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PAPER

Designing, Coding and Embroidering: A Workflow for Gender-Sensitive and Interdisciplinary Teaching

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ABSTRACT

Research suggests that girls' initial interest in computer science tends to decline during their teenage years, a trend that is not observed among boys. This paper addresses this gender gap and proposes integrating programming into handicraft lessons to provide a creative activity for all students. The project was conducted in three Austrian schools over one year (2019–2020), involving 229 middle school students. The evaluation included questionnaires and the assessment of programmed and stitched designs to structure gender-sensitive workshops. While boys consistently reported higher scores than girls in interest, sense of belonging, and enjoyment, girls' scores remained more stable. However, girls were significantly more likely to express pride in their final designs than boys, and overall, more girls completed individual designs as final products. These findings can be applied to interdisciplinary handicraft lessons in line with the Maker-Education movement to foster interest in programming.

KEYWORDS

visual programming, Embroidery Designer, computational handicraft, female teenagers

1 INTRODUCTION

Skills related to digitalization are becoming increasingly important worldwide [1]. New technologies such as the Internet of Things, robotics, wearables/augmented reality, artificial intelligence, blockchain, or big data are leading to new products, production processes, and distribution channels. Ultimately, these technological developments are resulting in new occupational fields, activities, skills, and qualifications as well. Technology and disruption will change every industry in the future. According to the WEF study [2], "The Future of Jobs 2018," positive job growth is expected in the coming years; simultaneously, the quality, location, format, and duration of new jobs will change significantly. Jobs will shift between continents (more jobs in Asia and the US), and depending on the technology acceptance and adaptability of the workforce, the impact will vary across industries. Women in

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Europe, in particular, will be strongly affected, as they are often employed in commercial occupations that will be under pressure due to digitalization. STEM subjects (Science, Technology, Engineering, and Mathematics) are professions that are gaining importance with digitalization. These are precisely the fields where women are underrepresented (the share of women working in STEM in Europe currently is 18.4%; [3], [4]). Worldwide, 36% of women work in the "technology, information, and media" sector [5]. In addition, many professions associated with commercial apprenticeships today are among those at risk from digitalization, data science, and automation (see WEF Gender Gap Report Chapter 3, "Gender Gaps in Jobs of Tomorrow" [2]).

While the number of women in some STEM disciplines, such as mathematics or the natural sciences, is slowly increasing, women continue to be severely underrepresented in the information and communication technology (ICT) sector. Women are underrepresented among information technology professionals in Central and Eastern Europe [6]. This contrasts with overall employment, where men and women are largely equally represented. Furthermore, a study in Switzerland [7] examined the career aspirations of boys and girls at age 15 and again at age 21, revealing the following trends: Young men at the age of 21 tend to aspire to higher status and more prestigious professions than those at the age of 15. About half of these career aspirations are STEM professions, such as computer scientist, electrical engineer, or architect. In contrast, most of the career aspirations of young women change only slightly, and among the ten occupations mentioned, there is practically no STEM occupation, such as primary school teacher, doctor, health care worker, or kindergarten teacher. This indicates that the advantages of occupational options are evaluated differently by boys and girls, leading to gender-typical occupational decisions. These gender differences in interests, self-concepts, and self-assessment of one's own abilities and skills become apparent early on, between 10 and 15 years of age [8].

But why are women essential in the field of ICT? According to a report by the European Commission [1], there are clear signs of unmet demand for skilled workers in most IT occupations. In particular, the large number of vacancies combined with low unemployment rates and the heavy reliance on foreign workers indicate that meeting the demand for skilled workers is challenging. High qualification requirements and the associated high specificity of IT occupations make it even more challenging to meet the demand for appropriately qualified skilled workers.

A possible solution could be to introduce children to these topics in an engaging way as early as possible. Competencies such as gathering information, problem-solving, and the use of tools to create digital content, such as programming, could be integrated into the classroom at early levels. Currently, this is only done to a limited extent in most countries. As a result, computer science (CS) remains largely unknown to most students worldwide. Creative subjects such as textile design or arts and crafts offer significant potential to change girls' attitudes toward STEM subjects, especially. Due to prevailing stereotypes, many girls do not feel comfortable, motivated, or capable of pursuing careers in these fields. Therefore, we need to broaden girls' horizons and make promising and creative STEM professions more accessible to them.

Our work builds on many years of gender-specific study on the impact of various programming activities using the Pocket Code App on girls' interest in learning programming [4], [8–13]. This project aims to develop a study-based, gender-sensitive curriculum for programming and stitching courses to encourage broader participation in programming activities. This is achieved by addressing structural inequalities and beliefs that have historically limited the involvement of marginalized groups, such as women, in technology. Additionally, the project aims to foster a gender-sensitive mindset among teachers and students to ensure equal opportunities for all students. By providing female students with access to quality CS education in a predominantly male-dominated field, the project aims to enhance their engagement and skills.

In this paper, we aim to address the following research questions:

- Do stitching and coding activities promote intrinsic motivation, especially in girls (e.g., interest, self-efficacy, sense of belonging, fun, and engagement)?
- Are there differences in the design and pattern creation processes in stitching and coding courses between genders?

Furthermore, supporting materials were developed based on our findings from interviews, observations, and final artifacts, which specifically supported the second cycle (during the COVID-19 pandemic).

To address the research questions, our paper is structured as follows: Section 2 summarizes the findings from the literature on girls in CS, both in and out of school. Section 3 introduces the "Code'n'Stitch,"-project the method, and the associated study involving 229 middle school students. Section 4 presents the findings, which are further discussed in Section 5. Finally, Section 6 concludes the paper and offers an outlook.

2 RELATED WORK

In recent years, there have been numerous individual projects and initiatives explicitly targeting young girls. An interdisciplinary study is investigating various approaches to positively change the current situation of women in technology. In these studies and projects, several characteristics have been repeatedly highlighted and will be addressed in this section.

However, it is important to emphasize that the issue of women's underrepresentation in STEM subjects is not caused by a lack of interest or skills among girls and women [14]. Instead, it is systemic barriers that hinder them from reaching their full potential in these fields. For instance, stereotypes labeling STEM subjects as "masculine" can discourage girls and women, eroding their confidence in their capabilities in these fields [15].

2.1 Different (low-threshold) offers for different age groups (out-of-school activities)

Choosing a career path is a multifaceted decision, often influenced by various factors or a continuum of events. Although some of the factors in the decision-making process are obviously beyond the control of teachers, such as students' backgrounds (household income, ethnicity, social environment) or the views and preferences of family members, many other factors can be addressed through student counseling programs. Different studies have concluded that the most significant results came from programs that had been running for several years at the undergraduate level [16], [17]. Early exposure to CS can strengthen self-efficacy beliefs, academic performance, and foster interest [16], [18], [19]. This has already been demonstrated in the literature study by the authors of this paper [18].

In addition, the findings of [20] assessed the long-term impact of a series of extracurricular outreach events that introduced students to the discipline of computing, nurturing creative computational thinking through problem-solving and game programming. Overall, their study shows that extracurricular programs for girls have a positive impact on their future educational career decisions. Their confidence in studying CS was further strengthened, and their attitude toward CS changed positively. Interviews and general categories were summarized in the findings to describe the long-term effects of an extracurricular computer event. Based on 20 interviews (2–5 years after the intervention), four general categories were summarized to illustrate the long-term impacts of an extracurricular computer course. First, six participants felt that the intervention confirmed their decision to pursue a career in CS. They appreciated the opportunity to create something new and connect games to their own identities. Second, for five participants, the intervention led them to consider CS as a possible career option. The new information and experiences they received from the intervention, as well as their physical presence in a university building, were instrumental in their decision to study CS. Third, for six participants, the intervention had no significant impact on their career plans. They did not choose CS as a major, although they participated in the intervention for a variety of reasons, such as a desire to experiment or the benefit of being able to create their own website. Finally, for three participants, the intervention confirmed that CS was not an interesting career option for them. However, the course helped them understand programming and dispel some of their misconceptions about this field.

