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Tailoring Full STEAM Ahead Empowerment: Creative Coding for 21st Century Girls

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Abstract

INTRODUCTION: This paper provides a comprehensive examination of the Creative Coding project's impact on female empowerment.
OBJECTIVES: The project addresses the gender disparity in STEAM fields by integrating coding and art for girls aged 10-15, using the Strudel tool that combines real-time live coding and music composition.
METHODS: Through observation and interviews with the girls who participated and performed at the end of the Creative Coding project, but also with those who dropped out, we cast a deep look into the positive and negative parameters to tailor concrete measures for every girl empowerment - not only super achievers. We collaborated with teachers and female mentors from the Computer Science and Engineering Department as relatable role models, to support feelings of belonging and spark curiosity. Using the new user-friendly Strudel tool that supports the integration of art, music, and audio-visual elements, we aimed at an engaging learning experience. To tailor new actions and increase attrition we used a mess map for analysis of the wicked problem of dropouts. Finally, collaboration among the girls and peer learning were expected as by-product effects.
RESULTS: Positive outcomes include increased interest, self-confidence, creativity, and aspirations in STEAM subjects among the girls. However, a more comprehensive and supportive environment is recognized as necessary to engage a broader group of girls in STEAM activities. The findings highlight the importance of cultivating curiosity, providing mentorship, promoting inclusivity and collaboration, and integrating creativity in education to inspire and empower girls in coding and STEAM disciplines.
CONCLUSION: The paper concludes by emphasizing the potential of Creative Coding practices and the audio-visual perception of music to enhance girls' empowerment, creativity, and interest in coding and STEAM fields.

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1. Introduction

The days of static roles in the job market are gone. The ever-evolving job market landscape is heavily shaped by technological development making change not just inevitable, but defining the very heartbeat of progress. With technology steadily supplanting manual labour, the future belongs to those armed with a diverse arsenal of skills. Yet, amidst this whirlwind of innovation and transformation, one trait stands tall as the beacon of success: creativity. In a world where adaptability is currency, nurturing creativity and innovation isn't just desirable; it's essential. These qualities are the compass guiding individuals through the labyrinth of modernity, shaping not just careers, but the very fabric of our future. It's increasingly important to nurture creativity and innovation in individuals, as they play a crucial role in navigating these evolving dynamics of the modern

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world.
To empower students to realize their full potential as adults and equip them with knowledge of worth to become future leaders, productive workers, and responsible citizens[15, 32] modern education systems are under increasing pressure to cultivate essential skills in students, including problem-solving, critical thinking, communication, collaboration, and self-management. Contemporary academia is acutely aware of this pressure and strives to employ effective teaching methods where traditional educational models are being replaced by innovative approaches that prioritize the development of critical thinking, problem-solving, and innovation skills among the younger generation. Research indicates that in order to meet the strong demand for interdisciplinary skilled labor, the incorporation of STEAM methodologies in the classroom must be executed through a practical project-based or problem-based learning approach, thereby guaranteeing enhanced results [38].

This needs for educational transformation that should cater to increased creativity has led to the widespread adoption of STEM education (Science, Technology, Engineering, and Mathematics) and, more recently, the integration of arts into the STEM disciplines through the STEAM model [39]. While arts and STEM may initially seem incompatible, they actually complement each other by fostering the generation of fresh, creative ideas and facilitating new thought processes [20]. The STEAM framework promotes holistic learning by combining systematic thinking skills from both scientists and artists [3]. It recognizes the innovative ideas that arts contribute to artistic, scientific, and societal domains [21, 35]. Moreover, the diverse nature of arts enables students to explore human nature, understand complex world dynamics, and develop empathy, which is considered one of the crucial skills in the 21st-century skills framework [6, 25]. The "Full STEAM Ahead" approach integrates arts pedagogy into STEM education, challenging the traditional pedagogies prevalent in STEM fields, particularly in engineering. It highlights the adoption of active learning approaches and aims to overcome disciplinary ego-centrism by incorporating pedagogies and delivery methods commonly associated with the liberal arts, such as studio-based learning (Connor, 2014).

However, gender disparity persists in STEAM fields, particularly in technical areas like engineering and computer science, where men outnumber women [33]. This disparity is even present in Sweden, a country renowned for its commitment to gender equality, where women are underrepresented in Swedish universities [31]. To address this significant issue and counteract the effects of stereotype threat[33], we have developed a Creative Coding project at the Chalmers University of Technology, Department of Computer Science and Engineering (CSE), Sweden.

In this paper, we present a deep analysis of the Creative Coding project and its effect on female empowerment. Creative Coding is an initiative that integrates coding and art across interdisciplinary areas specifically designed for girls aged 10-15. The project's objective is to equip these girls with knowledge, creativity, and social capital—essential skills that will empower them and boost their confidence in pursuing their future endeavors [12]. This project is implemented through a studio based learning approach that is commonly associated with the liberal arts disciplines and involves creating a learning environment where students actively engage in hands-on, experiential learning activities within a studio setting that emphasizes active learning, critical thinking, problem-solving, and creativity[10].

2. The Creative Coding project

The Creative Coding project developed at Chalmers University in Sweden, Computer Science and Engineering Department (CSE), was offered in the spring term, from March to June of 2023. It was delivered as a series of workshops spanning over 10 weeks, where girls aged 10-15 are introduced to coding using the innovative Strudel tool[24]. Strudel is a fascinating and unique tool that provides fast audio and visual feedback, allowing participants to compose music and engage in live coding sessions as depicted in Figure 1. Live coding music is a growing international phenomenon where programmers communicate their musical intentions to a computer and receive real-time visual and auditory output [30]. In this context, live coders write code that generates sound in real time, bridging the gap between coding and artistic music creation.

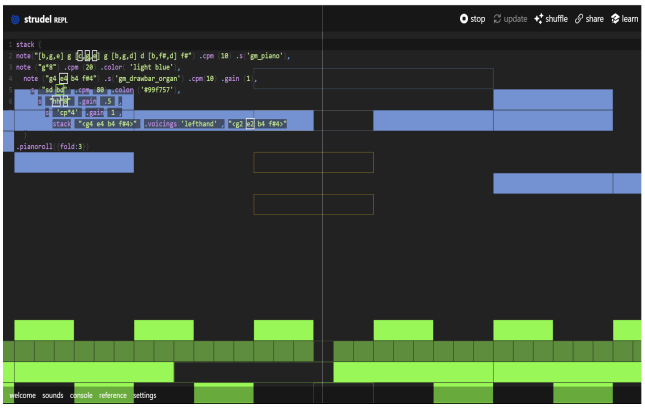

Figure 1. Strudel Interface

In spite of the conventional division between art and coding, we have purposefully decided to prioritize art, in this case, digital art as a central element in

our endeavors to tackle the issue of boosting girls' interest in STEAM fields. Drawing from scientific research and our collaborative experiences with the Gothenburg Opera House [25], we have merged these interdisciplinary domains to create an engaging and enriching learning experience for young individuals. Our hope was and is, that by providing a positive learning and coding experience we can help girls overcome stereotypes associated with STEM fields and inspire them to pursue careers in STEAM.

