RockStartIT: Authentic and Inclusive Interdisciplinary Software Engineering Courses

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***Abstract*—The RockStartIT initiative was explicitly designed to increase the representation of girls in software engineering (SE) by providing interdisciplinary courses that connect the subject matter to their interests and passions. The program has been successful in engaging a diverse group of high school students, encouraging them to explore computer science (CS) through problem-solving in the areas of their choice. The program's structure and approach have been instrumental in promoting interest in CS and increasing the understanding of the importance of using CS to solve real-world, interdisciplinary problems. The results of surveys conducted with program participants have shown that the program has been successful in providing girls with an alternative pathway into the field of computer science by building on their individual interests, which would not have been possible without the interdisciplinary approach.**

***Index Terms*—interdisciplinary teaching, e-learning, interest, engagement, diversity, gender, computer science education**

I. Introduction

An opinion piece by Dr Klawe and Dr Shneiderman [1] concluded in 2005 by offering this recommendation: *"Computer scientists can advance basic research while developing groundbreaking applications* ***in collaboration with other disciplines.*** *Doing so would once again help attract the brightest students, inspire public interest, and expand resources. Let's get started.*

Today, it is even more evident that CS education training future professionals cannot ignore the reality of a society where research and technological progress are primarily based on interdisciplinarity and transdisciplinarity [2]. The last decade further underpins the call for more collaboration with other disciplines and CS, as today's world is characterised not only by the advancement of classical sciences and the rapid progress in the field of CS but also by the emergence of new cross-border sciences and the massive increase in innovations as a result of the interdisciplinary transfer. Therefore, the interdisciplinary courses of the study appear to be not only thriving but also vital for CS's growth and continued survival [3].

The ubiquitous computing-driven progress and innovation in the real world should be mirrored in the experiences our students have while studying CS and software engineering (SE). Informatics Europe has already recognised this need in their recommendations for CS education [4]: *"All students should benefit from education in informatics ... studied both for its intrinsic intellectual and educational value* ***and for its applications to other disciplines****"*

One of the main reasons why interdisciplinary courses can be beneficial for motivating girls to study computing is that they provide context for the material being taught [5]. When computing is taught in isolation, it can be difficult for students to see the relevance of the material to their lives and interests. However, it becomes more relatable and meaningful to students when computing is incorporated into other fields, such as art, music, or social science. This can make the material more engaging and exciting, leading to increased motivation to study computing.

Another reason why interdisciplinary courses can be beneficial for motivating girls to study computing is that they can break down stereotypes about who can succeed in the field. Computing is often thought of as a field only for men or people who are good at math and science. However, when computing is incorporated into other fields, it becomes clear that there are many different ways to use and understand computing and that anyone can succeed in the field. This can help remove barriers and open the field to a more diverse group of students, including girls.

Furthermore, the Interdisciplinary approach provides a wide range of career opportunities for girls in the field of computing. It can open up opportunities to work in fields such as game design, virtual reality, and digital art, which can appeal to girls interested in these areas. This can also help to make the field more accessible and inclusive, as it shows many different paths to success in computing.

This paper proposes to grant special attention to the opportunities offered by the interdisciplinary learning and teaching of CS. We believe that CS education finds in interdisciplinarity a ground to overcome some of its diversity challenges. The traditional CS curriculum, especially in high school, is ineffective in promoting female interest in CS because girls find it challenging to identify with CS as such [6]. By tapping into their personal interests, we can create identities and interdisciplinary subcultures that resonate and provide an environment where all students who currently feel left behind can learn CS without feeling trapped by the dominant culture associated with the field today.

II. Proposed Directions

It is apparent that interdisciplinary programs have the potential to attract not only the most promising students but also the most diverse students, especially women and girls, to CS by providing alternative pathways into the field, simply by building on individual interests [5], [6]. The *interdisciplinary approach* [7] holds strong potential to strengthen women's engagement in CS through authentic interdisciplinary learning experiences.

