subsequently assigned to one of four tutoring styles. Subsequently word frequency counts were carried out in order to measure the verbal contribution i.e. the code coverage by type of interaction, language use and learning context of tutors and tutees. The styles could then be mapped onto the corresponding typology of the girls' attitudes to programing resulting from the cooperation between the tutors and tutees.

For analysing the programmed games we made use of the Dr. Scratch coding system [21]. Dr. Scratch maps CT concepts with different competence levels of basic, developing and proficiency. The authors redefined the original mapping of CT concepts to Scratch actions to be suitable to Pocket Code actions. Not all features of Scratch are available in Pocket Code (e.g. definition of block) or make sense on phones (e.g., mouse blocks or key tapped). These are replaced by equivalent actions or additional features of the Pocket Code app. Table 1 shows the matrix of CT concepts to Pocket Code actions based on Dr. Scratch. Adjustment to Pocket Code are highlighted in italic. Note that sprites in Scratch are called objects or actors in Pocket Code and backdrop are called background in Pocket Code.

## 4 Results and Discussion

We developed three different theoretical concepts in order to describe the tutoring experience in relation to the teenage girls' attitudes to programming and the tutoring orientations and styles and the sex of the tutors. In a second step, these results were compared with the evaluations of the coding projects in order to show the relationship between girls' types of attitudes and the complexity of their final projects.

### 4.1 The Tutoring Experience

We start by introducing the typology of teenage girls' attitudes toward programming. This is followed by a description of the tutoring orientation by male

**Table 1.** Mapping of CT concepts to Pocket Code programs based on the analysing system of Dr. Scratch

| CT Concept | Basic (1 point) | Developing (2 points) | Proficiency (3 points) |
|---|---|---|---|
| Abstraction and problem decomposition | More than one script and one object | Definition of blocks—Use of functions | *Use of clones—and use of physics bricks* |
| Parallelism | *Two scripts on green flag—when scene starts* | *Two scripts: key pressed, on sprite clicked—when tapped or when screen is touched* | Two scripts: when I receive message, create clone, when %s is true, background change to |
| Logical thinking | If | If-else | Logical operations |
| Synchronization | Wait | Broadcast, when I receive stop scripts | Wait until, when background change to, broadcast and wait |
| Flow control | Sequence of blocks | Repeat, forever | Repeat until |
| Interactivity | *Green flag –>Sensor values* | *Key pressed, object clicked, mouse blocks—touches property* | *video, audio, + vibration, pen brick* |
| Data representation | Modifiers of objects' properties | Operations on variables | Operations on lists |

and female tutors. The third concept describes the interaction of teenage girls' attitudes toward programming and the tutoring orientation that could result in four forms of tutoring styles. Finally, the analysis of the games created by girls is presented.

**Typology of Teenage Girls' Attitudes Toward Programming:** Teenage girls' attitudes toward programming can be differentiated on an activity level to describe the tutees mode of cooperation and participation in the programming activity. Subordinated to this, the interest and the security level have a strengthening (interest, security) or weakening (disinterest, insecurity) effect on the extent of the teenage participants' activities. Teenagers girls' attitudes toward programming represent a continuum with two poles, active and passive. In this model, on the two ends of the active-passive continuum, there are girls with an active attitude on one hand and girls with a passive attitude toward programming on the other. These two characteristics of the typology will be described in more detail to show how teenage girls' attitudes toward programming influence their participation and cooperation in tutoring units, their perception of the tutor, and how these experiences are related to stereotypical opinions and expectations of IT and gender. We further present the numeric distribution of the two characteristics in the conducted tutoring sessions.

*Active Girls:* Girls with an active attitude toward programming tried to get involved, cooperated and wanted to make decisions about their own games in the tutoring sessions. They were either generally interested in programming or confident in their abilities or both. Usually, at the beginning of the tutoring unit, they clearly presented their developed idea of the game and stuck to their idea even if the tutor proposed another variation, as the following situation shows:

*Girl: Exactly and my idea would be, [...] I'm not sure know how to do it [...], but it would be a great idea for a second level. [...] Tutor: Well, I would suggest [...] that there might be an explanation at the very beginning. What to do?*
*Girl: No, no, no. [...] I don't know if it's absolutely necessary. (T36: 64ff.)*

These types of girls had thought through the realisation of their ideas in the Pocket Code app and explicitly requested information or explanations from their tutors which they subsequently evaluated. They self confidently corrected their tutors if they did not understand something correctly or rejected his or her proposal if they did not like it. Girls with characteristics of the type active attitude liked to work independently without tutors. This strong desire to be able to work on their own meant that they expected their tutors to listen to them and support them realising their ideas. If tutors did not meet these expectations, active girls were disappointed by the tutoring sessions.

This active type of girls reported strong inhibiting effects of stereotypes on their interest and commitment toward programming in the group discussions: *"[...] people just think programming [...] that's something for boys and not for girls, (...), because if a girl engages in programming but only boys are there then, you feel somehow uncomfortable, because then everyone thinks: yes, she can't do that anyway. And... it's a bit unfair that you think that way, because... that's why there's ah... there are so few girls who are interested in it. And... [...] yeah... I would do it more often." (GD1, 229ff.).*

The girl expressed her general interest in programming but felt limited in following these interests by gendered stereotypes and expectations she described as unfair. The girls were aware of existing stereotypes and reflected on the effect of those and on how they felt in a male dominated field. The impression that others had low expectations in their skills exerted pressure on teenage girls and they consequently might turn away from programming. This is in line with Kessels et al. [19] who describe that the decision for or against the engagement in a certain area serves as a way of identity construction. Consequently it is unlikely that teenage girls develop or cultivate interest for programming, if they experience the field as solely masculine. In about 67.5% of the evaluated tutoring units, the teenage girls showed an active attitude toward programming, i.e. high level of commitment in the tutoring sessions and were characterised by a high degree of independence and intrinsic motivation.