2.2 Gender-sensitive computer science education

Extracurricular initiatives are not enough. Children may be excluded for various reasons (e.g., children in rural areas, high costs, or a one-sided focus on a specific target group, e.g., those with prior knowledge). While in some countries, CS is already a compulsory subject starting in Grade 5 (e.g., in different regions in Germany [21] and Switzerland [22]), in other countries like Austria, it is mostly an activity integrated into subjects [23]. Therefore, it is also necessary to encourage teachers to introduce various CS content into the classroom in a playful way and at an early age. This paper [19] summarizes the results of more than 800 publications to provide educators with a comprehensive and easy-to-navigate map of interventions. They came up with the following umbrella strategies:

- Use inquiry-based and real-world learning activities to engage students in computing.
- Showcasing as many facets and interdisciplinary applications of CS as possible, as early as possible, to attract students from diverse disciplines.
- Split classes based on experience, gender, or shared interests for optimal results.
- Give more emphasis to the process of thinking, designing, and problem-solving than to the actual programming.
- Use visual programming environments to teach introductory programming.
- Take students to events and excursions and share stories and role models from the history of computing with them.

In addition, the articles examined summarize efforts to increase girls' interest in CS. Six key aspects were identified to make CS more engaging for this target group:

combating false stereotypes, motivating and sparking initial interest, providing appropriate first exposure, creating a less hostile learning environment, fostering self-confidence, and sustaining long-term interest.

2.3 Highlighting the creative and multi-faceted nature of computer science activities

The study of [24] is an essential step toward understanding how to spark girls' interest in STEM. They implemented an after-school program for middle school girls that integrated narrative-based, blended learning, and design-based engineering activities. This initiative, which used design challenges and mentors from diverse backgrounds, appeared to increase girls' awareness of STEM skills, identities, and interests. A study by [25], building on the importance of fostering interest in STEM, also highlighted that a broad understanding and personal interest in CS are critical to girls' participation. In this context, teachers play a central role in fostering girls' CS aspirations, indicating the importance of the educational environment. When considering the characteristics of problem-solving strategies, [19] found that girls and boys approach problem-solving differently. While girls tend to define problems more broadly, boys tend to approach problems in isolation. This broad approach can put more pressure on girls as they strive to consider every detail. Other authors suggested that an effective strategy might be a mix of both approaches [26]. In addition, the holistic thinking attributed to girls and women is related to the concept of computational thinking (CT), an important aspect of our technology-driven society. CT is about organizing extensive information into complex patterns and identifying connections—competencies attributed to girls and women. However, it is critical to note the apparent underrepresentation of a multidisciplinary approach in CS education. This is related to the issue of student engagement, where the lack of challenge, skill, and relevance in the classroom can lead to disinterest. This idea is consistent with Csikszentmihalyi's concept of flow, which states that task difficulty should be carefully balanced to promote engagement [27]. In essence, these studies shed light on the various facets of promoting greater engagement of girls in STEM subjects and the potential strategies that should be explored.

Buhnova and Happe summarized a literature review on practices to create girl-friendly CS teaching [28]. Additionally, they gathered insights from their own experiences teaching girls in their courses. They identified the following key points:

1. Creating safe environments: It is crucial for girls to feel a sense of belonging. This can be achieved when they feel understood and when the goals and activities are meaningful and relevant to them.
2. Segregation: to provide all students with a fair share of instruction time and suitable instructional form.
3. Working in teams: Collaboration and teamwork can help increase girls' engagement and participation in CS classes (if organized appropriately).
4. Personalized learning: for example, by offering self-assessment interventions through encouragement and feedback to reduce frustration.

The fact that girls prefer a safer environment without pressure and competition and with more time for their tasks to be finished could be misinterpreted by the teacher as these girls being weaker, which is not necessarily the case [29].

Given the existing study on gender-sensitive pedagogy, there is still a need to understand the specific effects on girls' intrinsic motivation in STEM subjects, such as interest, self-efficacy, sense of belonging, and engagement (e.g., through playful elements). Our first proposed research question aims to address this gap and provide a more nuanced examination of how specific activities can foster positive attitudes and experiences for girls in science, technology, engineering, and mathematics.

2.4 Prior work with code and stitch courses

The concept of programming patterns is not new. The "TurtleStitch" project (https://www.turtlestitch.org/; [29]), based in Austria/Vienna, introduced this idea at the Scratch conference in 2015. Moreover, the Maker-Education movement has also recognized these possibilities [11]. Through the advancement of various physical computing circuits, computing fashion can be made wearable and interactive [30]. For instance, creating embroidered fabrics can be enhanced by incorporating conductive threads or LED lights, transforming them into e-textiles or even "smart wearables."

To sum up, programming patterns are widely used to teach programming to young people through textiles and wearables [31], [32]. Some researchers also concentrate on strategies to engage girls in technology by utilizing smart textiles or embroidery programming [4], [33].

Existing research lacks a detailed exploration of gender differences in design and pattern creation processes within stitching and coding courses. Understanding whether end products differ based on gender, either through adaptation during the project or from tutorial-based developments, is uncharted territory. The second proposed research question aims to address this gap and provide deeper insights into gender dynamics within these courses.

3 MATERIALS AND METHODS

3.1 The "Code'n'Stitch"-project

The "Code'n'Stitch" project was a two-year investigation (Sep. 2018–Sep. 2020) with the aim of testing digital pattern-making as an interdisciplinary method for learning programming in middle schools (Grade 5–7; https://catrob.at/codeNstitch). The project was a collaboration between Graz University of Technology (TU Graz; responsible for the app development), bits4kids (https://www.bits4kids.at/; in charge of the workshops and creating the learning cards and tutorials), the Styrian University of Teacher Education (providing didactic expertise), and the fashion shop "Apflputzn" (https://www.apflbutzn.at/), which introduced the topic of bio-fair fashion to schools and supplied bio-fair shirts and bags for stitching. This project was funded by FEMtech (https://femtech.at), an organizational unit of the Austrian Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation, and Technology (BMK), which aims to empower women in study and technology and promote equal opportunities. Therefore, a special focus was placed on the gender-sensitive design of the workshop. For instance, at the project's outset, a gender equality and diversity course was conducted with all project members and trainers who would lead the courses in schools. The material was prepared attractively and aesthetically, dialogues on role models were initiated (e.g., through course cards; see Figure 1), emphasis was placed on problem-solving (e.g., abstracting desired patterns), great importance was given to the design and creative process (two lessons were dedicated to designing), and a unique visual programming language was developed. The app and materials were developed by observing our target group, creating personas based on this, and conducting initial workshops for a needs analysis of the app in 2018/19 [11]. Thus, many of the points mentioned in Section 2 were taken into account.

Fig. 1. An example of a course card for encouraging dialogues and fostering role models (First cycle, 2019)

The focus of the project was to: 1) provide guidance and support to teachers without programming skills; and 2) show girls, in particular, a new way to express themselves creatively through programming. Furthermore, the Embroidery Designer App ([12]; https://catrob.at/ED) was developed. This is a new version of the Pocket Code App from the Catrobat project ([34]; https://catrobat.org) at TU Graz. The Pocket Code App offers a visual programming language where users can develop games, animations, interactive music videos, control drones, and more using smartphones or tablets. Similar to Scratch (https://scratch.mit.edu/), the Pocket Code App utilizes bricks as the foundation for creating program code. New bricks were created to expand their functionality specifically for this purpose. For instance, the needle brick allowed users to stitch and control embroidery machines. This version offers the possibility to create embroidery files with special blocks that conventional embroidery machines can execute. Besides these new possibilities that programming offers for handicraft lessons, it should be noted that handicraft lessons are still very traditionally oriented in many schools, and digital tools such as laser cutters are only slowly being introduced [35]. Especially within textile lessons, there are still very few possibilities, and the teachers usually do not have the necessary knowledge to combine this subject with CS content. The project is, therefore, especially aimed at teachers without prior programming knowledge.

3.2 Context and participants

We conducted our activities in the handicraft classes of three different schools in Graz, Austria. The workshops were divided into two cycles: September 2019 to

January 2020 (Cycle 1) and March to June 2020 (Cycle 2). Two classes finished the cycle 2 workshop in March 2020, before the onset of the Corona pandemic and subsequent school closures. Due to the pandemic, adjustments had to be made from March 2020 onwards. This paper primarily focuses on the first cycle, as some evaluations, such as questionaries, were discontinued due to the shift to online or hybrid classes. Nonetheless, many new insights were also obtained through online courses, which are detailed at the end of the paper. Figure 2 depicts the contexts of both cycles.