In order to enhance girls' learning in Creative Coding sessions, we made a conscious effort to choose female teachers and mentors primarily from the CSE department. Knowing that mentorship is clearly recognized as mutually beneficial for both mentors and mentees, going from personal satisfaction to career advancement we focused on recent findings that good mentors need a combination of soft and technical skills [36]. Among the selected teachers and mentors, the majority were women, while there was only one male teacher. By including female role models in the sessions, we aimed to create an environment that fostered positive learning experiences for the girls. In order to provide more relatable mentors [28], we invited a mix of female members of the CSE department - some of them were professional software developers while some of them do not know to code also as mentees. To boost girls' confidence and also encourage them to explore coding and technology with enthusiasm, the presence of female teachers and mentors was crucial for breaking down gender stereotypes and promoting inclusivity within the field of computer science.

Thinking of the best ways to support and improve girls' learning experience we have put special importance on close collaboration between mentors, teachers, and their peers. By working together, we aimed for the creation of a supportive network where the girls could learn from each other and build social capital [22, 23, 28]. This collaboration would not only facilitate their technical skills development but also cultivate teamwork and communication abilities, which are essential not only in the field of coding but as one of the most important 21st-century skills. Overall, our goal was to positively influence girls' learning experiences and empower them through the integration of female role models, collaborative learning, and the acquisition of social capital in Creative Coding sessions.

Finally, the Creative Coding project has been designed to respond to the social demand for more girls in STEAM fields and thus, help them become active solution designers of their social integration and mobility. To achieve that and to contribute to addressing the under-representation of women in STEAM due to societal, stereotypical, and other factors, we have opted for a process that involves early intervention in schools to encourage more girls from dis-empowered neighborhoods of Gothenburg to pursue STEAM education and careers.

The Creative Coding Project is supported by three pillars. The first pillar is learning to code through the informal learning practice of making music. The second pillar is social capital acquisition through the mentorship of positive role models and meeting peers. The third pillar is being present at Chalmers University building Kuggen through which we implicitly say that girls are very welcome.

3. Ethical Considerations

This initiative prioritized the equitable treatment of all girls, irrespective of their backgrounds, ethnicity, socioeconomic status, or abilities. A comprehensive endeavor was undertaken to ensure that every girl had an equal opportunity to participate. To achieve this, the project's information was diligently disseminated through diverse and viable means, ensuring its broad reach and maximizing the chances of engagement from a large pool of potential candidates. In order to conduct the project's research, working both as researchers insiders and outsiders [2], which was primarily focused on females between the ages of 10 and 15, parental consent was absolutely necessary. Therefore, it was made sure that the parents' informed agreement was gained before the research began and that they were given a thorough explanation of the research and interview process. The technique of handling the data acquired and how the personal data is kept securely was explained to the parents.

The participants' psychological well-being was also given a lot of consideration by creating a friendly and encouraging environment. This entailed attending to any emotional or psychological difficulties that could emerge throughout the project and offering suitable support and direction. The teachers took the initiative to inform the candidates about the project and the steps involved because the majority of the participants were unfamiliar with the collaborative live coding experience. Communication with the participants and their families was kept open and transparent throughout all phases of the research. This required outlining the project's goals, actions, and any potential dangers or advantages in explicit terms. At the conclusion of the session, feedback from the participants was collected in order to determine what needs to be improved in the sessions that will follow.

4. Methodology

The Creative Coding sessions were organized as two-hour sessions from 5-7 pm each Thursday and two four-hour sessions from 12-4 pm on two Saturdays. Workshops were hosted by two PhD students of the CSE department, and the venue was the Department of

Interaction Design at Kuggen, the Chalmers University of Technology Sweden. The series of workshops culminated in a concert where girls performed their coded music in Visual Arena, Lindholmen.

Through the workshops, the participants were iteratively acquainted with the fundamentals of the Strudel tool. Taking good care of a friendly positive and safe atmosphere, girls were granted the opportunity to explore the logic of coding, meet the basics of live coding, and the basic concepts associated with Strudel commands. Subsequently, through their collaboration with PhD students and close mentorship which is based on old Bloom's study [5] that revealed a significant enhancement in the grades of students who received intense tutoring, participants advanced towards coding music using these rudiments. Gradually, they learned to improvise their code based on their preferences and investigated working collaboratively in pairs and teams.

The Creative Coding project started with 16 girls of different cultural backgrounds. Since the whole process is novel and unusual, we wanted to learn from the girls [25] and hear in their own words how they describe their experience in this process. Bearing in mind their very young age (10-15), we sent hard copy requests to all parents for consent to interview the girls. After obtaining parental consent for running a research study in parallel with a coding session we chose two complementary methods for analysis of Creative Coding sessions impact - observation and interview. During the sessions we conducted a close observation of the workshop participants, studying their interactions and approaches towards teachers, mentors, and peers. A weekly observation diary was created to carefully monitor their transitions and document participants' progress. Once Creative Coding workshop sessions were finished, an open-ended focus group interview was conducted to evaluate girls' progress, motivation, the feelings of belonging, and well-being. This method was chosen to make girls feel comfortable, safe, and more engaged suggested in the scientific literature[1]. Their identity was completely anonymized in the data, and the data was saved just for the purpose of the study. The data collected were noted and subjected to rigorous analysis using Braun and Clarke's (2006) six-phase framework for thematic Analysis [9].

5. Analysis and Results

In this section, we present the analysis of the collected data and its results. As mentioned above we analyze the Creative Coding project through observation and interview.

5.1. Observation

Through detailed thematic analysis of weekly diary data, we gained a more comprehensive understanding of the various aspects and experiences within the Creative Coding project. Based on the observations, the following 8 themes and sub-themes were identified:

Theme 1: Initial Excitement and Exploration.

- **Sub-theme 1.1: Unboxing and Equipment Exploration**

  As for the full participation in the Creative Coding program composing music played a central role, a lot of the audio equipment was necessary to support coding on computers. We have bought sound cards and headphones for each participant. To start with coding music girls needed to get acquainted with the equipment and learn how to connect the devices. The girls exhibited eagerness and exhilaration when unboxing the coding equipment, indicating a sense of creativity, engagement, and joy when introduced to novelty.