*Passive Girls:* Girls with a passive attitude toward programming showed little or no effort to develop and realize their own ideas. They did not actively participate in the tutoring sessions and were either uninterested, insecure, or both. They voluntarily handed over the control of their game to their tutors and gladly followed their tutors' suggestions:

*Tutor: So what do you want to happen when you tab the "Play"-button?*
*Girl: Ahm. Maybe I don't know, she could also like... She could like wink (blink?) with the eye or so like or I don't know.*
*Tutor: Ok. Like add another look.*
*Girl: Ok so should I go back?*
*Tutor: No, is this what you want as your game? I mean we can just take the scripts we have for the object [...] and put it into the object of the play button so that she changes her eye shadow colour [...]*
*Girl: Oh, ok ya. We could do that. [...]*

Girls of the passive attitude type prefered to be tutored by those who gave clear commands and decided the next programming steps. If this did not happen from the start, as in the example above, the girls actively asked for help and suggestions. In addition to that they perceived too many questions or too few direct commands unpleasant as they did not feel competent enough to come up with their own ideas. The impression that programming was not for them was likely to be confirmed in such tutoring sessions as the girls had the impression that they were not capable of coping with technical challenges. Gender stereotypes about programming thus nourished their self-doubt and insecurity. In the group discussions, they referred stereotypes to justify and legitimise their refusal to participate actively in the programming sessions: *"I don't know girls sit together often and... talk, gossip, do make-up [...], and boys... play some PlayStation-games together and then maybe the thought comes up that they want to do it themselves, or... kind of just because they are more into computers and stuff" (GD7, 279ff.).*

This teenage girl described dichotomous and opposing characteristics of girls' and boys' interests. She positioned herself in the group as a typical girl and consequently clarifies that programming was incompatible with her self-perception. This is consistent with common gender and IT stereotypes, which tend to attribute natural technical skills to men and social skills and preferences to women [20].

In about 32.5% of the recorded online tutoring sessions, the teenage girls showed a passive attitude toward programming. Depending on the degree of (dis-)interest or (in)security, passive girls did not actively cooperate and showed very little intrinsic motivation to participate in the programming process. This passive attitude was also reflected in the 26.9% share of verbal contribution in the transcripts of the tutoring sessions which was about 10% lower than by teenage participants with an active attitude toward programming. Furthermore, in tutoring sessions with passive girls, the extent of direct commands with 39% (code coverage) was clearly higher than in tutoring sessions with active girls, whose transcripts only showed 21% direct commands.

**Tutoring Orientations by Male and Female Tutors:** The typology of the tutoring orientation differs the way tutors offered support. On one end of the spectrum, there were tutors who supported their tutees by direct instructions and dictating, and on the other end there were tutors who ensured that their tutees reach their goals independently by giving hints and providing explanations. These two characteristics of the tutoring orientation typology will be described in more detail to show how the tutors' orientation shaped the programming sessions and further affected the tutees' inclinations on how to participate in their programming project as well as their overall learning experience.

*Dictating Tutoring Orientation:* Tutors of the dicating tutoring orientation were characterized by dictating the programming steps to their tutees. They anticipated most of what was needed instead of trying to motivate their tutees to think and try by themselves. Their focus was on the success of the programming project rather than the learning experience of the teenage girls. Due to this orientation on programming, the tutors took the more active part in the tutorings sessions and their tutees thus had to take the rather passive part of an executor of their tutors' command:

*Tutor: Right. And now "if position true ", there "if touched object elephant " and there it should be now, "send to all ", [...] and there we make a new, a new thing and we call it hit, ok and now you go up again.*
*Girl: But then we don't have to change "if you receive " or something?*
*Tutor: Yes exactly. I was just about to do that. Very smart (laughs). And it goes up [...] that means 'when program starts', we first have to put an 'if you receive' block over it. (T22, 93ff.).*

The sequence shows that tutors of this type did not respond to girls' suggestions or failed to recognize such attempts. Instead of honoring the teenage girls' knowledge, the tutor pointed out that her suggestion would have been the next step he was about to take. Instructions via a dictation mode that were not accompanied by an explanation made it difficult for the tutees to develop an understanding of what happened during their tutoring sessions and subsequently made it hard to continue working on their script independently. Approximately 29% of the recorded tutoring sessions were from tutors with a predominantly dictating orientation. In those sessions about 18% of the tutors' verbal contribution were directives. We observed a slight gender difference as female tutors used 31% more directives while male tutors used 24%, in contrast to Mulac et al. [22] findings. One explanation for this outcome is the (over) adaption of women to the male dominated IT culture [12] that could also become visible in their language use.

*Supporting Tutoring Orientation:* Tutors with a supporting tutoring orientation intended to realize their tutees ideas and made sure that the tutees understood the programming process. Their focus was on the tutees, their ideas and their learning process rather than the programming output. They actively involved the teenage girls in the programming sessions by letting the tutees come up with their own ideas and solutions, yet guided by their tutors:

*Tutor: Yes, you could do a " hide "script with" looks " now, that it will be hidden after 20 s, but you know what could be the problem?*
*Girl: That you can still type it, right? [...]*
*Tutor: Yeah, it should. But what happens if you type it at 19.5 s, at 20 s you get a "hide " command, what happens at 20.5 s. Take a look at your script, maybe you will recognize it.*
*Girl: That it will be shown again, that Leonardo will be shown again, maybe. (T115, 314ff.)*

To encourage the girls' involvement, supportive tutors were asking questions about the tutees' own ideas, their knowledge and skills, or the next programming step. Besides their involvement through questions, tutors offered explanations to the programming sequences. Such supporting tutoring orientation allowed tutees to take an active part in the tutoring sessions and their own programming project as they were supported to understand what and how they were programming and subsequently felt encouraged working on their script independently.

Approximately 71% of the recorded tutoring sessions were from tutors with a predominantly supportive orientation. We also detected a gender difference in language use during these tutoring sessions which was in contrast to Mulac et al. [22] findings, as male tutors used more explanations (31%) than the female tutors (22%). However, the verbal share of the teenage girls' active participation (explanations and suggestions) in the recorded tutoring sessions did not significantly differ between male and female tutors.

**Tutoring Typology:** On the basis of the two topologies of teenage girls' attitudes and the tutoring orientation, we developed a typology of four tutoring styles. These results show that the tutoring experience is shaped by the interplay between tutees' attitudes to programming and the tutors' orientations and that it is necessary to take both parts into account in order to reach the best learning experience and outcome, see Table 2. We will describe these four forms of tutoring styles - authoritative, collaborative, motivating and instructive - in more detail in order to illustrate this interplay.

*Authoritative Tutoring:* In the authoritative tutoring style, tutors with a dictative orientation met girls of the type active attitude. This combination resulted in step by step instructions by the tutors in imperatives without any explanations. Consequently, there was little or no room for independent work for the teenage girls. In sessions with an authoritative tutoring style there was constant negotiation of the active position in the session and the decisions about the game. On the one hand, the tutors wanted the girls to follow their instructions to program a functioning project. On the other hand the girls repeatedly tried to get involved, to take over control themselves and realise their gaming idea:

*Girl: I would like it...*
*Tutor: Not to this but above so you need the block "When program starts"*
*Girl: Ah yes...*
*Tutor: And just do "When program starts" above, one up okey does not matter.*

*Girl: Yeah. [...] I'd just like to have it underneath but...*
*Tutor: Then you just take x 0 and y -500. (T80, 115ff.).*

The sequence illustrates how the repeating attempts to intervene and participate in the programming process failed as the tutor interrupted the girl with his commands. For these active girls, who would have liked to understand how to implement their tasks and prefer to work independently, such tutoring style was very frustrating. With the result that they stopped participating actively and ended up in a rather passive position. Consequently, this tutor/tutee constellation was unlikely to provide a positive learning experience or success and did not meet the purpose of mentoring to offer teenage girls role models, support, encouragement, and confirmation [10].