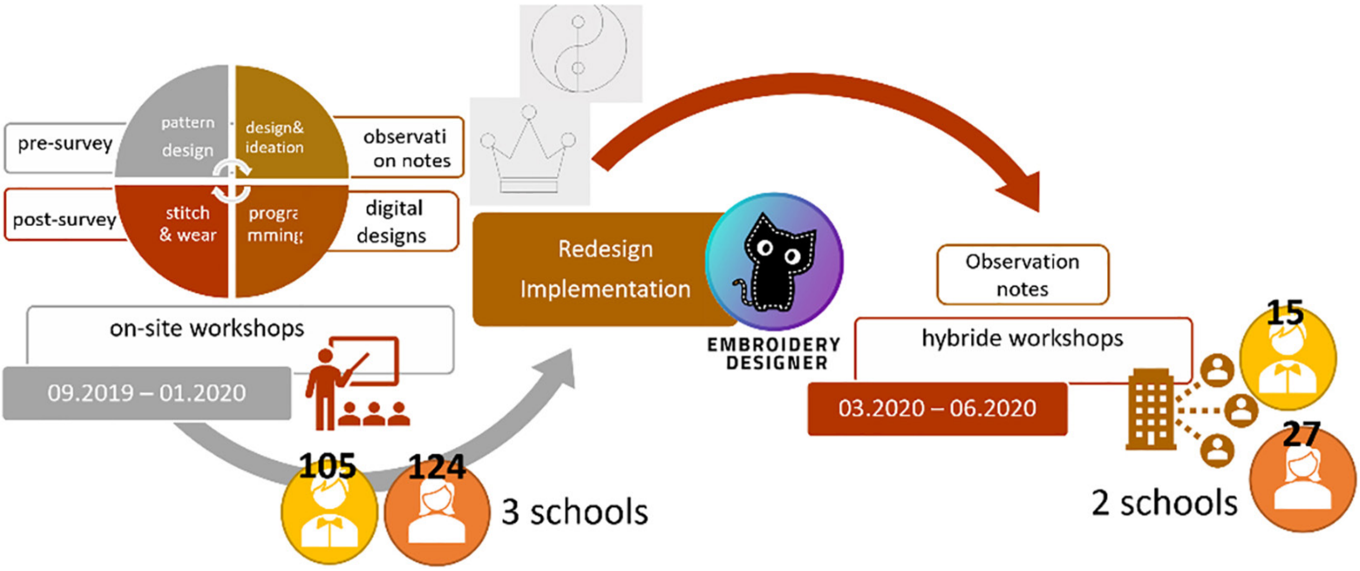

Fig. 2. Study design for cycle 1 (pre-Corona) and cycle 2 (post-Corona)

3.3 Workshops

The workshops during the first cycle were based on eight 50-minute lessons, summarized in four units. In these units, students went through four open-ended and interest-driven phases: 1) the pattern design phase; 2) the design and ideation phase; 3) the programming phase; and 4) the stitch and wear phase (see Figure 3). In the last unit, the whole team was present and helped students embroider their designs with programmable embroidery machines in schools. Additionally, some students finished their designs independently.

In the following, the different phases are described in more detail: During the pattern design phase, the students discussed with the teacher different types of stitches, fabrics, and other information related to embroidery that they will come across when working on textile projects. Then the student groups created their own designs based on initial internet research or their own ideas. In this step, students were motivated to think about what geometric shapes are used in their design, what angles are needed, as well as other mathematical features of their design (e.g., formulas). This phase was intentionally placed before the programming unit to not limit students' ideas and designs from the beginning. Students received approval and tips from the course instructors (trainers from bits4kids or the TU Graz team) on whether their sketches constituted a "programmable" design. For example, designs that contain too many details, curves, or completely flat fills are considered complex.

In contrast, good embroiderable designs are lines, circles, or other geometric figures. For this, students started to draw their desired design on a piece of quadratic paper. During the programming phase, students received instructions on important control structures in programming (e.g., loops, conditions, messages, etc.). After this, students had four lessons on programming with the Pocket Code App before they stitched their designs on fabrics (stitch and wear phase). In these units, failure and overcoming unforeseen challenges are expected and part of the learning process [36].

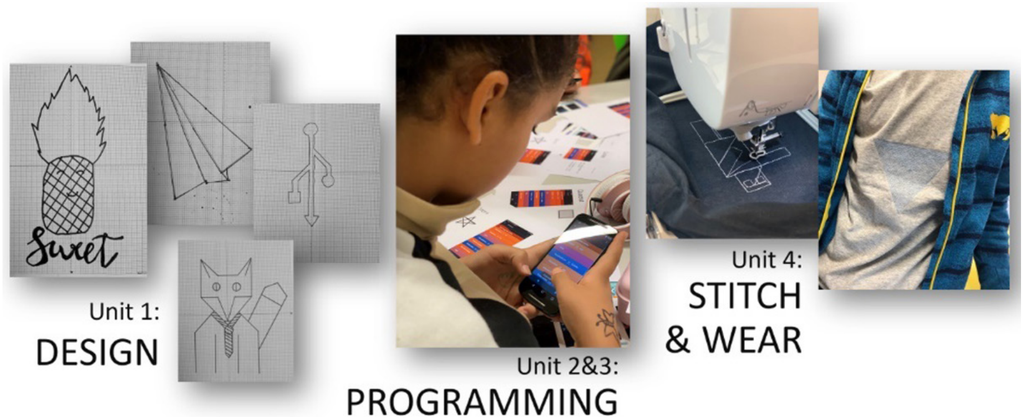

Fig. 3. The design – code – stitch workflow

229 students participated in the workshops during the first cycle. Table 1 shows the gender distribution across the workshops in relation to the individual schools.

Table 1. Distribution and grades/gender of participating schools/students during the first cycle

	Female	Male	Total
	123	106	229
School 1 (secondary school, Grade 7, students between 12 to 13 years old)	34	44	78
School 2 (grammar school, Grade 6, students between 11 to 12 years old)	56	28	84
School 3 (middle school, Grade 5–7, students between 10 to 14 years old)	33	34	67

In these workshops, we use a prototype version of the app. At that time, there was only one command available to create patterns: a single stitch. Although all possible patterns could already be created using this single command, we recognized the necessity of incorporating more nested commands for common use cases.

The second cycle of the project was initially planned to work in the same three schools with the same classes and students. However, due to school closures resulting from the COVID-19 pandemic, the study design had to be significantly revised. Nevertheless, in the conclusion of the paper, we briefly outline the main results that have emerged during these modifications. Building on the findings from the first cycle, additional features were incorporated into the app (e.g., more stitches), along with tutorials inspired by students' suggestions (refer to Figure 4).

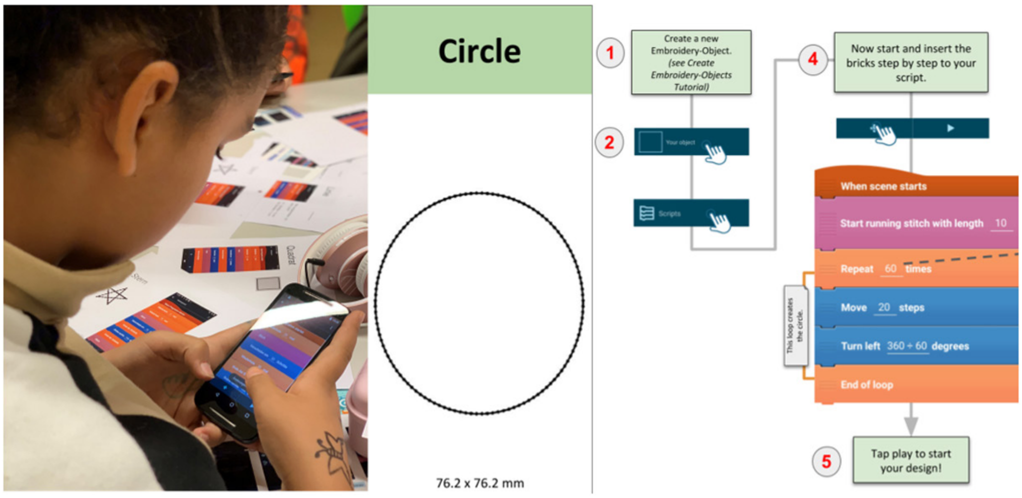

Fig. 4. Tutorial for creating a circle, step-by-step

At the end of the second cycle, a wide range of tutorials for various patterns (easy to medium) were made available, such as stars, flowers, or a Minecraft creeper figure. The second cycle aimed to validate the developed tutorials and the adaptation of the app in the school context based on the students' experiences. After the second cycle, the following resources were created: Following, a Wiki page (see Figure 5) will serve as a knowledge repository for all the materials we created. Second, an Instagram account where we posted new tutorials, photos, and videos online daily. Third, we created YouTube videos with short beginner tutorials and linked them to the wiki pages.