- **Sub-theme 1.2: Interest in Coding**

  The participants actively engaged in exploring the new tools and features, demonstrating curiosity about the coding process and its potential for creativity. The concepts of Strudel and live coding were entirely novel to the participant, but their desire to delve into the software indicated an eagerness to learn something new. Strudel represents a novel live coding platform that enables the composition of dynamic music pieces within the confines of a web browser. This platform has been designed to be easily accessible to individuals of varying levels of expertise, ranging from novices to professionals. As Strudel requires quite a low threshold of knowledge of coding for sending interesting audio-visual feedback to the user, the experiments with code, in other words making changes and listening, and watching it, were easy and ensured creative flow.

Theme 2: Learning and Retention.

- **Sub-theme 2.1: Understanding Coding Concepts**

  Due to Strudel's repressiveness participants were able to grasp the fundamental syntax of the code with relative ease, as it proved to be quite straightforward and well-suited for beginners. A subset of the participants exhibited prior experience with Scratch (coding language with a simple interface suitable for young learners) and Block Coding (coding using visual methods), which facilitated their comprehension of the coding principles in Strudel. The participants exhibited an aptitude for understanding and applying the coding concepts conveyed during the sessions, thus attesting to their progress

along the learning continuum. They were able to establish logical connections between the musical notes and the corresponding codes, which is indicative of their progress in their learning journey. Participants coding their own music pieces can be observed in Figure 2.

Figure 2. Participants coding music

- **Sub-theme 2.2: Challenging to Remember Commands**

  The Strudel system offered a wide range of commands and functions for generating music. However, certain participants encountered difficulties in recalling all the coding commands, indicating the necessity for supplementary reinforcement and practice. The teachers stressed the importance of regular practice in achieving greater familiarity with the commands, rather than attempting to memorize them all at once. As a helpful measure, the participants were introduced to the well-defined documentation in strudel to support their coding works.

- **Sub-theme 2.3: Recall and Discussion**

  During Creative Coding sessions, participants had to recall their previous knowledge from memory to effectively engage with new concepts in the Strudel programming language. The initial portion of the Creative Coding session was consistently dedicated to reviewing the concepts and commands acquired during the preceding lesson, thereby ensuring that participants possess a sound understanding of the material. Notably, participants were able to recall and actively discuss previous session topics, revealing a strong retention of acquired knowledge. Interestingly, we observed that younger participants below 12 years encountered greater difficulty in recalling commands when compared to their elder counterparts, however, this is a common occurrence.

Theme 3: Collaboration and Peer Learning.

- **Sub-theme 3.1: Group Work and Sharing**

  The participants of the project were girls between the age group of 10-15 from different schools and areas in Gothenburg. Initially, it was observed that the participants exhibited a reluctance to engage in communication, owing to their unfamiliarity with one another. But in due course of time, they started observing each other, discussing their works and doubts with their classmates, and started editing the codes of their peers as part of group work. The project fostered a collaborative environment where girls worked in groups, shared their work, and exchanged feedback.

- **Sub-theme 3.2: Peer Learning and Feedback**

  During the sessions, the educators consistently highlighted the significance of effective communication and productive discussion within the classroom environment to enhance comprehension and collaborative efforts. Consequently, the attendees attentively listened to and provided feedback on each other's musical creations, promoting mutual learning and a harmonious community. The instructors ensured that all participants' work was presented to the entire class during each session, enabling peers to evaluate and enhance their own presentations by incorporating the received feedback.

- **Sub-theme 3.3: Encouragement and Motivation**

  The project created a supportive community where girls encouraged and motivated each other, contributing to a positive learning environment. The teachers, mentors, and other members of the Creative Coding team also encouraged the participants by giving positive reinforcements and comments on their works in Strudel. Although there were instances when girls felt discouraged by the perceived superiority of their peers' work, the teachers offered relevant guidance and positive reinforcement to lift their spirits and encourage them to continue.

Theme 4: Mentoring and Guidance.

- **Sub-theme 4.1: Teacher's Role**

  Teachers played a crucial role in providing guidance, explaining coding concepts, and offering feedback to help girls overcome challenges. They encouraged the participants to try and experiment with code and to explore the software to unleash its potential to create music. The teachers were able to give individual attention to the candidates and ensured the inclusion of all participants in the session.

- **Sub-theme 4.2: Mentor's role**

  In addition to the presence of teachers, mentors were selected from the pool of Ph.D. students

and lecturers affiliated with the CSE department. These mentorships were specifically designated to serve as exemplars for the participating girls. Our primary objective was to furnish participants with guidance and positive role models, with the intent of inspiring them through the mentorship relationship. Nonetheless, the practical realization of the mentors' role proved to be hindered by various constraints, including restricted time allocations for sessions, inflexible scheduling on the part of the mentors, and limited availability of mentors. As a result, the effective implementation of the mentors' involvement in the initial phase of the project was compromised due to the absence of a comprehensive strategy and methodological support for leveraging their support.

- **Sub-theme 4.3: Engaging Discussions**

  Teachers were engaged in discussions with the girls about their project progress, offering strategies and support to enhance their learning experience. The participants actively participated in the discussions and collaboratively worked while creating music. The teachers gave the participants the freedom to raise their queries and concerns regarding their work and progress.

Theme 5: Overcoming Shyness and Fostering Inclusion.

- **Sub-theme 5.1: Encouragement to Participate**

  Some girls were initially shy and required encouragement to ask questions and actively participate in the sessions. With the support of teachers and peers, they were able to overcome this challenge and thereby fostering inclusivity and creating a safe space for everyone to engage. It was also apparent that parents played a significant role in motivating the participants to overcome their shyness. This was evident when some participants mentioned during a discussion that their parents encouraged them to practice for the concert at home and urged them to ask questions and clarify doubts during training sessions to achieve the best results.

Theme 6: Iterative and Creative Process.

- **Sub-theme 6.1: Experimentation with Sounds and Colors**

  The project aimed to inspire girls to explore various sounds, colors, and coding techniques, thus promoting a creative and iterative mindset. Throughout the learning process, and due to the amazing audio-visual capacity of the Strudel tool, the participants were encouraged to iterate and learn from their mistakes. Notably, the girls utilized the Freesound platform to identify and recreate sounds within Strudel and used online collaborative tools like Google Docs to share and work collaboratively. This proactive involvement showcased their eagerness to experiment and work creatively, indicating their explicit ability to learn and experience more technical aspects.