*Instructive Tutoring:* In the instructive tutoring style, tutors with a dictative orientation met girls who were categorized as having a passive attitude. As already described, these tutors mainly spoke in imperatives, explained little and took the active role in the programming process, but with the difference that they met passive types of girls who expected and demanded this kind of instruction:

*Girl: Okay. Should I, what should I do?*
*Tutor: We have to redo the background.*
*Girl: Good. How to do it? [...]*
*Tutor: Go back, once again, and now SLOWLY (laughs) open the backpack, unpack, select the owl and unpack as object. [...] And now [...], delete or if you want, you could just disable it.*
*Girl: Okay. How to disable something? (T1, 111ff.).*

Both the tutor and the tutee had their fixed positions in these sessions, the tutor gave commands while the girl executed them or requested new directions for each step. Therefore, there was no negotiation for control or participation in the programming sessions. Although the tutor could follow his interests of programming a game according to his or her ideas and the girl could hold on to her passive attitude this instructive tutoring style did not provide a positive learning experience nor success. Because it did not promote the girls' interests and ideas or lead to an acquisition of programming skills, it rather reinforced gender stereotypes than eliminating them and thus clearly failed the purpose of mentoring in IT [2,10].

*Motivating Tutoring:* The motivating tutoring style occured when tutors with a supportive orientation met girls of the type passive attitude to programming. Tutors with a supporting orientation tried to encourage the girls to think and work independently. They explained a lot and tried to involve the tutees by constantly asking questions:

*Girl: And now?*
*Tutor: When do you want to go the rope, the position from the rope in the picture. Immediately right?*
*Girl: Yes, but how do I do that?*
*Tutor: Now you have to ask yourself when does the program need to do that?*

*Immediately after start, or when it's tabbed or.*
*Girl: Ahm, immediately...I think. (T95, 101ff.).*

This tutor met a tutee with a passive attitude to programming who prefered to stay passive and did not like questions that require her involvement. If these girls were disinterested, they were annoyed by the constant requests of the tutors for more cooperation. The situation was different if the girl showed a passive attitude due to uncertainty: Here, supporting tutors offered an opportunity to experience a positive programming session. After such sessions the girls were surprised about their abilities and rated themselves as "better than expected". This experience had the potential to correct stereotypes and thus to encourage adolescent girls to engage in programming activities which they were not interested before, one of the central concerns of mentoring in the IT-sector [2]. Consequently, this tutor/tutee constellation could provide a positive learning experience and success when insecure girls were guided by their tutors and thus decide on their projects and understand the programming process in detail.

*Collaborative Tutoring:* In the collaborative tutoring style, tutors with a supportive orientation met girls of the type active attitude to programming. The kind of support that the supportive type of tutor offered was exactly what active girls preferred by asking questions and offering guiding explanations:

*Tutor: Right, we need to change the place. Where could that be?*
*Girl: Uhhhh, "motion" right?*
*Tutor: That's right, try "motion".*
*Girl: Ok and then you have to change the Y, right?*
*Tutor: There's... Exactly [...]*
*Girl: Okay, then... The upper one is better because otherwise you have to do both separately. [...] (T100, 104ff.).*

This girl prefered to work independently and asked for support when needed. In the tutoring session she determinedly participated in the programming process by frequently making her own suggestions or asking questions about additional know-how. Therefore, in tutoring sessions with a collaborative tutoring style a lot of negotiations or discussions took place: One side suggests something, the other reacts to it and together they negotiate and decide what the best option was. This tutoring style was ideal for girls with an active attitude to programming and fulfilled the essential functions of mentoring such as support, encouragement, and confirmation [10]. It offered a positive learning experience and success because of the detailed explanations given by the tutors and the constant possibility of thinking and working together. The girls could develop an in-depth understanding of their programming steps and felt in charge of their game. Same as the girls- and tutors typology, the four forms of tutoring could be strengthened by quantitative content analysis. Table 3 shows that in tutoring with a dictating type of tutor (authoritative, instructive) instructions and direct commands occured to a much higher extent than in tutorings with supportive tutors (collaborative, motivating). While in authoritative tutoring 57% of code coverage were instructions and commands, in collaborative tutorings they only cover 20%. Table 3 also shows the role the type of girls' attitude played: while, supportive tutors with passive girls (i.e. motivating tutoring style) explained a lot and gave only a few commands, the girls' participation was lower than sessions with active girls (i.e. collaborative tutoring style). Girls in general engaged more in the style of tutoring they felt most comfortable with: Girls of the active type preferred supportive tutors who let them engage which showed in the highest girls' share in the spoken exchange coverage (36,2%). The second highest share (30,4%) was shown in tutoring sessions with instructive style: the girls had a passive attitude to programming and thus felt comfortable with their tutors' commands.

**Table 2.** Code coverage in % according to tutoring styles

| Code coverage in % | Authoritative tutoring style | Instructive tutoring style | Collaborative tutoring style | Motivating tutoring style |
|---|---|---|---|---|
| Explanation (girl) | 8% | 5% | 10% | 3% |
| Suggestion (girl) | 2% | 2% | 5% | 3% |
| Directives (tut) | 32% | 26% | 14% | 17% |
| Commands (tut) | 25% | 16% | 6% | 9% |
| Explanation (tut) | 24% | 23% | 26% | 34% |
| Word coverage (girl) | 26.05% | 30.40% | 36.2% | 25.04% |
| Word coverage (girl) with tutor: male/female | 20.92%/27.38% | 28.39%/31.86% | 34.8%/38.2% | 24.16%/28.20% |
| N= | 8 | 27 | 80 | 8 |

## 4.2 Characteristics of the Programmed Games

In this section we will describe the characteristics of the final games the teenage girls programmed in the course of the RemoteMentor project. The results should provide a decomposition of the programs and show if and how often programming concepts were used. In contrast to the Dr.Scratch suggested analysis we did not count how often these concepts were applied but we counted the use of different concepts, i.e. the variety of concepts in each project. It happened that some concepts were applied very often, e.g. loops or broadcast messages when one had to intercept multiple clones of objects or copies of objects (i.e. separate objects).