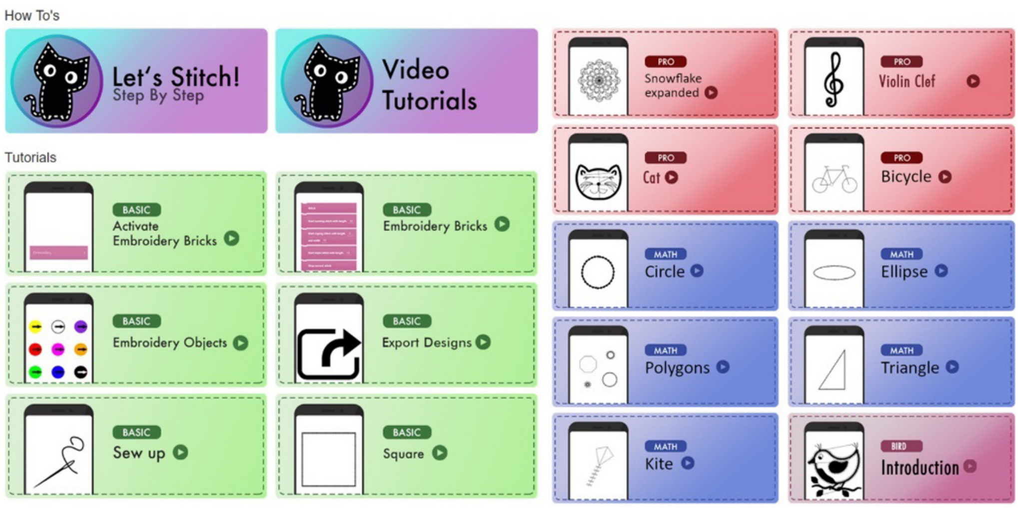

Fig. 5. Tutorial on Catrobats Wiki page

3.4 Data collection and analysis

Following permission from the school and teacher to conduct the research, the legal guardians of the children were informed of the research and signed their consent. For anonymization, we used individual codes for the students that were written in the surveys and used for the name of the programming patterns to be uploaded. These alterations have not distorted the scholarly meaning. The anonymized data made available to the public cannot be used to identify individuals. The data that support the findings of this study are openly available [37], [38]. Under these circumstances, data collection and analysis proved to be rather difficult. During the first cycle, a total of 229 students (123 girls and 106 boys) aged between 10 and 14 participated in the questionnaire. Some problems were also encountered during the first cycle. For example, the pre- and post-project questionnaires were filled out differently per class. Some students filled out both questionnaires as planned (n = 110), others only the pre-questionnaire (n = 51), and still others only the post-questionnaire (n = 55; 14 pupils accordingly did not fill out either questionnaire). The questionnaire was used to ask about intrinsic motivators considered important for girls in CS, such as interest, self-efficacy, sense of belonging, and fun [8]. A 4-point Likert scale [39] was used to measure the variables that refer to 1) strongly disagree, 2) disagree, 3) agree, and 4) strongly agree. The questions have been developed on the basis of literature [40], the CATS Attitude Scale Items [41], and other studies [42]. No questions have been asked that could foster stereotype threats, as proposed by [41], e.g., "Girls can do technology as well as boys." To demand their attention, using no neutral value and counter questions is recommended [43]. Thus, it is not always "the higher, the better." Furthermore, prior knowledge of programming was only inquired about in the pre-questionnaire, while their experiences during the workshops were only addressed in the post-questionnaire [44]. Therefore, our questionnaire is being validated for the first time in this paper and tested for the reliability of all items on the scale. IBM SPSS Statistics was utilized for data analysis. Initially, frequencies for the four intrinsic parameters were calculated to gain more insights into the distribution and frequency of each value in the corresponding variables. This process aids in developing an understanding of the data and identifying potential problems or outliers. Subsequently, a reliability analysis is conducted to assess the internal consistency of the scales in the questionnaire. This step involves calculating statistics such as Cronbach's alpha to determine if the individual items on a scale are coherent with each other. A t-test is then employed to determine gender differences and examine possible variations between genders in relation to the means. Finally, an analysis of covariance, also known as an ANOVA (analysis of variance), is used to analyze potential differences between groups over time. This is achieved by calculating the means to generate summary statistics for each scale or intrinsic parameter. To explore the practices students used in creating their designs, as well as the challenges, situations, questions, and uncertainties that arose, data for analysis was gathered from field notes in the classroom [45]. Subsequently, the programmed and stitched designs were collected. For the analysis, design sketches were compared with the final products (programs) to determine if students were able to realize their original designs, if they created a tutorial instead, or if they had to make other adjustments. These programs were analyzed by gender and by patterns. A total of 217 final products (DST files) were collected from the first cycle.

This multiple-data-source approach provides a more comprehensive picture of classroom activities and student participation. However, the evaluation of the second cycle is incomplete due to the inability to distribute post-questionnaires and the unavailability of all program files. Consequently, only the experiences from the remote units are detailed for analysis to be utilized in future online and hybrid formats.

4 RESULTS

4.1 Evaluation of the questionnaires

For the evaluation of the intrinsic parameters of the questionnaire, the following datasets were utilized [37]. The initial question inquired about students' programming experiences. Out of 112 students, 76.47% of girls and 64% of boys reported having no programming experience. All analyses were conducted at a significance level of less than 5% ($p < 0.05$).

Item interest. The first block of questions on interest included the following: “1a: Learning about programming interests me.”; “1b: I find it important to have an idea about programming.”; “1c: I find computer science and programming boring.”; and “1d: I like programming.”

The items in the questionnaire designed to assess “interest” demonstrate reliable measurement properties. The questions utilize a unidimensional scale, and the distribution of individual items follows a normal distribution, indicating good data quality. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is significant (T1: 763, T2: 797), suggesting that the data is suitable for factor analysis.

Moreover, the overall explained variance exceeds 1 (T1: 2.546, T2: 2.802), indicating that the derived factors capture a substantial portion of the information in the data, supporting construct validity. Additionally, the reliability assessment yielded a Cronbach’s alpha coefficient of T1: .807 and T2: .857 for the four items, indicating acceptable to good internal consistency.

Overall, the pre-questionnaire mean score on interest in programming indicates a general agreement towards having an interest ($m = 3.20$, $sd = .643$). After the intervention, the post-questionnaire mean decreased slightly ($m = 3.04$, $sd = .729$), showing a small decline in interest level with increased variation in responses. When the data are examined separately by gender, the following picture emerges: The results show that the interest between T1 ($m = 3.19$, $sd = .63$) and T2 ($m = 3.07$, $sd = .70$) tended to decrease slightly over time ($t(109) = 1.69$, $p = .094$). To test whether gender moderates interest in programming, a repeated-measures analysis of variance was conducted. Figure 6 shows that interest has declined only among boys. Although the interaction effect is not significant ($F(1, 107) = 3.786$, $p = .054$), boys’ interest at T1 ($m = 3.35$, $sd = .73$) compared to that of girls ($m = 3.08$, $sd = .55$) was significantly higher ($t(107) = 2.19$, $p = .031$).