- **Sub-theme 6.2: Editing and Improvisation**

  Participants were given the opportunity to edit and improvise existing code, promoting their individuality and creativity. They also edited and improvised using the code of their group members and peers, which gave them further opportunities to explore the coding strategies. This allowed them to broaden their knowledge while discussing with their peers.

Theme 7: Concert Preparation.

- **Sub-theme 7.1: Motivation for Performance**

  The participants were clearly introduced to the idea of having a concert at the end of the Creative Coding project. The clear objective of preparing for a concert motivated girls to work towards their public performances individually and as a team. From the beginning of the project, the participants were aware that they can perform on the stage and in front of the audience. Those who did not feel good about being on the stage were given the opportunity to perform in some other way, for example, just playing the code. Still, all girls embraced this challenge in an impressive, brave way.

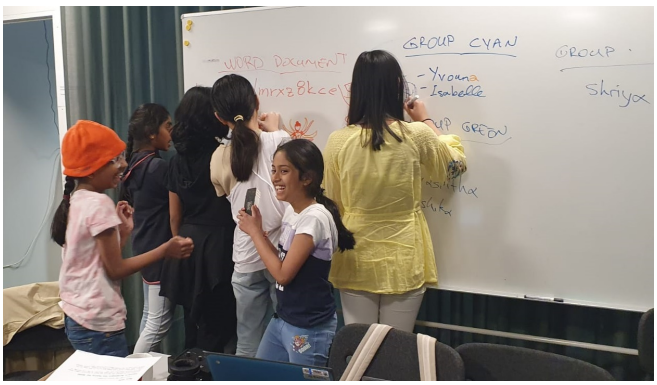

Figure 3. Participants creating groups

- **Sub-theme 7.2: Planning and Roles**

  Planning for solo, duo, and trio acts provided girls with the opportunity to take on different roles, promoting personal growth and skill development. It was admirable to see the girls taking the initiative to do a solo, duo, and

trio. The participants were given the freedom to choose their partners for the performance and this gave them the freedom to explore and communicate further with their team members. Participants actively selecting their partners for their performance is observable in Figure 3.

Theme 8: The Performance.

- **Sub-theme 8.1: Transformation and Collaboration**

  The candidates' performance demonstrated the significant transformation they underwent throughout the project, from initial hesitation to becoming a cohesive team, promoting cooperation and synergy. We observed that the participants were able to collaborate harmoniously with their fellow team members on stage during live coding.

- **Sub-theme 8.2: Self-Confidence and Expression**

  Regardless of their very young age, the girls displayed impressive and unexpected self-confidence during their Creative Coding presentation. They proudly showcased their individual and collective aptitude for task completion and their passion for creatively expressing themselves through music. (A sample music from one of the participants can be experienced through the following link: https://strudel.tidalcycles.org/?fYMWmFziVVnh). Their enthusiastic and well-prepared self-introduction and impressive live coding were indicative of this aspect. Participants engaging in live coding can be observed in Figure 4.

  In conclusion, through the careful and detailed implementation of Braun and Clarke's (2006) six-phase framework [9], we managed to reveal crucial insights into the girls' experience with Creative Coding sessions. The identified themes and sub-themes highlighted the girls' enthusiasm, learning, collaboration, mentoring, inclusivity, iterative and creative process, and final performance.

5.2. Results of Observation

By giving a deep, holistic look at these eight topics a number of conclusions can be drawn. The initial theme of excitement and exploration displayed by the girls indicates a strong curiosity to explore new tools and features, which is a crucial skill in motivation and learning [16]. Furthermore, the girls demonstrated a surprising ability to comprehend coding concepts, even when faced with challenges in recalling specific commands. With more practice, they were able to improve their retention of these concepts. When exploring in a supportive and safe environment,

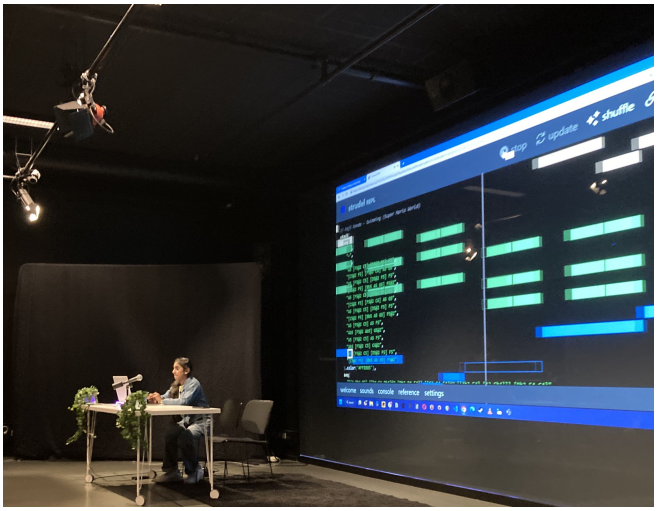

Figure 4. Performing on stage – Live Coding in Strudel

girls' group work, sharing, and feedback sessions demonstrate their great capacity for collaboration and peer learning.

It also became apparent that mentoring and guidance can promote inclusivity and encourage introverted participants to engage actively, ensuring an empowering and inclusive environment for all. We agree with Millar and colleagues (2022) that to be more successful in supporting a diverse group of participants more carefully developed strategies should be planned to ensure closer mentor–participant relations. It is important to note, that the Creative Coding iterative and creative process enhanced experimentation, improvisation, and individual expression through coding techniques. Together with the concert preparation, and performance, this stimulated a goal-oriented approach that advances personal growth, self-confidence, and skill development.

5.3. Interviews

Girls' first-hand testimony takes us to an even deeper understanding of the effects and capacities of the Creative Coding project. Here we present the analysis and results of the data collected through direct communication with the girls. In this communication, we used open-ended questions and a quantitative Likert scale [37]. Again, by using Braun and Clarke's (2006), we identified 5 themes. They read as follows.

Theme 1: Interest and Engagement. There were participants who lacked prior experience in coding, while others had a basic understanding of block coding and Scratch, which served as their foundational knowledge. A few girls had previously engaged in coding using game platforms. Integration of music/art with coding made the learning experience more engaging. Girls

found the combination of creative elements more interesting than traditional coding methods or games. One of the girls said,

> *"I was interested in coding, but I like this combination better."*

This statement makes a clear appreciation and preference for coding together with art.

Participants expressed a high level of interest in coding and art. The majority of participants expressed a strong passion for art, and when asked how many stars (from 1 to 5) they would give to art, all of them gave a rating of 5/5. Some girls mentioned attending guitar and piano classes, indicating their active engagement in artistic pursuits. The following quote clearly illustrates the relationship between coding and art.