In such situations, duplicated objects would give these projects high rates if we would have followed Dr. Scratch's approach here. For our analysis instead the project received points (1, 2 or 3) once per applied concept, according to the Table 3. A percentage of 28.79 of the projects included all three abstraction concepts, 46.07% of the projects had all parallelism concepts included, and 10.61% of the projects had all flow control concepts integrated. Regarding the data representation, 27.27% of the projects made use of basic and developing (properties and variables). The project with the highest score reached 26 points, and used 14 concepts while the lowest rated project had only 6 points with a use of 5 concepts.

### 4.3 Relationship Between Girls' Attitudes Types and CT Concepts Used in Their Games

Next, we tested the relationship between girls' attitudes types and applied CT concepts. Games made by girls of the active type received at average 18.78 points, games made by girls of the passive type or active/passive type, received at average 17,03 (passive: 18.24, active/passive: 15.33). Table 3 shows the girls' attitudes types correlated with the average values of the different CT concepts. We correlated the average usage of concepts within the different typologies of girls. The results were significant at $\alpha = .05$ at two levels: Girls of type active used significantly more CT concepts in their projects than girls who were once categorized as passive and once as active ($p = .0096$, $\alpha = .05$). Furthermore, girls of type active used significantly more concepts of data representation than girls of type active/passive ($p = .0296$, $\alpha = .05$). The results were significant at $\alpha = .10$: girls of type active used significantly more CT concepts of flow control than girls of type passive ($p = .0731$, $\alpha = .10$) and active/passive ($p = .0901$, $\alpha = .10$). Additionally, girls of type active used significantly more CT concepts of data representation than girls of type passive ($p = .0910$, $\alpha = .10$). Overall, passive girls used more CT concepts of abstraction and problem decomposition (such as clones and physical bricks), more concepts of logical thinking (such as other-if conditions), and more concepts of interactivity (such as sounds or vibration components), but not significantly. One could assume that girls of the passive type received more instructions from their tutors on the use of competence concepts that were not discussed in the class before, such as clones or physical bricks, or that they needed more motivation and were encouraged to use sound or other effects in their projects. So it can be assumed that many CT concepts that were of the "proficiency" type were suggested by tutors. Girls of the active type used the inclination sensor variable very often, which was part of their tutoring game before they started their own project. This shows that they independently made use of the skills acquired in the course of the RemoteMentore project.

**Table 3.** CT concepts in relation to girls' attitudes types (*significant at $\alpha = 0.05$, **significant at $\alpha = 0.10$)

| | Type active | Type passive | Type active/passive | Total |
|---|---|---|---|---|
| Abstraction and problem decomposition | 58.56% | 61.76% | 45.83% | **57.07** |
| Parallelism | 80.63% | 70.83% | 73.61% | **76.77%** |
| Logical thinking | 13.96% | 20.59% | 16.67% | **16.60%** |
| Synchronization | 31.53% | 31.37% | 25.76% | **30.30%** |
| Flow control | 56.31% | 48.04%** | 47.22% ** | **52.52%** |
| Interactivity | 38.74% | 45.10% | 25.00% | **37.88%** |
| Data representation | 58.56% | 26.47% ** | 22.22% * | **29.55%** |
| Total | **46.12%** | **44.89%** | **37.60%** * | **44.25%** |

## 5 Conclusion

The results of the sociological analysis showed that rather than the sex of the tutors itself, it was the nature of their tutoring that framed the introductory programming experiences of the teenage girls. These results show to what extent the tutoring experience depends on the combination of teenage girls' attitudes toward programming and the different tutoring orientations and styles which can lead to both positive and negative outcomes of the learning experience and success. These results further indicated that girls of the type active attitude or insecure passive attitude with persons of supportive tutoring orientations benefit from such one-on-one remote tutoring sessions. Which implies in further projects the deployment of tutors with a supportive orientation and also well educated and sensitizes to gendered aspects in CS and IT. The results of the analysis of the CT concepts showed that throughout girls of the type active applied more CT concepts than girls of mixed types, but overall projects made by girls of the type passive attitude included more CT concepts of abstraction and problem decomposition, logical thinking and interactivity of the type advanced and proficiency. These concepts were not discussed in the first units (before starting their actual game) and were probably proposed by the tutors. This shows that girls of the passive type were more likely to be encouraged to use advanced concepts, while girls of the active type were more likely to independently integrate concepts they had already heard about in the introductory unit and overall used significantly more types of different CT concepts. It remains open whether the girls of the passive type who used these advanced concepts also understood them, as opposed to simply following the instructions of the tutors. This also became visible during the focus group discussions. Gender stereotypes also found its way into the experience of the project. Teenage participants (esp. passive girls) tended to evaluate programming projects such as the RemoteMentor project critically: They stated their impression about a (hidden) agenda behind these kinds of school projects: to get all of them interested in programming regardless of their general interest in IT. Something they evaluated as pointless as they did not believe in someone's willingness to fundamentally change their interests. This resonates with the gender equity discourse [1] that identifies the cause of the low female share in the IT-sector in womens' attitudes and thus aims to change them than the IT-sector or the male dominated environment. The open and probably repeated communication of project goals are thus fundamental in school contexts. The relationship between tutors and tutees was only task-based and could not develop into a deeper relationship due to the short project duration and the nature of online communication. The effect of role models or the dilution of stereotypes was thus limited and short-termed. This short- termed and tasked-based relationships were furthermore problematic, especially for insecure teenage girls who would have prefered to be tutored by more familiar persons or at least female tutors, as Blake-Beard et al. [4] argued, they would have felt more confident with members of their own gender group. However, these teenage girls in our study stated that after their first online programming session they felt more confident about the online tutoring and did not mind about the tutor's gender. In summary, the remote tutoring proved to be a promising approach to support, and motivate at least a certain group of female students when they were supported by adequately skilled tutors in programming.

## 6 Outlook

In the future, the Catrobat Community Platform will be extended with social communication features which focus more on the principle of helping each other. Currently, our platform is very limited and is only used to upload projects from the app and share them with the world. Other users can download and play them, and further view and modify the source code, and then upload their new version again (i.e., remix). To support social communication features, several improvements are planned. Users will be able to ask questions online and will be connected to other users in chats who can help them. These principles are inspired by online computer games, in which players who do not know each other are automatically connected and can play together [15]. This also removes a hierarchy or barrier that occurs in a tutor/tutee relationship and promotes working in collaborative coding teams, following the principle "teaching is the best learning".