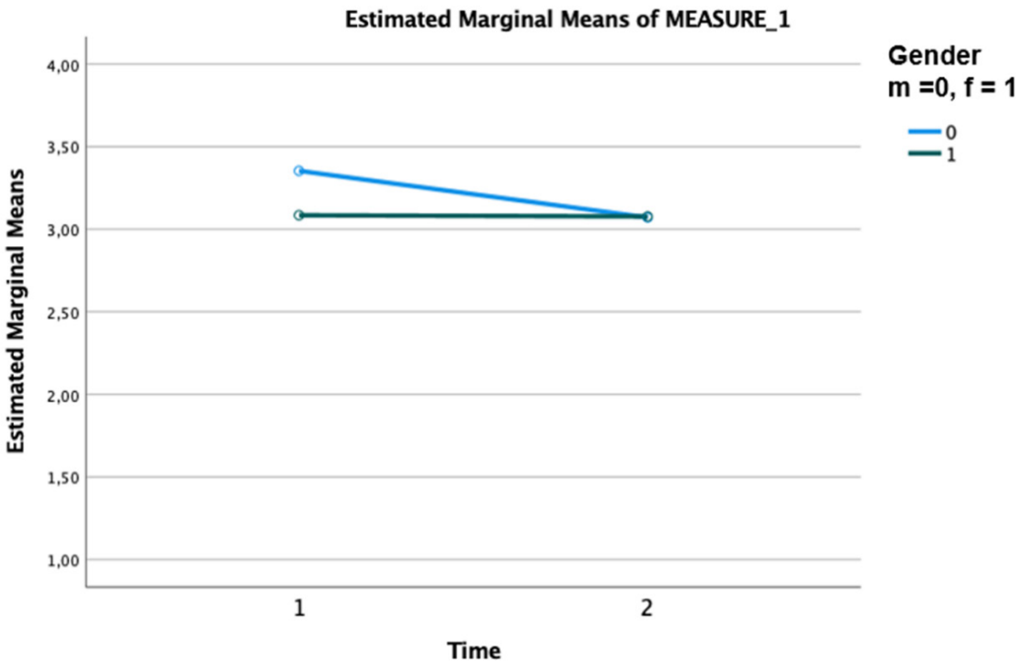

Fig. 6. Change in interest in programming, differentiated by gender

Item self-efficacy. The second block of questions on self-efficacy included the following: "2a: I generally feel confident in using my smartphone or PC."; "2b: I can learn programming."; "2c: I have little confidence when it comes to informatics (computers, smartphones, programming)"; "2d: I try to find several ways to solve problems I encounter in everyday life"; and "2e: Programming reflects my way of thinking." The results of the items concerning "self-efficacy" present some statistical challenges. Firstly, the KMO measure shows a value in the acceptable range (above 5: T1: .614, T2: .676), indicating that the data are reasonably suitable for factor analysis. However, the value is slightly below the desired value (above .7), indicating a potential for random influences on the results and, therefore, could be improved.

Overall, it is a one-dimensional scale with a total variance explained greater than 1 (T1: 1.738, T2: 1.901). Secondly, the reported Cronbach's alpha values are below the generally accepted threshold of 0.7 (T1: .506, T2: .563), suggesting that the test items may not correlate well with each other when measuring the same construct or that the items may be interpreted differently by respondents.

The mean scores at T1 ($m = 3.05$, $sd = .472$) and at T2 ($m = 2.91$, $sd = .525$) suggest that the intervention may not have improved participants' sense of self-efficacy concerning programming and that the effect of the intervention may vary greatly across participants. The self-efficacy scores for the t-test show the following results: At T1, boys' mean score was slightly higher ($m = 3.107$, $sd = .497$) than girls' ($m = 3.007$, $sd = .450$), but this difference was not statistically significant ($p = 0.182$). At T2, both mean scores decreased, with girls ($m = 2.846$, $sd = .544$) decreasing more than boys ($m = 3.013$, $sd = .475$), but this difference was also not statistically significant ($p = .48$). However, a significant change in self-efficacy over time can be seen ($p = .004$), indicating an overall decrease regardless of gender, but no significant interaction was found between time and gender ($F (1, 107) = 1.005$, $p = .054$), indicating that the change in self-efficacy from T1 to T2 was not significantly different between boys and girls.

Item sense-of belonging. The third block of questions on sense of belonging included the following: "3a: I can imagine what people in technical professions do."; "3b: I can imagine how programming works."; "3c: I can imagine that programming is important for my future profession."; "3d: A technical profession would suit me."; and "3e: I think I have the same or similar characteristics as people who program."

In the scale test of the "sense of belonging" item, the KMO measure shows that the data are well-suited for factor analysis (T1: .773, T2: .731). The scale is identified as unidimensional (total variance explained: T1: 2.601, T2: 2.667). In the reliability test of the item, Cronbach's alpha (T1: .760, T2: .771) indicates a good level of internal consistency for this item.

The mean scores for this item at T1 ($m = 2.47$, $sd = .659$) and at T2 ($m = 2.4$, $sd = .671$) suggest that while there is some variability in responses, it is not excessive. Responses tend to cluster reasonably around the mean, suggesting that most participants feel a moderate sense of belonging to the program. The results of the t-test examining gender differences on the item sense of belonging in programming show some notable differences: boys at T1 ($m = 2.655$, $sd = .693$), girls ($m = 2.328$, $sd = .572$). This indicates that, on average, boys reported a stronger sense of belonging in programming than girls (significance level $p = .001$).

Mean scores at T2 showed the following for boys ($m = 2.637$, $sd = .735$) and girls ($m = 2.268$, $sd = .585$). Once again, boys reported a significantly stronger sense of belonging to programming than girls ($p < .001$). Additionally, this time, the rate of change over time did not show a significant difference between the genders ($F (1, 107) = 1.940$, $p = .167$).

Item fun and games. The fourth and final related block included questions about fun and games: "4a: Programming is fun for me."; "4b: I like playing computer games.”; “4c: I like using game apps.”; and “4d: When I play or program on the computer, I sometimes forget everything around me.”

The statistics presented for this item indicate acceptable consistency and suitability for factor analysis. The KMO measure (T1: .675. T2: .677) indicates moderate suitability of the data, and the total scores are above 1 at both time points, indicating general compatibility. Cronbach’s alpha values (T1: .709, T2: .683) are relatively good, although the value for T2 is lower than desired.

The mean values at T1 (m = 2.89, sd = .747) and at T2 (m = 2.91, sd = .728) show a stable central tendency and relatively low dispersion. The results of the t-test showed significant gender differences in this domain at both T1 and T2. At T1, boys reported a higher mean score (m = 3.218, sd = .632) than girls (m = 2.625, sd = .709), a difference that was statistically significant ($p < .001$). This difference increased very slightly at T2, for boys (m = 3.258, sd = .608) and girls (m = 2.670, sd = .702), also showing significance ($p < .001$). However, the interaction effect is not significant over time ($F (1, 106) = .973$, $p = .326$).

In summary, scores in all areas either remained stable or declined slightly after the intervention. Boys consistently reported higher scores than girls in the areas of interest, sense of belonging, and fun/games, with statistically significant differences in the categories of interest (at T1), sense of belonging, and fun/games. There were no significant gender differences in the self-efficacy domain. The scale results suggest that the questions for this item may need to be adjusted.

Further, an investigation was conducted to identify correlations with the interest in programming at both T1 and T2. Several moderate-to-strong correlations were found (see Figure 7). According to [46], the effect size is considered low if the value of r fluctuates around 0.1, medium if r fluctuates around 0.3, and large if r fluctuates more than 0.5.

Correlations

		Interest in Programming Pre	Interest in Programming Post	Self-efficacy in Programming Pre	Self-efficacy in Programming Post	Sense-of Belonging in Programming Pre	Sense-of Belonging in Programming Post	Fun and Games Pre	Fun and Games Post
Interest in Programming Pre	Pearson Correlation	1	.409**	.634**	.273**	.548**	.278**	.374**	.320**
	Sig. (2-tailed)		<.001	<.001	.004	<.001	.003	<.001	<.001
	N	161	110	161	110	161	110	161	109
Interest in Programming Post	Pearson Correlation	.409**	1	.363**	.534**	.461**	.602**	.171	.382**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001	<.001	.075	<.001
	N	110	165	110	165	110	165	110	164
Self-efficacy in Programming Pre	Pearson Correlation	.634**	.363**	1	.482**	.497**	.390**	.310**	.258**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001	<.001	<.001	.007
	N	161	110	161	110	161	110	161	109
Self-efficacy in Programming Post	Pearson Correlation	.273**	.534**	.482**	1	.411**	.611**	.271**	.443**
	Sig. (2-tailed)	.004	<.001	<.001		<.001	<.001	.004	<.001
	N	110	165	110	165	110	165	110	164
Sense-of Belonging in Programming Pre	Pearson Correlation	.548**	.461**	.497**	.411**	1	.630**	.431**	.326**
	Sig. (2-tailed)	<.001	<.001	<.001	<.001		<.001	<.001	<.001
	N	161	110	161	110	161	110	161	109
Sense-of Belonging in Programming Post	Pearson Correlation	.278**	.602**	.390**	.611**	.630**	1	.255**	.430**
	Sig. (2-tailed)	.003	<.001	<.001	<.001	<.001		.007	<.001
	N	110	165	110	165	110	165	110	164
Fun and Games Pre	Pearson Correlation	.374**	.171	.310**	.271**	.431**	.255**	1	.646**
	Sig. (2-tailed)	<.001	.075	<.001	.004	<.001	.007		<.001
	N	161	110	161	110	161	110	161	109
Fun and Games Post	Pearson Correlation	.320**	.382**	.258**	.443**	.326**	.430**	.646**	1
	Sig. (2-tailed)	<.001	<.001	.007	<.001	<.001	<.001	<.001	
	N	109	164	109	164	109	164	109	164