> *"I would give a 4/5 for coding and 5/5 for art".*

Girls found Creative Coding more enjoyable and stimulating compared to conventional coding techniques or game-based learning approaches. The project's emphasis on creative expression through coding captured their attention and sustained their interest. A participant said,

> "*This combination of music and coding is better than coding with games*".

Theme 2: Positive Experience and Confidence. All girls reported a positive and enjoyable experience during the Creative Coding project. They expressed enthusiasm for attending the sessions and actively participating in coding activities.

> " *I joined Creative Coding as I like music and I thought it would be fun to learn to code music.*"

said one of the girls. The Creative Coding project was described as a fun and enjoyable activity that some participants considered pursuing as a hobby. "I feel like I have a new hobby now" were exact words. The girls felt positive about their overall experience, indicating a sense of satisfaction and enjoyment. Participation in the Creative Coding project contributed to an increase in participants' confidence in their coding abilities, leading to feelings of empowerment about their future in the science and technology fields. This is how they describe it.

> *"Strudel is fun, I feel like I have learned something interesting. Here I had the freedom to explore my own interests."*

Girls' testimonies clearly show that participation in Creative Coding workshops fostered a sense of empowerment and self-confidence.

Theme 3: Importance of Female Mentors and Role Models. Participants highlighted the significance of having female mentors who could relate to their experiences. Female mentors provided guidance, support, and encouragement, which boosted their confidence and motivation. A participant said,

> "*I feel it is good to have female mentors/teachers. The teacher was approachable, and she patiently heard and solved my doubts*"

. Girls felt supported and believed in by their mentors, creating a positive learning environment. Having mentors who understood their challenges and aspirations helped them overcome barriers and doubts.

Theme 4: Building relationships, social capital acquisition and feeling of well-being. Participants formed strong bonds with their mentors, built on trust, respect, and mutual understanding. Positive relationships with peers fostered collaboration, shared learning, and a sense of camaraderie. The girls expressed a preference for mentors who provided positive feedback and conveyed information in a positive manner. Some girls mentioned that the decision of whether to have a mentor should be left to the individual, allowing them to decide if they need one. Teachers and mentors created a supportive environment that encouraged open communication and collaboration. Participants felt comfortable asking questions, seeking help, and expressing their ideas. One of the interviewees said,

> "*I felt secure and included in the group.*"

Collaborative activities and group projects allowed participants to bond with their peers. Sharing experiences and collaborating with other girls enhanced their sense of community and support. Participants desired more time for breaks and interactions with classmates, indicating the importance of socializing and connecting with peers. This is how they describe it -

> *"Working together on a piece of code was fun, we made a horror theme for the concert".*

Theme 5: Time Constraints and Attrition. Some participants mentioned that time constraints and conflict with their other extra curricular activities might have contributed to a few participants leaving the course. The Creative Coding project finished 8 girls out of 16. Limited availability and conflicts with other commitments impacted their ability to fully engage in the project. The girls noted that flexibility in scheduling sessions and accommodating individual time constraints could help address attrition and increase retention rates. Adapting the project to fit participants' busy schedules would allow more girls to fully participate.

Table 1. Key Insights from Combined Interview and Observation Results

Insight	Description
1. Passion for Creative Coding	Participants displayed a strong passion for combining music and coding, finding it engaging and enjoyable.
2. Positive learning experience	The project fostered a positive learning experience, leading to increased confidence and empowerment.
3. Importance of female mentors	Female mentors played a crucial role in providing guidance, support, and motivation, enhancing participants' confidence.
4. Collaborative and supportive environment	Collaboration and positive relationships with mentors and peers created a supportive learning environment.
5. Encouragement and inclusivity	Shy participants required encouragement to participate actively, contributing to inclusivity in the learning process.
6. Exploration and creativity	Participants actively experimented with coding techniques, promoting creativity, experimentation, and individuality.
7. Motivation through performance	The prospect of a concert motivated girls to work individually and in teams, fostering goal-oriented efforts.
8. Transformation and self-confidence	Participants transformed from hesitant individuals to a cohesive team on stage, displaying self-confidence and creativity.

5.4. Results of Interview

Based on the findings derived from the interviews of the participants in Creative Coding workshops, and the analysis of the collected data, several conclusions can be drawn. As already pointed out by scientific literature [11, 13, 19] the integration of art, into the teaching and learning processes, has the potential to enhance engagement and attract girls to STEAM fields. The integration of music, or art as a final result of coding practice, and audio-visual perception of music holds great potential in enhancing the interest of girls in the fields of coding and STEAM. Music has been found to positively affect physiological factors such as heart rate, blood pressure, and hormonal levels, as well as psychological experiences like restlessness, anxiety, and nervousness [14]. Therefore, the incorporation of music to support interdisciplinary learning can lead to immersive and emotionally engaging learning experiences for girls.

Additionally, coding visual elements (enabled through the Strudel software tool) to correspond with various aspects of music such as tempo, pitch, and intensity can further elevate the audio-visual perception, resulting in the creation of captivating experiences. With that in mind, we argue that the adoption of art as a final destination increases plausible learning experiences, feeling of belonging, and well-being. The participants that undergo such learning and experience performance of their creation are more confident, and empowered to explore further within science and technology fields.

Here we list the insights from the results of interviews and observations (see Table 1).

- Passion for Creative Coding - the experience of creating music through coding was engaging and enjoyable, making girls passionate about it;
- Positive learning experience - with a lack of pressure and a lot of support from teachers and mentors, a positive learning experience is delivered which increased confidence and motivation of the participants;
- Importance of female mentors - female role models, and mentors, are very important for providing guidance, help and support;
- Collaborative and supportive environment - a strong focus on collaboration with peers, mentors, and teachers resulted in a positive, supportive learning environment;
- Encouragement and inclusivity - shy, introverted participants required special attention and encouragement to participate actively. Consciously devoting time to them contributed to inclusivity in the learning process.
- Exploration and creativity - having an open process without rigorously defined expectations,

resulted in free experiments with coding, promoting creativity and individuality.

- Motivation through performance - preparations for public performance, and concert, gave another layer to the whole learning experience, motivating girls to work individually and in teams (preparing for solos, duets, etc.)

- Transformation and self-confidence - the whole journey from hesitant individuals to a strong, cohesive team on the stage in front of the audience with the big screen in the back, resulted in a strong display of self-confidence and creativity.

The support and encouragement delivered through collaboration with their teachers, emphasizes the significance of representation and the need for more diverse role models to inspire girls in STEAM. We should not forget that girls stressed the importance of having opportunities to bond and collaborate with their peers to foster a sense of community, belonging, and support.