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# A Holistic Pedagogical Model for STEM Learning and Education Inside and Outside the Classroom

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**Abstract.** This article discusses how to innovate STEM learning and education in- and outside of the classroom. It proposes to use a holistic framework for pupil-centered learning processes called Learn STEM. It was developed by an international research consortium based on the findings from mixed methods research. The research included a literature review, semi-structured interviews and three online surveys with the participation of teachers (n = 217), headmasters (n = 24) and learners (n = 354) from more than ten countries. Furthermore, the findings from the mixed methods research are also informing the international research consortium to design a teacher training programme and to develop an online course. This article provides first summaries of the research results related to the holistic pedagogical model and to the training programme. After a short overview of the final holistic pedagogical model Learn STEM, the paper presents one example how the holistic pedagogical model Learn STEM can be used for improving STEM learning and education outside the classroom. Finally, an outlook for future research is focused.

**Keywords:** Holistic pedagogical model · Learn STEM · STEM learning · STEM education

## 1 Background

The whole world is changing in our so called "digital age": Thus, societies and their citizens are confronted with increasing demands (Organisation for Economic Co-operation and Development 2016; Stracke 2011; World Bank 2016). More competitive 21st century work environments require the building and continuous improvement of strong competences and abilities, in particular within science, technologies, engineering and mathematics (STEM) (Stracke 2014, 2019; Weinert 2001). Thus, learner should develop profound knowledge, skills and competences that they can apply in all areas of life, with special focus on transversal competences such as team work, rational thinking


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and investigative and creative work (Dewey 1966; European Commission 2007; Piaget 1953; Rousseau 1968; Stracke 2012a, 2012b; Vygotsky 1988; Westera 2001).

To address innovations in STEM education in schools, an international research consortium was established to address and improve the quality and efficiency of STEM learning and teaching (Stracke et al. 2019a). The research consortium designed Mixed Methods research and conducted it with the overall aim of the development of a holistic pedagogical model for learning STEM (Stracke et al. 2019b). To facilitate its introduction and implementation, a teacher training programme and an online course are planned. Therefore, the consortium consists of a combination of research partners, secondary schools and teacher training providers from six European countries.

This article presents briefly the design and methodology of the Mixed Methods research (Sect. 2) and provides an overview of its key findings related to the pedagogical model (Sect. 3) and the teacher training programme (Sect. 4). In the following, the holistic pedagogical model Learn STEM will be introduced (Sect. 5) and its application for STEM learning and education outside the classroom will be discussed through the example of the Tiny House project (Sect. 6). The article concludes with an outlook on the next future activities, challenges and further research demands for innovative STEM education inside and outside the classroom (Sect. 7).

## 2 Research Design and Methodology

The international research consortium Learn STEM started the Mixed Methods research with a literature review providing an in-depth overview of the current status of STEM education in schools and the needs for its changes and improvements. The research findings were quite homogenous: there is a huge demand for innovative STEM education as well as for related teacher training and it could be summarized that further research on learner-centered and competence-based pedagogies is required (see e.g., Harlen 2015; Organisation for Economic Co-operation and Development 2016; Vasquez 2014; World Bank 2016).

Thus, the research consortium has developed a strategy and plan for a three-year Mixed Methods research that integrates surveys and interviews. The overall objective of Learn STEM was to design a holistic pedagogical model based on informed the results from literature review, surveys and interviews to improve and innovate STEM education in schools in the future.

The pedagogical model was developed and continuously revised and improved in iterative cycles leading to 35 interim versions in total before a final draft was launched (Stracke et al. 2019b). Several interim versions were presented and debated with the audiences in interactive workshops at international conferences: Consequently, the final draft included the feedback from school researchers, teachers and headmasters.

Furthermore, the research partners have generated three surveys on STEM education: one survey for teachers, one for headmasters and one for learners. The surveys asked the three target groups similar sets of questions items with the same clusters and formulations in addition to the demographic questions. Through this design, the comparison of the question was guaranteed. All three surveys were implemented and published at the same time by the Learn STEM coordinator. They were online accessible for all interested persons worldwide opening on Friday, 22nd of February 2019 and closing on Friday, 14th of June 2019 after 16 weeks.

The following sections present the key findings of the Mixed Methods research related to the pedagogical model Learn STEM (Sect. 3) and the teacher training programme (Sect. 4).

## 3 Research Results on the Pedagogical Model

Teachers, pupils and headmasters have been asked with respect to their beliefs of STEM, their opinion on the main aspects of the pedagogical model for innovative STEM education and the Learn STEM Inquiry Learning packages with some more detailed examples of STEM Teaching. The majority of participants has been pupils (354) with a bias from the Netherlands (111), followed by teachers (217) with a bias from Portugal (111) and 24 headmasters from six participating countries.

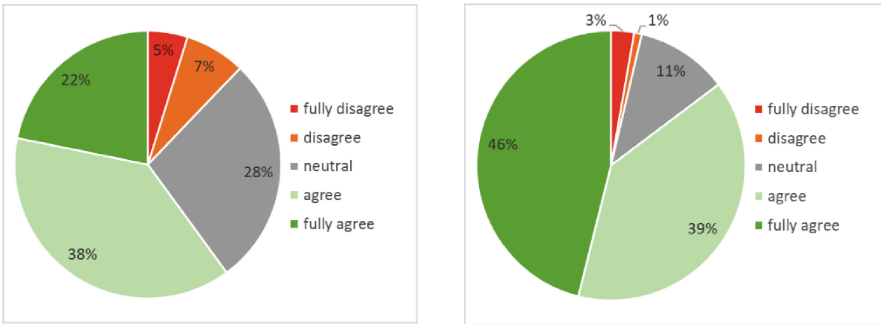
The largest group of pupils was in the age from 14–17 (69.4%), whereas the largest group of teachers was between 45–54 (40%) and headmasters between 55 and 64 (45.8%).

A relatively large part of pupils could not decide whether their STEM education is exciting or boring (49%). Only 32.8% found it exciting. This contrasts to 51% of the learners who recognize the importance of STEM since they stated that STEM is important for the future employability and career opportunities. These data may point to the rather large human potential, which can still be explored and developed in order to increase motivation and enthusiasm for STEM. The view is supported by the results of 39% who would like to have more STEM education in their schools and 41% who cannot decide. The latter rather large group of learners seems to correspond to the large number of pupils who are not satisfied with the way STEM is taught nowadays. The present situation in school is good only for 33% and 23% do not like the way how STEM education appears in and outside the lessons.

The approaches how to improve STEM educations in the developed pedagogical model are well received by the learners. Most importantly, 60% of the learners support the idea of practical exercises in order to increase and develop STEM interest and ability. 57% state that real life projects are helpful to learn STEM topics and also 57% are motivated to work in groups with their classmates to search for solutions (and only 9% disagree on that).