**. Correlation is significant at the 0.01 level (2-tailed).

Fig. 7. Correlations between T1 and T2

Given that four items—interest, self-efficacy, sense of belonging to programming, and fun/games—show many strong positive correlations at both T1 and T2, this suggests that these variables are interrelated and influence each other over the duration of the programming course. For example, the positive correlation between interest and self-efficacy at T1 ($r (161) = .64, p < .001$) and at T2 ($r (110) = .273, p = .004$) may indicate that children who feel more capable (higher self-efficacy) tend to show more interest in programming and vice versa. Therefore, encouraging and improving students' self-efficacy could promote their interest in programming. A strong positive correlation between sense of belonging in programming and the other variables suggests that as children's sense of belonging in programming increases, so does their interest at T1 ($r (161) = .548, p < .001$) and T2 ($r (110) = .461, p < .001$), self-efficacy at T1 ($r (161) = .482, p < .001$) and at T2 ($r (110) = .411, p < .001$), and the item fun and games at T1 ($r (161) = .630, p < .001$) and at T2 ($r (110) = .431, p < .001$). This may suggest that creating an inclusive, welcoming learning environment where students feel a sense of belonging may have a positive impact on their engagement and performance in programming. A strong correlation between fun/games and the other variables (e.g., interest in programming at T1 ($r (161) = .374, p < .001$)) suggests that incorporating playful elements into the programming course can potentially increase the other factors (except interest in T2 $r (110) = .171, p = .075$).

The post-questionnaire (T2) contained two additional questions ($n = 165$): "5a: I felt comfortable and taken seriously in the "Code'n'Stitch" project." and "I am proud of the design I created." Both questions aimed to gather more information about the classroom climate and participants' designs.

To determine significance, a t-test was utilized. Girls showed higher agreement with question 5a compared to boys, but this difference was deemed insignificant (girls $m = 2.8632$, boys $m = 2.71$, $p = .376$). On the other hand, the results for the second question were considered significant (girls $m = 3.588$, boys $m = 3.177$, $p = .003$). This indicates that girls significantly expressed more pride in their designs than boys.

4.2 Results of the sketches and final programs

At the end of cycle 1, 217 final products (DST files) were uploaded on the Catrobat sharing page, and all 217 programs were embroidered on t-shirts or bags. For this, various designs were created. Table 2 shows whether students created their own designs or used prepared tutorials [38].

Table 2. Tutorials or own designs (final product) divided by gender

		Female	Male
Category 1	Tutorials	36 of 116 (31%)	40 of 97 (41%)
Category 2	Own designs	80 of 116 (69%)	57 of 97 (59%)

Figure 8 shows the various shapes that have been created. These are screenshots from their final DST files. This standard stitch-based file format can be read and converted by many commercially available embroidery machines (e.g., machines by Brother or Bernina).

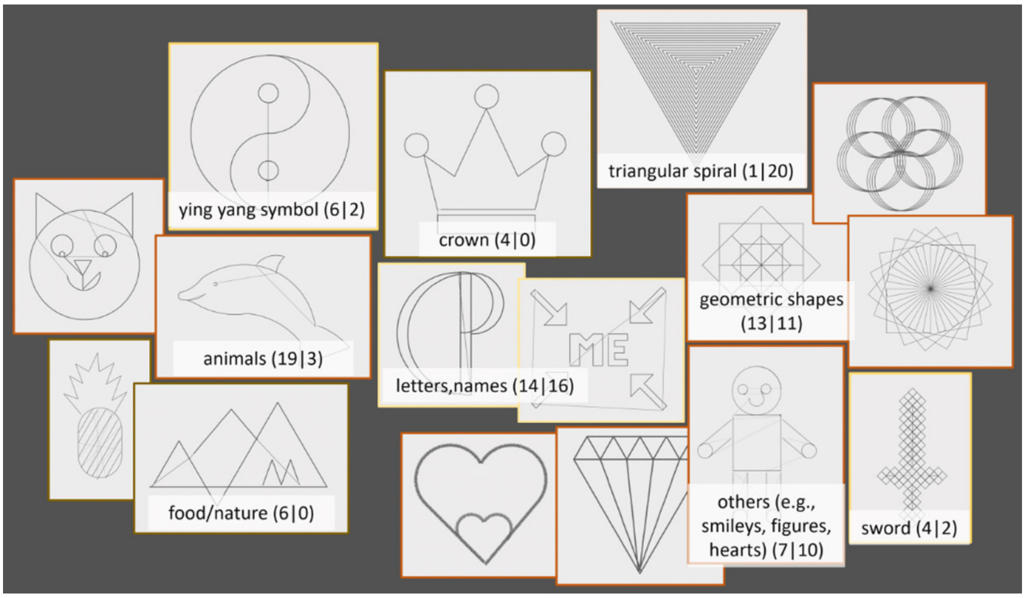

Fig. 8. Different patterns (final products) divided by gender (first number: female, second number: male students)

The initial sketches were used on-site during the units. Some were copied or collected, but not all were secured. A total of 81 (f = 47, m = 34) initial sketches that could be assigned to final products were collected. 35 students (f = 23, m = 12) implemented their final product based on their initial sketch, and 39 (f = 21, m = 18) had to change their idea during the programming. 7 (f = 3, m = 4) students could implement their initial sketch with modifications. Figure 9 shows examples of an initial template compared to the final product. Figures 10 and 11 display some examples of an idea sketch compared to the final product, which was changed during the workshop. Figure 12 illustrates an example of an initial template compared to the final product (the DST files) with modifications.

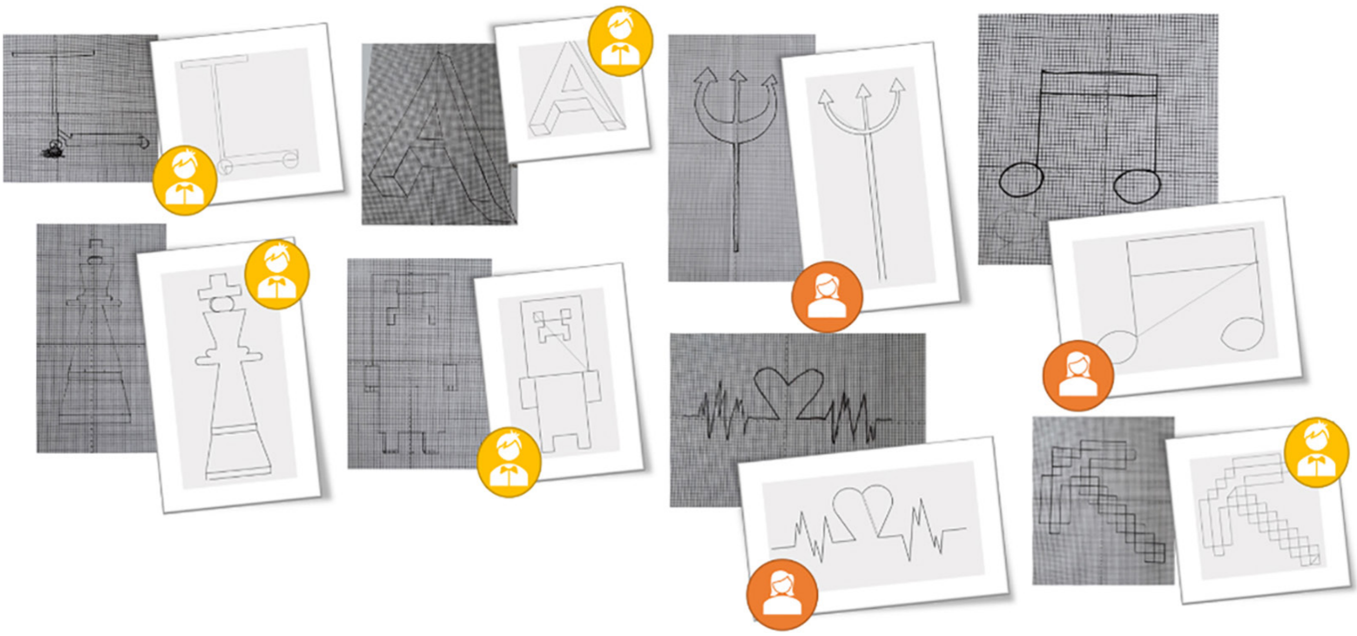

Fig. 9. Some examples of an initial template and final product (DST file)