A. Leading Question

We seek to understand how CS education can become more accessible and fruitful for a diverse audience, especially girls and women. It starts with the fundamental question of what it takes for girls, in particular, to feel more engaged and find more relevance in the discipline for themselves. So we are looking for the answer to the question: *What does a learning experience need to look like to provide opportunities for girls to engage, enjoy and identify with it?*. To understand the implications, we combine research findings and evidence from different areas of educational research, and CS educational research in particular.

B. Authentic Computer Science Experiences

There is a strong desire for more authentic experiences in CS [6]. Although inquiry-based teaching is very effective in meeting this desire by teaching scientific practices and ways of thinking, it is not widely used, and there is a gap between scientific recommendations and teachers' awareness of these practices and their comfort in using them. To increase comfort in using these practices and to get teachers involved, the benefits and motivations for doing so need to be understood. The relevant context of CS and inquiry-based learning is often essential for many women and students from other study backgrounds [8] who would not otherwise study CS. There are three cumulative effects that authentic CS experiences offer in this regard:

1) **A better understanding of the work and life of a software engineer:** [9] explains that girls often have little idea of the different career paths in CS (e.g. data scientist, web developer, graphic designer, project manager, technical writer). It is recommended to always present technology in connection with possible professional or personal applications to change young girls' attitudes towards IT careers [5]. *Interdisciplinary contexts offer many more opportunities for efficient, realistic learning experiences than would be possible for any single discipline, and [10] show that such experiences provide early experiences in the real world.*
2) **A better understanding of the usefulness of CS:** Women express a desire to make a positive difference and solve real problems, and CS applications are full of such opportunities. Many women, in particular, tend to choose interdisciplinary courses as they offer excellent opportunities to address major humanity problems and thus contribute to the "social good", which is a strong driver for many women [11]. *Embedding science and technology in an appropriate social context and motivating it by a relevant problem significantly impacts women's perceptions of CS [5].*
3) **A better understanding of the importance of non-stereotypical skills:** The shift in knowledge and technological progress emphasised 'transferable' skills. The exact sciences, such as mathematics, CS or physics, are based on theories and are used to calculate and model how things should be. In the experimental sciences, such as biology, chemistry or sociology, empirical observations play a central role. The moment that computer-driven innovation takes place at the boundary between these two, interdisciplinary knowledge and skills are needed to bridge the methodological gap - the ability to identify opportunities, find creative solutions, recognise errors and problems in multiple domains, interpret and communicate results and observations made in the danger zone at the interface of multiple disciplines. *Women seem to be gaining confidence and expressing their non-stereotypical skills [6], primarily when employed at such intersections.* Furthermore, employers in SE are looking increasingly for skills to work on interdisciplinary problems with interdisciplinary teams [12].

Authentic interdisciplinary learning practice embraces these outcomes through its essential quality of inquiry-based learning that spurs curiosity and interest. *That curiosity is essential, not just as motivation, but can be considered an important outcome of the experience itself.* Inquiry-based learning demonstrates and reinforces scientific thinking, problem-solving skills, and understanding of the tasks and value of the computer scientist in the real world. Learning approaches that use such interdisciplinary diversity enhance students' problem-solving skills and improve their creative meta-thinking, communication skills and perception. This opens up a context that allows students to develop within the framework of their competencies and interests as well as to visit disciplines and gain experience with tasks that were rarely encountered before.

Towards this end, various means and strategies can enrich formal education with interdisciplinary experiences, from integrating CS solutions into non-computing courses to integrating non-computing knowledge into CS courses via practical applications and real-world projects or examples. Each of these experiences would help students feel more comfortable exploring and experimenting with CS, feel the stability and confidence of a familiar knowledge base, and identify themselves with relevant problems.