The response to the training aspects in STEM education has been more divers since 45% think that repeating tasks and content is helpful to obtain a good learning outcome but 14% disagreed on that. The same picture appears when the learners are asked about self-controlled learning without a prescribed curriculum since 32% like this idea, but 20% dislike it and the majority cannot decide. This indicates that the usage of new approaches in STEM education is not only a challenge for teachers, but also for learners since they need to be become more independent and responsible.

Although 53% of the teachers are not teaching STEM 62% would like to increase the time devoted to STEM education in school and 76% want to see this integrated in the school vision and policy. Interestingly the teachers, who have been asked in the 6 different countries with rather different educational systems, have strongly agreed on the most important aspects of the pedagogical model developed in the Learn STEM project. 85% support the concept of practice during the learning process. Figure 1 illustrates the response of teachers and learners to the question of the usefulness of practical exercises during STEM education. Clearly the high potential of this area for future developments can be seen. But also more than 75% agreed that STEM education should be complex, social and process-oriented. Even 69% support the idea of holistic STEM education.



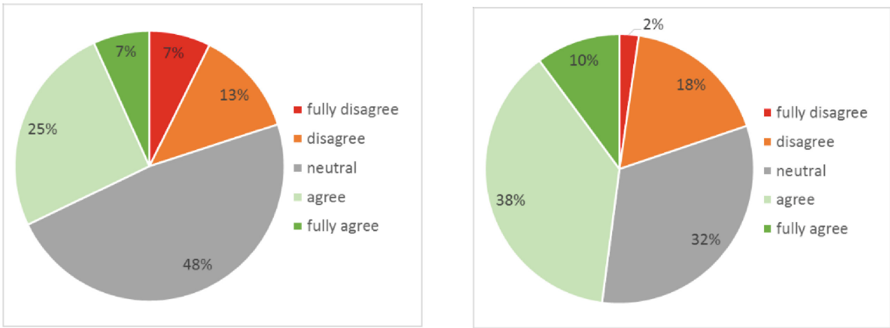

A) B)

**Fig. 1.** Responses on practical exercises by A) the learners and B) the teachers.

The overall support of the developed pedagogical model is rather clear with 74% agreement on the usefulness of the approaches for enhancing the quality of school education. However, in few aspects the picture is more divers. 48% think that STEM education should be self-regulated by the learner, whereas 20% disagree and 32% are not decided. Figure 2 compares the response on the question concerning the self-regulation of teachers and learners. It points to the necessity of changing the established roles of teachers and learners or at least modifying them. 57% of the teachers support the concept of repeating tasks and content as essential in the STEM learning process, whereas 19% disagree on that. The opinions on the balance between specialized topics and general knowledge vary significantly since 34% recognize too many specialized topics, 21% disagree and 45% are neutral with this.

Interestingly the group of headmasters – although not very large – is most supportive for the new concepts in STEM teaching. Here 96% would like to increase the time spent for STEM topics and 79% want to increase the quality in STEM education. Here the importance of the STEM area for the future development of the society is very well recognized. Concerning the five aspects of the Learn STEM model: Complex, holistic, process-oriented, practical and social, 88% are supporting these ideas. 92% think that the model is useful for improving STEM education in the schools.

The headmasters are also open to new conceptual ideas in implementing improvements in STEM education and agree with 76% that the process should be self-regulated. They also recognize that repeating tasks and content is helpful to the learning process with 50% agreement. However, with respect to the balance between general overview and many specialized topics the result is also divers as for teachers and learners: 41% state too much focus on specialized topics and 30% disagree.




A) B)

**Fig. 2.** Results of the survey by A) learners and B) teachers on the question whether self-regulated learning without prescriptive curriculum is helpful in STEM education

In addition to the survey personal interviews have been carried out in the different focus groups. Here there have been 58 participants, with teachers as the largest group (36). In general, the situation of STEM education in school has been reflected and the main ideas of the pedagogical have been discussed. Beside the points, which have already been analysed after the questionnaire, some new aspects have been evolved during these personal discussions. Interestingly the discussions did not question the proposed approaches, but concentrated constructively on the implementation of the model and how potential difficulties can be overcome. Obviously the pedagogical model has met actual demands and wishes of learners and teachers as well. One can group the discussion points accordingly:

a) Aspects which are connected to humans

Teachers are not trained for self-regulated and interdisciplinary STEM teaching. In several countries they need to overcome borders between different disciplines and they need to learn to work together with teachers of other subjects. Teachers will also have to accept to become learners since not all actual subjects will have a backing by the study course they chosen previously.

Learners are also not trained for self-regulated learning and thus, have to learn to work on projects and take responsibility. This might be complicated by the fact that many pupils do not know in which direction the professional career will go after school; thus, it is very important to connect STEM education with everyday life problems.

b) Institutional aspects and regulations

In many countries the aim to have motivated and well-trained pupils is well recognized, but a tight curriculum hinders flexibility in developing new approaches in school. Engaged teachers have to find a compromise between training for exams and the personal development of pupils. For interdisciplinary work several teachers have to work together which also needs organization and planning in the school.

c) Technical and financial aspects

Since practice during the learning process is so important, the technical basis for experiments in the different fields is essential. This is not only connected to computers, but mainly to hands on experiments in physics, chemistry, biology, engineering or interrelated topics. Here new ideas for collaboration of schools or schools with research institutes or companies are necessary. However, also governmental institutions need to be approached.

The mixed method research, which has been performed in the six participating European countries, has clearly shown the necessity for improvements in STEM education. It also verified that a more holistic approach with interdisciplinary focus, aspects of self-regulation, practical experiments and training modules is an attractive way to go. The surveys and the interviews have also allowed a further specification and development of the five basic characteristics of the pedagogical model which will be shortly explained in the following Sect. 5. Before, the Sect. 4 will present an overview of the findings from the Mixed Methods research on the training programme.

## 4 Research Results on the Teacher Training

In order to define a training programme valid for different European countries and in line with the European policies, based on a common methodology and set of instruments, the partners conducted a survey and interviews during the focus groups with different types of stakeholders: school management, school staff and students. The presence in some interviews and/or focus groups of teacher trainers, curriculum developers and policy makers strengthened the results of the inquiry and attributes a validation to the conclusions and recommendations. The results of these interviews, together with the analysis results, were used for defining the concrete skills and competencies trainers need for being able to successfully teach STEM using the pedagogical model Learn STEM.

An important aspect of the research was to discover what content should be included in the teacher training programme in the view of teachers and principals. The results from the teachers and the principals were very much in line and did not include any contradiction. When we look at the ranking, given in both survey groups, to the content that needed to be included in the teacher training programme, we notice a very similar image (Table 1).