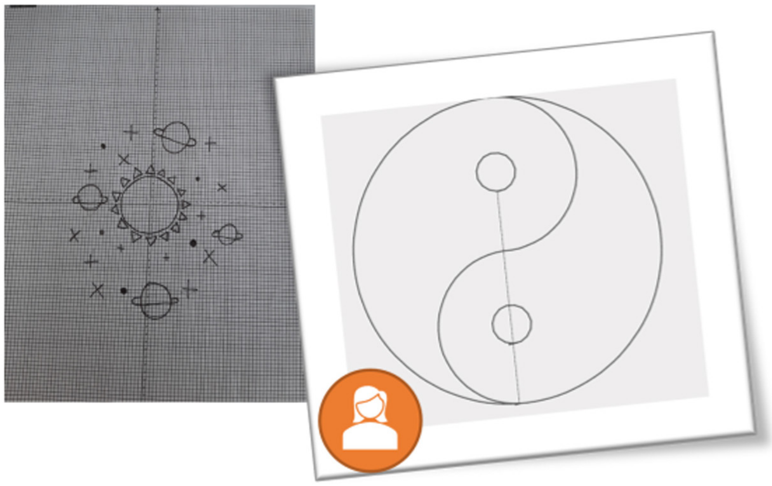

Fig. 10. Example of an initial template and changed the final product

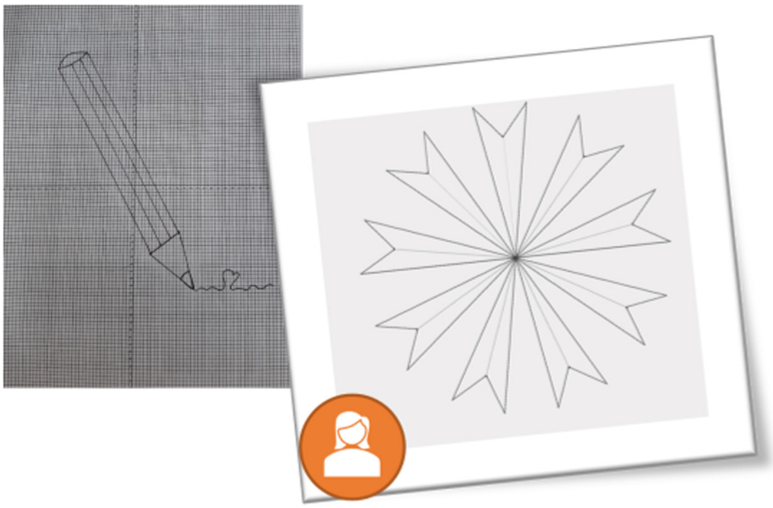

Fig. 11. Example of an initial template and changed the final product

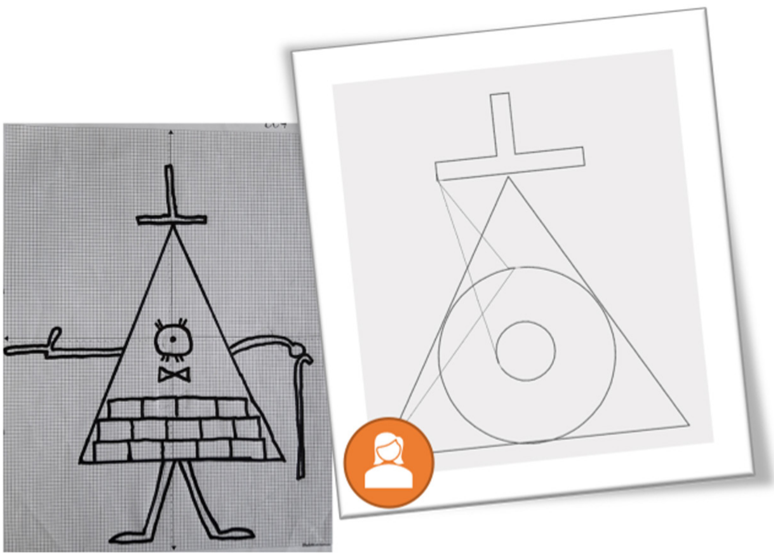

Fig. 12. Example of modifications of initial template to the final product

4.3 Evaluation of the field notes

The on-site observations during the first cycle revealed the following insights: The students encountered challenges in programming various patterns using only one stitch. They needed to quickly incorporate new stitches, such as the "ZigZag" stitch for wider lines or automatic stitches while moving the objects. Many of the patterns were too large for embroidery, requiring the use of external applications such as "Stitch Pro" to determine the final design size. It was observed that the lessons were more effective when the teachers actively participated in the teaching process. Students desired to showcase their designs to the teacher, emphasizing the importance of receiving feedback. When teachers were not engaged, children's motivation and enjoyment of the lessons decreased. In terms of gender-specific observations, boys displayed more confidence in programming but were quicker to seek help when faced with challenges. On the other hand, girls tended to start with tutorials and hesitated to create their own designs initially. However, they demonstrated greater persistence, were more likely to persevere, and produced more unique designs consistently. These observations were also reflected in the questionnaire.

5 DISCUSSION

The questionnaire conducted during the first cycle also reflected many of the problems with the app prototype. A limitation of the study is that the questionnaire was no longer conducted after the app was further developed to be used in cycle 2. Nevertheless, the pre- and post-evaluation of the questionnaire tells us a lot about gender-specific perceptions of intrinsic motivation. For example, there are several interpretations one could draw from this analysis regarding the relationship between interest in programming and gender. The initial significant difference in interest between boys and girls could have been influenced by other factors not included in the study (e.g., pre-knowledge of programming, interests in designing programmable patterns, etc.). It is important to note that although the average score has decreased, this does not necessarily mean that the intervention has "failed." It could be that participants have a clearer understanding of programming after the intervention and can more accurately evaluate their interests (maybe they find it also too difficult or not fast forward). This could be more of an issue for boys than girls. It's possible that gender stereotypes about programming may have influenced the initial interest levels as well. For example, boys might have been more interested in T1 due to societal expectations or biases. These may have been less influential at T2, leading to a smaller difference in interest (note that the mean values were still between agree and strongly agree).

Especially in the area of self-efficacy, the average values unfortunately do not show a positive picture and indicate a clear deterioration. However, the analysis also showed that the questions were not optimally selected to cover this aspect. It can be concluded that the intervention had a differential effect on participants perceived self-efficacy during programming. The overall decrease in self-efficacy scores from T1 to T2 could possibly be due to the challenges and complexities encountered during the programming intervention. This could also be seen in the fact that many switched from their own patterns to predefined tutorials. Furthermore, as indicated in the evaluation of the field notes, this many participants can be attributed to the app still being quite difficult to use, requiring a lot of help or tutorials to create a design. In particular, the question "I can learn to program" may have reflected participants' difficulty or slow progress in grasping programming concepts, thus negatively influencing their self-efficacy beliefs. Since there were no significant gender differences in changes in self-efficacy, the effect of the intervention seemed to be similar across genders. Nevertheless, it would be crucial to further explore potential gender-specific factors influencing these perceptions.

The results revolving around a sense of belonging indicate that boys are more likely to be able to place themselves in these roles and feel a sense of belonging to programming. This underscores the need for more interventions to promote girls' interest and affiliation in programming. For example, the programming course could benefit from including more real-world examples that are relevant to girls or creating more supportive and inclusive learning environments. It would be advisable not to base the unit's solely on programming but to give a broader picture of CS, as shown in Section 2.

Results regarding the "fun and games" item indicate significant gender differences in enjoyment of games and programming, with boys reporting higher levels of fun than girls. The intervention aimed at tailoring creative and more holistic activities to girls' interests could help increase their engagement and enjoyment in these areas.

Finally, girls showed a higher level of agreement with both post-questions, indicating a greater sense of pride in their designs (question 5b), which was a significant finding.

In summary, the results showed:

- Both genders showed a general interest in programming, with boys showing significantly more interest than girls.
- Both genders exhibited a general decrease in interest and self-efficacy related to programming after the intervention.
- There were significant differences in the sense of belonging and enjoyment of games, with boys scoring higher in both aspects.