However, running the Creative Coding pilot project presented in this paper, resulted also in a quite high level of dropouts (almost 50%). To cater for all, to reiterate and find better methodological approaches and creativity in teaching, we looked at the reasons responsible for that outcome. In the next section, we present our findings and propose remedies for the next Creative Coding sessions.

6. The Challenge of Dropouts

Despite having a promising objective, the first phase of the Creative Coding project encountered a dropout rate of 50% during the early stages of its commencement. Acknowledging the complexity of the dropout problem and the interconnected nature of its various contributing factors, the dropout problem has been approached as a wicked problem[27, 34] and was analyzed using a mess-map as shown in Figure 5. This holistic perspective resulted in understanding the multifaceted challenges faced by participants in the Creative Coding project and resulted in the need to identify more comprehensive interventions and solutions to tackle this issue.

A thorough investigation was carried out by conducting interviews with participants who discontinued their participation in the Creative Coding project to gain insight into the causes of attrition. The transcripts of these interviews were carefully examined to identify possible patterns in them. Based on the interviews with dropout students, several key factors have been identified that have led to the attrition in the project. The most dominant factors that contributed to attrition include untailored methodological approaches, a lack of social connections among mentors and participants, a lack of commitment to the project, a lack of intrinsic motivation, perceptions of difficulty in a fast-paced learning environment, and limited emotional and cognitive engagement of participants throughout the workshop.

6.1. Results of interviews with dropouts

The main insights from the interviews with the dropouts of the Creative Coding project are listed as follows:-

- **Lack of social connections:** The lack of strong social bonds with the teachers and peer participants resulted in a diminished sense of attachment to the project itself[8]. A participant said,

  > *"You waste 10-20 minutes waiting for explanations."*.

  This statement indicates the over-reliance on educators to resolve uncertainties, as well as the lack of association and collaboration with fellow participants. The lack of social connections among mentors and participants hindered engagement and motivation. This challenge aligns with insights 4 & 5 in Table 1 indicating the importance of a collaborative and supportive environment which will eventually lead to encouragement and inclusivity in the learning process.

- **Lack of commitment:** The lack of passion for challenging tasks where the participant needs to combine music and coding along with a negative mindset lead to a decreased sense of perseverance. In addition to this, low commitment levels in the assigned tasks[7] arose due to the lack of social bonding with peers. A participant said,

  > *"It just started becoming harder."*

  This was stated as a reason for discontinuing the project which indicates that when the complexity of the tasks increased, the participants started losing their motivation to persevere, potentially due to frustration or difficulty in maintaining focus. This challenge aligns with insights 1 & 4 in Table 1 implying that a supportive environment and instilling a passion for the project could enhance the commitment to the project.

- **Lack of intrinsic motivation:** Participants who lacked genuine interest and enthusiasm for coding and art are more likely to drop out because they do not find the activities inherently enjoyable or interesting, unlike the participants who had a passion for the intersection of art and music[18]. A participant said,

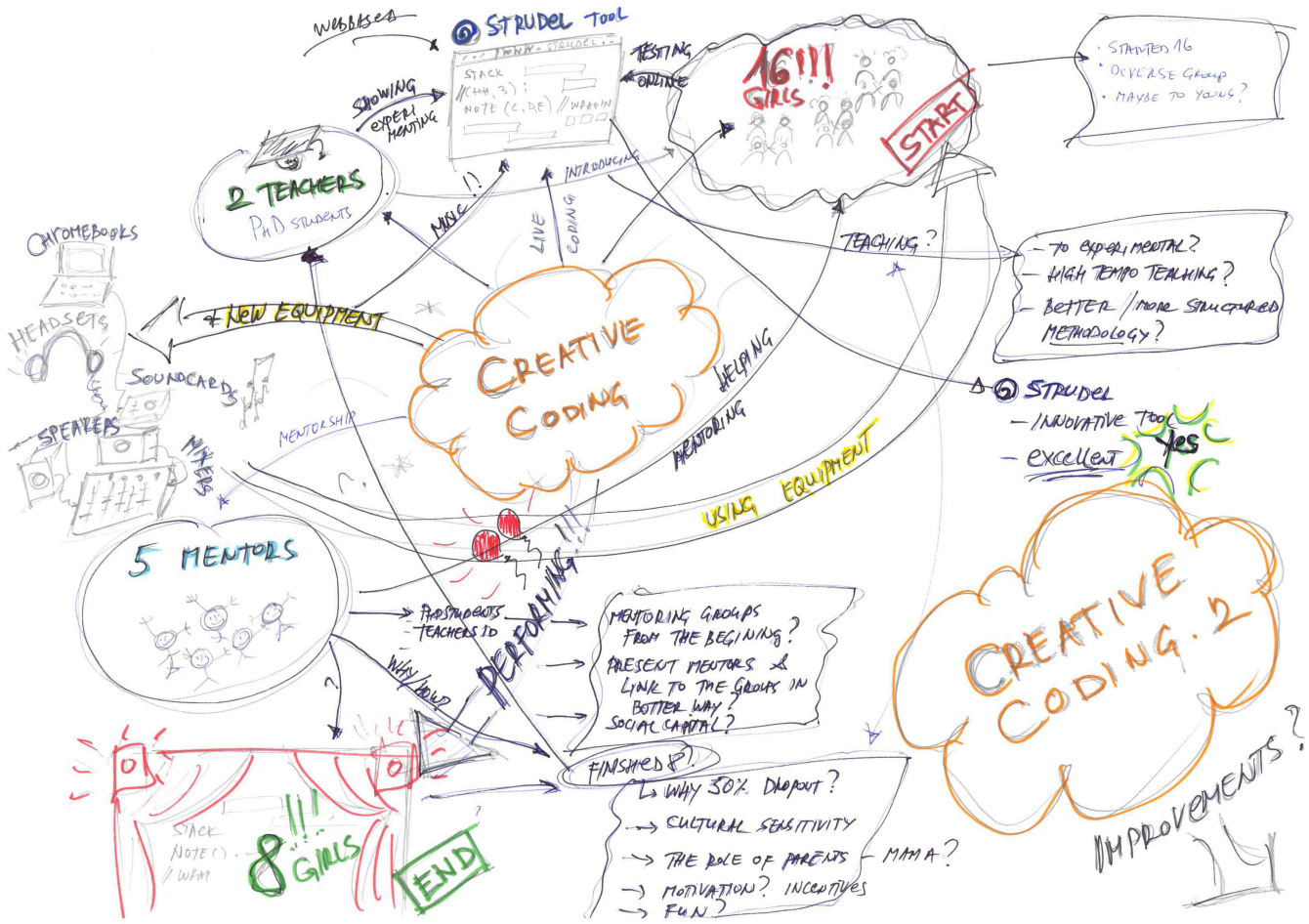

Figure 5. Mess-map

"I felt like I was not going forward, like going backwards."