**Table 1.** Top 7 of the content that needs to be included in the Teacher Training Programme.

| | Teachers | Principals |
|---|---|---|
| 1 | Development of interdisciplinary modules | Development of interdisciplinary modules |
| 2 | Soft skill enhancement | Soft skill enhancement |
| 3 | Open content material | Learner-centred pedagogics |
| 4 | Learner-centred pedagogics | Self-regulated competence building |
| 5 | Self-regulated competence building | Holistic view on STEM |
| 6 | Curriculum design | Curriculum design |
| 7 | Holistic view on STEM | Open content material |

The only small difference is that teachers attribute a higher importance to the development of open content material then the principals, while principals value more the holistic view on STEM.

In some countries the educational material is provided by Ministries of Education, official Education Authorities, educational publishers or networks of schools. In other countries the teachers have the autonomy to develop their own educational material. As in the participating countries, STEM is recently introduced, there still is no established tradition of providing good examples of STEM content. This can explain the higher need teachers express, to have access to have to open content material.

The society requires every time more that schools prepare the learners to understand general ideas, rather than accumulate specialised knowledge. Also the emphases on the ethical component of STEM and its contribution to the learners' personal development are asked by the society. Principals are responsible for the general policy of the school and that way they tend to have a broader helicopter view on the school. That way they are more sensitive towards demands and thus to a holistic view on STEM.

Based on the analysis of the online survey, interviews and/or focus groups of the teachers and principals, the teacher training programme must at least include aspects of pedagogics, didactics and assessment. A short introduction on the rationale why STEM is needed, can be useful. Teachers and principals ask to develop fresh, sprinkling ideas and examples to implement real life STEM education with research activities and a cyclic approach.

Teachers and principals want to include the development of interdisciplinary modules, soft skill enhancement, learner-centred pedagogics, self-regulated competence building, curriculum design and the holistic view on STEM next items in the teacher training programme. The teachers also favour the development of open content material. This question is addressed through the Inquiry Learning Package that also is a part of the intellectual outcome of the project.

When selecting or presenting examples and exercises in the teacher training programme, one must be aware of gender-related background. The teacher training programme should also prepare teachers to tackle gender in their STEM teaching. This conviction was reported to us during the interviews and focus group with teachers and teacher trainers. While principals didn't bring this up spontaneously, they all agreed when this idea was discussed.

The survey, interviews and focus group with the learners, revealed that the learners believe their teachers could make STEM subjects more interesting by changing or adjusting the pedagogical and didactical approaches. The learners are pointing towards the importance of a modern and challenging learning environment in which real life and practical exercises are included. In a STEM project the different topics should be present and the focus of the project should be oriented to the exploration and research, rather than purely to the end result or end product. The use of activating teaching methods, less frontal teaching, development of the 'investigation skills', stepping away from 'lecture-style' teaching and moving towards more practical exercises, are the most common given examples the learners bring fort worth, to make STEM teaching more attractive. Practical exercises such as experiments, computer work will increase the interest of the learner in STEM (survey results: fully disagree and disagree: 12%).

A second reported set of aspects relates to the education system and the school organisation. Interesting and effective STEM teaching needs a certain degree of autonomy and flexibility. When the curriculum rigidly decides on the content and didactical approaches of every lesson, when the teachers are strictly obliged to follow text books with prescribed exercises, a motivating and qualitative level of STEM teaching cannot be achieved. Learners ask for a flexible school organisation that allows outside activities, study visits to laboratories, research centre or enterprises. A flexibility that empowers their teachers to include also non-formal learning, multi-media, iterative learning, practical work and more experiments into their STEM teaching.

And finally, learners report that the use of traditional assessment methods where only the result is evaluated, isn't consistent with the idea of a process-oriented approach where learners discover STEM in a self-regulated and creative way through exploration and creation. Especially learners from countries with an examination system, based on a very detailed list of content, are afraid that this central assessment doesn't reflect their learning progress, their gained STEM knowledge and their build STEM skills. This is for sure the case when the final evaluation still is composed out of separate subject goals, and not inspired by the interdisciplinary character of STEM-learning. This concern was also brought up during some interviews with teachers and principal.

In summary, the survey results of the teachers and principals are mainly focussed on the improvement of the pedagogical and didactical knowledge and skills. Teachers also emphasise the need of having access to open content material. The analysis of the learner's survey indicate that their motivation can be enhanced by being offered activating, practical and real life teaching in a flexible educational environment with an appropriate assessment. We took this in account when editing the teacher training programme, STEM examples and STEM exercises. This resulted in a proposed structure (Table 2):

**Table 2.** Learn STEM teacher training programme.

| Modules | Structure |
|---|---|
| 1. Introduction: Why STEM learning in schools? | Introduction<br>Presentation of the four subjects of STEM |
| 2. Pedagogical characteristics | Introductory exercise<br>Explanation of the Pedagogical Model and its 5 elements<br>Exploration of the Pedagogical Model using an existing STEM lesson<br>Reflection on the use of Pedagogical Model<br>Reflect about the whole cycle<br>Continuation in peer-cooperation |
| 3. Didactical realizations | Introduction<br>Human Centred Approach<br>Scaffolding<br>Open, problem-based learning<br>Closed methodologies<br>Additional training methodologies |
| 4. Assessment approaches and tools | Why do you assess<br>Who will assess?<br>What to assess?<br>When to assess?<br>Ways to assess? |

## 5 The Holistic Pedagogical Model

The pedagogical model Learn STEM focuses on the learner who shall become the owner of their own learning processes (Stracke et al. 2019b). Thus, the role of teachers needs to change: teachers should facilitate such learning processes and act as coaches. However, teachers may also guide and supervise the learning process. Learn STEM can be combined with other approaches and methodologies to learn and teach STEM.

Learn STEM is based on educational theories and positions and focuses mainly on the following five characteristics of the learning process (Fig. 3):

- Complex
- Process-oriented
- Holistic
- Practical

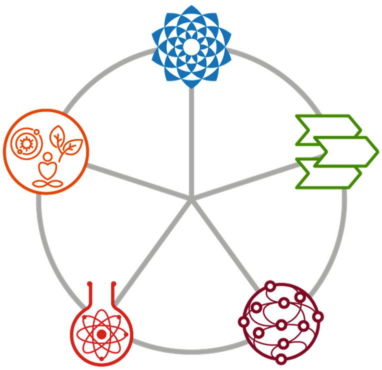


**Fig. 3.** The pedagogical model Learn STEM.

- Social

Learn STEM addresses three core elements: knowledge, skills and competences. Learners can gain STEM knowledge and build STEM skills. Through their reflection and iterative training, learners can build STEM competences following the principles of assimilation and accommodation. As presented in Learn STEM, the learning process should be interdisciplinary and holistic. Learning is considered as a process with iterative quality improvement cycles. Accordingly, Learn STEM allows flexibility for the teachers who can act more as a coaching mentor or as an instructing tutor depending on the situation in their intended STEM learning and given educational system.