These findings may indicate that the intervention, although generally considered valuable, may not have been fully responsive to the needs and interests of all participants. To empower girls through their programming and achieve better overall outcomes, it may be beneficial to expand the scope of future interventions beyond just programming patterns. Incorporating elements identified in the literature as positive, such as role models and clarity about IT careers, could provide a more comprehensive and effective approach to improving girls' experiences in STEM education. We also expect that better results can be achieved with the new version of the app (available since 2020).

Regarding the questionnaire itself, most scales were reliable, with the exception of the self-efficacy scale, which had slightly lower internal consistency. A renewed use of the questionnaire in this context will be possible within the Swiss project "Making at School." Overall, the correlations in Figure 7 suggest that to promote an engaging, effective, and enjoyable learning experience in a programming course for children, it is beneficial to build children's self-efficacy, ensure that they feel a sense of belonging, and incorporate elements of fun and play into the curriculum. Because these elements are interrelated (most of them show a strong positive correlation), improvements in one area are likely to have a positive impact on the others. However, as with all correlational analyses, causality cannot be definitively determined from these results, and further studies may be needed to better understand the specific causal relationships and their implications for children's programming.

Regarding children's final projects, we observe that 69% of the girls actualized their own designs as final products, while only 59% of the boys did so (see Figure 8). This discrepancy may indicate the girls' interest in bringing their own designs to life and boosting their motivation for programming. Girls frequently adhered to their initial designs, making adjustments or modifications based on available resources or time constraints, yet their unique ideas remained distantly identifiable.

Students encounter challenges in programming, such as converting a pattern into programming code using geometry. These issues are spread across various modalities, involving interactive identification of errors, solution development, and testing. A comparable problem was also observed in Study B by [36].

The girls who programmed with the help of tutorials often used the Ying-Yang symbol, swords, and crowns (see Figure 9), while the boys frequently chose the triangular spiral. This tutorial appeared to be a favorite among boys. Additionally, for their own designs, girls favored animals, closely followed by letters, names, and geometric shapes. On the other hand, boys tended to prefer letters, names, and geometric shapes such as smiley faces, hearts, and diamonds for their final products. Some girls created nature or food shapes, while none of the boys did. It is evident that girls and boys tend to select different shapes or designs for their final products. Therefore, it is crucial to present them with a wide range of design possibilities to spark their interest and enhance their motivation to create unique designs.

5.1 Lessons learned for the design process (design-workflow)

We were able to derive the following insights from the code and stitch units:

- There may be gender-specific differences in students' perceptions of intrinsic motivation when it comes to programming. There is room for improvement, especially in addressing gender disparities and measuring self-efficacy. It may be beneficial to integrate a more comprehensive understanding of CS and real-life applications to sustain students' engagement and motivation.
- The app used in the study was difficult to use, which may have contributed to the decline in self-efficacy and other items among students. It may be advisable to incorporate additional tutorials and resources to support students, especially in the basics of mathematics (circle, triangle, angles, etc.) and programming, particularly if they are doing so for the first time.
- Girls tend to be more interested in realizing their own designs as final products, while boys tend to choose existing shapes or designs for their final products. It may be helpful to expose students to a wide range of possible design options to spark their interest and increase their motivation.
- Embroidery machines and the results of self-designed work hold significant value for students, particularly for girls. This could enhance motivation and interest in technology and computer science.

Further lessons learned from the field notes:

- An important part of the process is the design. It is crucial to make it clear to the participants which patterns are easy and which are more difficult to implement

in programming code. It was beneficial that the participants emailed us their designs in advance so that we could think about different support options.
- Teachers should be involved so that they can conduct their own courses in the future.
- Initial programming of designs could be guided, for instance, through tutorials with CS teachers.
- After taking the initial steps, some students displayed great talent and found joy in programming independently.
- Students still wear their shirts a year after the course. They are very proud of their work and such as to show it off.

6 CONCLUSION AND OUTLOOK

The study conducted provided valuable insights into girls' and boys' motivation and interest in programming patterns. The first study question aimed to understand whether such activities promote intrinsic motivation, especially in girls. The second study question examined gender differences in the design and pattern-making process during stitching and coding lessons. In summary, our study underscores the importance of gender-sensitive pedagogical approaches in programming education. The findings highlight the need to develop interventions that promote a sense of belonging, enhance self-efficacy, and address the specific interests of boys and girls alike. The insights gained through this research are crucial to efforts to effectively engage all students in computer science.

In addition, the COVID-19 pandemic was an unexpected event that forced many projects to spontaneously rethink and move to online or hybrid teaching. In our case, this challenge led to some progress, as described in this section. After homeschooling started, the planned classroom sessions in cycle 2 could not be held in the originally planned form. However, we were able to quickly switch to hybrid course formats with increased resource use. Videos and online tutorials were created for students to access at any time. The concept of "bring your own device (BYOD)" was well promoted, especially in hybrid lessons, due to hygiene regulations, which alleviated teachers' concerns. Remote workshops and online coaching sessions for students were conducted by trainers and staff at TU Graz. The existing course concepts were expanded to include online formats. Course materials had to be adapted (see Figure 1). As a result of the project, a blended learning format is now available for code and stitch courses (also accessible on the Wiki).

Furthermore, on the well-known website hourofcode.org, which offers many tutorials for all age groups in more than 45 languages, a course based on the workshops could also be added. The website is used by millions of students and teachers in over 180 countries. Moreover, new stitches have been implemented. We have already succeeded in filling areas of objects with the app (see Figure 13). This type of stitch is called tatami-stitch. It is not about the stitch itself but more about the algorithm to optimally divide the area and then fill it with the stitch type. This functionality clearly sets the Embroidery Designer App apart from other comparable embroidery design programming environments. Furthermore, a connection with e-textiles, or "smart wearables," is interesting. Here, finished embroidered patterns can be extended, for example, with the help of sew-able LEDs or single-board computers such as BBC micro-bits (see Figure 14). Instructions have also been prepared for this on the Wiki.

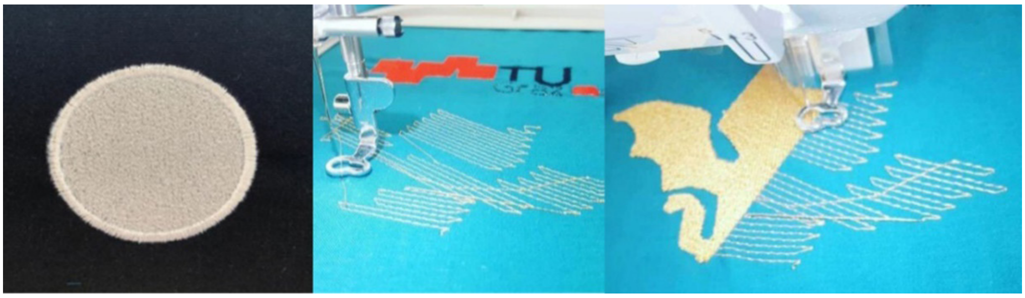

Fig. 13. Area filling of objects

Fig. 14. Connection of embroidery designs and e-textiles or to "smart wearables"

Findings, especially from cycle 2, have led to two new projects. Collaborating with bits4kids and TU Graz, an online course website was initiated and didactically prepared for the project "online platform" in 2021. This project was funded by the Austrian Research Promotion Agency (FFG). which also supported "Code'n'Stitch." In the end, children, both in and out of school, were able to utilize a learning management platform and a Discord server for support in workshops. bits4kids has conducted approximately 10 workshops in last 2 years, held both on-site in schools and during summer courses, as well as online through an "Online Coding Club" or during "Online Coding Weeks." The TU Graz team incorporated their findings into various workshops such as "Girls Coding Week" or "Maker Days for Kids." At Zurich University of Technology, the project results sparked a new initiative: "Making at School" (https://explore-making.ch [46]), with teacher training and workshops on digital designs, e-textiles, and "smart wearables." While the concept is still under refinement, the foundational idea from the funding project remains stable.

A final project conducted by bits4kids, which will start in 2022, aims to inspire girls with embroidery designs for computational thinking as a creative activity. The core element is the digital ecosystem with the network learning world, "KOALA." This initiative is tailored to meet the needs of girls.

- Learning independently and self-directed with creative, gender-appropriate tutorials.
- Learning through female coaching by women for women, also serving as role models.
- Learning through networking and exchange can take place among individuals in a secure virtual space.

Finally, in December 2022, the Embroidery Designer App was also awarded the Europe Social Impact Award by Huawei.

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