When the participant started losing interest in the tasks, the passion for the project decreased leading to a lack of intrinsic motivation to continue pursuing the project. Additionally, certain participants may lack inner drive and enthusiasm, possibly stemming from low self-esteem or confidence issues. This challenge aligns with insights 2 & 6 in Table 1 stating that freedom to explore and learn through creativity coupled with positive learning experience can be a way to enhance the intrinsic motivation of participants.

- **Low self esteem and self-concept:** Participants with low self-esteem and self-concept felt unsupported and experienced negative perceptions of the project leading to high dropout rate. A participant said,

"I like creating music but I felt I was not creative enough, it just didn't click, the spark was missing."

which indicates that few participants felt low self-esteem when they had to encounter challenging scenarios. This challenge aligns with insights 3 & 8 in Table 1 indicating that more active involvement from the female mentors in supporting the participants to foster confidence in them could have enhanced their self-esteem.

- **Methodological approaches & Fast-paced learning environment:** The methodological approaches used in the project execution were not tailored to the diverse needs of the participants led to the participants being confused and disengaged, and they question the project's relevance and value to their aspirations leading to attrition[18]. Furthermore, the dropout rate indicates a disconnection between the project's objectives and the participants' engagement, suggesting the need for more customized and pedagogical approaches to teaching and mentorship. In addition, the perception of difficulty in a fast-paced learning

environment enhances the feelings of frustration and inadequacy. A participant said,

> *"I was starting to be confused, I kept forgetting.".*

This statement serves as an indication that the participant gradually disengaged and lost interest, leading to a state of confusion while attempting to complete the tasks in the project. The rapid pace of the sessions with limited time for reflection might have contributed to stress, anxiety and perceived difficulty among the participants leading to a high attrition rate[29]. This was evident when a few participants suggested that they would prefer more breaks between sessions to relax and connect with fellow participants. This challenge aligns with insights 3, 4 & 7 in the Table 1.

- **Behavioral, Cognitive and Emotional engagement issues:** Issues such as hyperactivity, attention problems, and negative moods affected participants' engagement levels, particularly among younger participants, leading to increased dropout rates[29]. During the observation of the sessions, it was noted that very young participants had less attention span resulting in distractions that ultimately led to the display of hyperactive behavior and disengagement from the sessions. This challenge aligns with insights 4 & 5 in Table 1 indicating that younger participants needed a more supportive environment and encouragement to participate in group activities and challenges when compared to their elder counterparts.

6.2. Interventions for enhancing participation and retention

From the dropout rate of the workshop, it was clear that it is essential to cater to the diverse interests and needs of the participants to tackle the challenges of attrition and to promote sustained engagement of participants. After the thorough analysis of the mess- map and interviews with dropouts, the following interventions are planned to be executed in the next phase of the Creative Coding project as shown in the Resolution map in Figure 6. Resolution map compiles, assesses, and organizes the complex data pertaining to a wicked problem to determine the courses of action and the possible outcomes from those actions as solutions for the wicked problem [17].

- **Changing the teaching methodology:** To begin with, it was essential to make a significant change in the teaching methodology with more emphasis on music/art. By critically evaluating the current teaching methodology, a few changes were proposed to be incorporated in the upcoming sessions of Creative Coding as listed below:-
  - Each session must have well-defined blocks of codes prepared in advance that deliver positive music outcomes with the flexibility to be easily combined with other blocks of codes. These materials can be then referred to by the students at home as part of revising and practising music. This structured approach will facilitate utilizing the time more effectively during the Creative Coding sessions.
  - For the upcoming session, there will be a much stronger focus on creating real music rather than creating just any sound on Strudel. This could enhance the learning experience of the participants due to more artistic expression.
  - As Strudel does not provide the option to save previously developed material, online collaboration tools need to be used to share and save the works of the participants to prevent the repetition of commands during each session. This way time can be saved and a more structured and organized approach can be incorporated in the teaching methodology.
  - To improve the effectiveness of teaching methods, a collaborative approach known as the "ping pong game" as shown in Figure 7 has been introduced and other gamified activities are planned for implementation in the next phase of Creative Coding project. "Ping pong game" refers to an interactive method where participants bounce ideas back and forth, much like the back-and-forth nature of a ping pong game. This approach involves participants exchanging ideas, insights, and information in a fun and engaging manner through online collaboration tools, thereby expanding the scope of interactive learning. This approach encourages active participation, stimulates critical thinking, and fosters a collaborative learning environment. This not only deviates from conventional lecture-style learning but also fosters collaboration and teamwork among the students. By fostering this playful and cooperative atmosphere, a dynamic learning environment is created that nurtures creativity and innovation in our students.
- **Diverse teaching team:** As music is one of the most important factors for a more involved

Resolution map for the wicked problem of dropouts		
Changing teaching methodology	Action: Prepare well-defined code blocks focused on music creation.	Outcome: Facilitate efficient learning and encourage positive music outcomes.
	Action: Emphasize creating real music over just sounds.	Outcome: Enhance learning experience and artistic expression.
	Action: Utilize online collaboration tools for sharing and saving work.	Outcome: Save time, adopt a structured approach, and prevent repetitive work.
	Action: Implement "ping pong game" & other gamified activities for collaborative learning.	Outcome: Encourage active participation, critical thinking, and teamwork.
Structured involvement of female mentors	Action: Assign specific groups to mentors from the beginning.	Outcome: Develop stronger mentor-student relationships and personalized support.
Selection of participants	Action: Focus on age range of 11-15 years for better group dynamics.	Outcome: Ensure appropriate support and engagement based on age.
	Action: Refine selection process for a diverse group with varying interests and experience.	Outcome: Create an inclusive environment catering to different needs and preferences.
Creative Coding ambassadors	Action: Offer public performance opportunities (AHA festival, Kulturhuset Bergsjön).	Outcome: Promote Creative Coding, empower participants, and fuel STEAM interest
	Action: Train successful participants to mentor new participants.	Outcome: Foster leadership and peer-to-peer learning.
Diverse Teaching team	Action: Include a music composer and live coding expert.	Outcome: Introduce diverse music aspects and emphasize its importance.
Continuous feedback loop	Action: Regularly seek feedback from participants and stakeholders.	Outcome: Improve the workshop model based on data and feedback.
Visual expression	Action: Integrate online tools for collaborative drawing and expression.	Outcome: Enhance artistic expression, collaboration, and creative output.