Training modules for teachers help them to support learners solidifying acquired algorithms and knowledge and gaining confidence in using them. Practical courses are valuable tools for the learners during the learning processes as they allow to expand knowledge as well as to develop practical skills. In everyday life tasks, learners can demonstrate and use their knowledge and skills and successfully apply their developed competences in new situations.

Learn STEM incorporates The complexity of STEM learning activities is integrated in Learn STEM and relates them to the diverse STEM disciplines as well as to other (STEM) areas: Learn STEM connects STEM education and learners with our society and offers insights into the complex relationships between STEM and the whole society.

Through that approach, Learn STEM wants to discover and to stimulate the interests of STEM learners and their ability and motivation handling different perspectives of science, technology, engineering and mathematics. As a consequence, Learn STEM may encourage more pupils to select and follow a career in STEM professions. This may help to meet the demands of the society including the search for innovative scientists and engineers who are well educated, motivated and able for critical and design thinking as well as orientated to problem solving.

In order to stimulate the interest in STEM topics STEM education has to take steps out of the class room. This is on the one hand connected to topics which relates STEM topics to everyday life problems, but it also comprises the contact to companies and research institutions. By this the learners will be in a new environment and come in contact with new topics and problems. This can create attention and stimulate the engagement with STEM-related content. Besides that, the contact to persons, who are working in the STEM field, can help to open professional perspectives for the learners and to develop own aims and objectives.

## 6 Example for Using Learn STEM Outside the Classroom

In this section, we present one example for the usage of the holistic pedagogical model Learn STEM outside the classroom (Stracke et al. 2019a, 2019b). It is used in the Agora school in Roermond located in the south of The Netherlands. The school is following a learner centered approach where pupils learn in small communities on challenges. These challenges are based on the interests of the pupils and most of these challenges are created by themselves. The teachers are called coaches and support the pupils in the learning process by guiding them through the different steps they have to make to solve their solutions for challenges. Experts are also involved in the process. These experts are expert in a specific domain.

In this case we want to explore the case of the Agora "Tiny House" project. This case is a typical case how pupils, experts and coaches learn in realistic challenges. The five pupils are between fourteen and fifteen years old. The team is completed with one coach and two experts in the domain of government and engineering.

The idea of the project Tiny House was born during a workshop on sustainable houses done by a parent of one of the pupils. He asked to help building a sustainable house with him, where he could live with his wife and children (Fig. 4).

**Fig. 4.** Workshop on sustainable houses.

A Tiny House can be described as a complete home with only the really necessary spaces for easy living but also sustainable. Natural energy sources are used such as sunlight, geothermal heat, etc. They are consciously built and inhabited based on the need to live a simpler life, less focused on consumption and with a smaller ecological footprint. The design and construction of small homes make smart use of space and innovative technologies. A Tiny House is max. 50 m2, ideally (partly) self-sufficient, of good quality and aesthetically built, functioning as a full-time inhabited home. Being mobile is not a condition but often a means, being completely off-the-grid is a possibility but not a requirement.

A big challenge for pupils to build a real product, the tiny house that meets the expectations of the client. The case was complex, because this was not a very easy challenge. A lot of different components are part of this case:

1. The construction and the layout of the tiny house concerning sustainability.
2. Finding solutions for basic needs like collecting energy, water management, heating the house with sustainability in mind.
3. Finding investors to finance the production of the tiny house.
4. Finding a location to place the tiny house.

To solve these problems, the team works in an agile and iterative way working and learning in different sub-teams. Every Wednesday morning the team came together for having a meeting. To guide the process, they have followed the Design Thinking method. Following this method, the pupils had to empathize, define, ideate, prototype, and test their products. Pupils were partly responsible of a part of the project. They have worked and learned from and with their experts. During the period of this project pupils have learned about how to connect to other partners outside the project, how to present their idea to potential investors and how to get in dialog with the government about finding a location. They also have updated or upgraded their knowledge and skills about how to construct a sustainable tiny house with all the requirements and restrictions (Fig. 5).

**Fig. 5.** Prototype of a tiny house.

The prototype of the tiny house has been realized by the team. The next step is to build the real tiny house and to find a location to live. More about the Tiny House project can be found at their website online: https://www.tinyhouse-agora.nl

## 7 Conclusions and Outlook

The paper introduces the holistic pedagogical model Learn STEM for innovative STEM education and explains its usage outside of the classroom through the Tiny House project. The pedagogical model Learn STEM was developed based on the findings from Mixed Methods research designed and realized by the international

Learn STEM research consortium. The Mixed Methods research combined an in-depth literature review with interviews in focus groups and three online surveys for teachers (n = 217), headmasters (n = 24) and learners (n = 354). The paper presents first results from the comparison of the surveys for teachers and headmasters: Teachers and headmasters share a similar perspective on the current STEM education with specific interesting differences. Overall, the grading on the usefulness of the pedagogical model Learn STEM was very positive by the teachers (74% fully agreed or agreed) and even better by the headmasters (92% fully agreed or agreed).

Accordingly, the findings from the Mixed Methods research, the international research team designs a training programme and an online course for teachers and headmasters. The objective is to initiate a debate on future innovative STEM education and learning in schools following the five characteristics from the introduced pedagogical model Learn STEM: complex, process-oriented, holistic, practical, and social. Research has analysed the opportunities for (open) online education and the needs and preferences to use it in (STEM education within) schools as well as lifelong learning (Stracke et al. 2017). The design and fulfilment of the appropriate quality is currently the main challenge for (open) online education (Stracke 2019): The re-usage and adaptation of international standards such as first ISO norm for technology-enhanced learning ISO/IEC 40180 (2017) and the Quality Reference Framework (QRF) for online courses and learning support the design of online education (Stracke et al. 2018). These first international quality standards were already applied and used as basis for the holistic pedagogical model Learn STEM presented in this paper. Furthermore, the online course for the teacher training programme of Learn STEM will also benefit from them.

It can be concluded that further research is required to precisely focus the specific requirements of school teachers and headmasters how they can introduce and facilitate pupil-centered STEM education with different approaches of open and closed methodologies inside and outside the classroom that is following the five principles of the pedagogical model Learn STEM.

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# Author Index