Figure 6. Resolution map for the wicked problem of dropouts

and pleasurable learning experience, the new teaching team will include a music composer and a live coding expert who will team up to bring more creative pieces from the participants. This improvisation in the teaching team aims to bring more aspects of music into the learning experience emphasizing that music is the key to pleasurable and joyful experience.

- **Structured involvement of female mentors:** In the first iteration of female mentorship, there was a lack of planning and preparation of mentors for their responsibilities and tasks in the project. They were simply left to approach those participants who sought help, which occurred later in the process, once the girls had acquired knowledge and were able to compose. However, a much closer approach to building mentor-student relationships needs to be implemented in the upcoming sessions of Creative Coding project. Female mentors will now mentor groups that are defined and assigned to them from the very beginning of the sessions. Each mentor will work with a specific group of participants from the start, allowing for more time and weeks to develop closer relationships between the mentors and participants. This methodology will be more beneficial than mentors randomly

assisting different groups weekly, as it may not prove advantageous to specific participants who require additional time to establish rapport with their mentors.

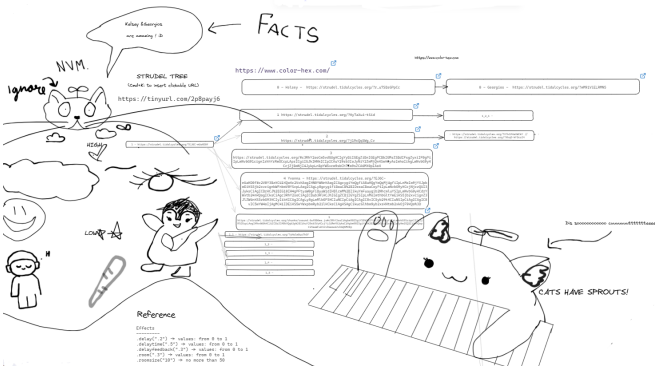

Figure 7. Ping-Pong online collaborative file

- **Selection of participants:** The age range of the participants must be adjusted to fall within the bracket of 11-15 years and it is essential to be more meticulous in forming groups to ensure that girls of similar ages can collaborate. This intervention needs to be done to stabilize the behavioural and emotional engagement of the participants. Younger participants require more support and mentoring compared to the older ones. Furthermore, the process of selecting participants should be refined to ensure a diverse group with varying levels of interest and experience in both coding and music. By selecting girls who demonstrate a passion for music alongside an interest in technology, we can create a more inclusive and supportive learning environment where all participants feel empowered to explore and experiment at the intersection of coding and music.

- **Creative Coding ambassadors:** The concept of Creative Coding Ambassadors is being introduced to provide participants with the opportunity to participate in public performances, for further empowerment, but also to promote Creative Coding practice. These performances include events such as the AHA festival and performances at Kulturhuset Bergsjön, which offer them additional platforms to present their creative works. By doing so, their interest in STEAM is further promoted. Moreover, interested participants who successfully completed the first cohort of Creative Coding will additionally serve as mentors for new participants in Creative Coding thereby transitioning into a leadership role for the project.

- **Continuous feedback loop:** Lastly, continuous evaluation and iteration are essential for refining the workshop model and addressing emerging challenges. By actively seeking feedback from participants and stakeholders regularly, we can identify areas for improvement and implement necessary changes.

- **Visual expression:** The sessions of Creative Coding often conclude with the participants engaging in the act of drawing indicating the strong need for visual expression of their thoughts and ideas as shown in Figure 7. Even as part of the ping pong game, participants expressed their ideas through images and other visual representations. In order to enhance this experience, there is a need to integrate online tools to facilitate collaborative expression and drawing. By incorporating these tools, the main objective is to enhance their artistic expression, collaboration and teamwork. Moreover, we perceive the potential of using these visual components in their public performances, thereby intensifying their creative outputs.

By addressing the problem of students leaving, we can not only ensure a more inclusive and supportive learning environment for young girls but also unlock their full potential in STEAM disciplines by promoting gender diversity and empowering future generations of female leaders in technology and the arts.

7. Future Work

The observed rate of students dropping out of the Creative Coding project presents a multifaceted and challenging issue that is commonly referred to as a wicked problem. To achieve long-term results and promote gender diversity in STEAM disciplines, it is crucial to delve deeper into the critical aspects of these wicked problems and then develop solutions that can address a multitude of factors that interact in complex ways. The possible interventions suggested in this paper need to be further validated during the upcoming session of the Creative Coding project and more improvised strategies need to be devised for better implementation of the project. Another area of focus is to explore the potential integration of music creation into coding practices to achieve aesthetic resonance within the interdisciplinary realm of art and technology. This integration can foster a sense of empowerment and connection with individuals and the surrounding environment. In addition, it is essential to go deeper in understanding the impact of creativity expressed through visual art, music, performance, and technology as catalysts for empowering and stirring a sense of empowerment among the participants.

8. Conclusion

The research findings demonstrate that Creative Coding workshops have proven to be highly beneficial for girls' engagement in STEAM fields. The Creative Coding project had a positive impact on various aspects of the girls' involvement, including their interests, self-confidence and well-being, creativity, explorations, and aspirations in STEAM subjects. The girls exhibited great enthusiasm and passion for exploring new tools and concepts, and their dedication to practice allowed them to enhance their learning and retention. Notably, they demonstrated remarkable stamina and bravery in preparing for their public performance and surprised everyone with their newfound self-confidence. Girls are eager to showcase their abilities and assert their power in STEAM domains.

The integration of art, music, and audio-visual elements in the teaching and learning processes proved to be highly and surprisingly effective in creating a positive learning flow and attracting girls to STEAM subjects. The use of user-friendly software, such as Strudel, that provided interesting audio-visual feedback played a crucial role in facilitating this positive learning experience. Additionally, the preparation for the public performance added a final touch to the girls' personal empowerment and well-being, as they felt proud and enthusiastic about presenting their musical creations. However, it is important to emphasize the need for more efforts to create an inclusive and supportive environment where a wider group of girls feel comfortable and empowered to fully engage in STEAM activities.

Overall, the findings highlight the significance of nurturing curiosity, providing mentorship and guidance, promoting inclusivity and representation, fostering collaboration, and integrating creative elements in education to inspire and empower girls in coding and STEAM disciplines. The report argues that the Creative Coding project has the potential to enable innovative learning experiences by simulating synesthetic experiences, where musical elements are linked to visual elements, thus allowing the creation of multimedia art that engages multiple senses simultaneously. The report highlights the potential of Creative Coding practices and the audio-visual perception of music in boosting girls' personal empowerment, creativity, and interest in coding and STEAM disciplines. It emphasizes the significant role of music creation in this process, as it contributes to increased curiosity. The music is the key.

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