C. Teachers' role in Interdisciplinary Teaching Practice

It is apparent that teachers who teach across subjects have to shoulder the burden of learning concepts, identifying effective teaching practices and creating teaching materials from two disciplines. Teachers, their personalities, and their ways of teaching determine the potential of a learning environment to be successful and engaging for everyone [13]. On the one hand, it is the teachers' responsibility to educate the

students as dictated by the curriculum. On the other hand, there is another responsibility: getting students excited about the subject where for many teachers their passion for their profession is grounded. However, teachers in SE classes face different prior experiences, expectations, misconceptions and stereotypes, resulting in different needs for students to make them enthusiastic. Due to time capacity constraints, lack of material, etc., it is almost impossible for teachers to prepare lessons in a way that fulfils all the constraints. While interdisciplinary learning settings provide many advantages, they add substantial effort to the teachers' limited time and resources. The nature of interdisciplinarity requires combining knowledge from different domains, which is one strength of it, but makes it challenging for teachers unfamiliar with related topics. Thus, for most teachers, creating and preparing interdisciplinary settings is a great challenge, if not impossible at all [14].

Our initiative support teachers in this process and delivers novel opportunities to enhance diversity-addressing learning. In particular, we aim to deliver authentic CS experiences as digital CS courses that teachers can use to enrich their lessons and allow them to focus on their passion - on actually "teaching" by supporting and engaging students in their learning process. Parts of our vision are reflected in a statement from a teacher who used a prototype of our tool in his lesson said: *"this is exactly how I imaging teaching material should look like - I'm able to use it in my lesson without having a lot of overhead with preparation, it is self-explaining, and students are having fun"*.

III. Organisation of the program

The RockStartIT Program was approved and funded in September 2020 by Vector Foundation and was introduced as a part of educational programs offered by Karlsruhe Institute of Technology (KIT) in Germany to high school students. The program targets the following research topics aiming on increasing of engagement of diverse groups by:

- Allowing for authentic interdisciplinary experiences in CS and problem-based learning connected to everyday lives of students
- Supporting the guided-inquiry by relevant and personalized feedback including positive encouragement
- Providing teachers with easy to use interdisciplinary materials

The content of RockStartIT is structured in different domain-connecting courses, so-called "expeditions". They are called expeditions, because students are not just learning the content; it is much more about starting an immersive journey, getting involved in a problem statement, and exploring new knowledge and techniques to make a change. We aim to lead students through learning experiences in which an exciting setting, question or challenge inspires curiosity. Students naturally experience exploration by asking and answering questions using CS methods, technologies and data. This means that we form together a motivating question or hypothesis that triggers the need, for example, to collect or analyse data by student, where the student should apply CS methods and technologies to reason, make observations, evaluate, and draw conclusions about the inquiry question. Thus our goal is to learn CS by doing science that engages scientific investigation. This is a means to provide a better illustration of what is and what to expect from CS than traditional siloed introductory CS courses.

In the expeditions, students experience computational thinking methods and processes as means to solve problems arising in various disciplines rather than an object of study in itself. All activities in the expeditions are followed by relevant and encouraging feedback. Correct answers are valued by a positive statement that states what learning achievements were made. An explanation, hint or encouragement to try again follows wrong answers. RockStartIT's key aim is to improve students' perception of CS by delivering a broad and contemporary picture of its concepts and their ubiquitous applicability. In particular, computational thinking concepts are motivated by interdisciplinary relevance and the impact of making a change.

IV. Selected Expeditions

All of our expeditions are inspired by topics that, at first glance, are often rooted in other domains but offer the potential to illustrate the strengths of CS and its applicability to achieve more extraordinary things. Our vision is to provide a comprehensive variety so that every student can choose a suitable start in CS connected to their personal interests. Some examples are outlined in the following.

A. Beyond Biology - Save the Bees

In this series of expeditions, students learn how they can use technology to contribute to significant challenges like the colony collapse disorder. In the process, they explore STEM and biological phenomena and how CS can help understand them and create new knowledge. With the help of expeditions, students can experience scientific ways of working and experience inquiry-based learning for themselves. In six expeditions, they experience the joy of expeditions into the unknown, equipping themselves with STEM work methods and tools and applying them to solve their problems.

They start into the first mission learning about the biological background and the problem statement - *How can we help the bees?* (#1). In their second expedition (#2) they learn the basics of web development by building their own website using HTML and CSS to inform as many people as possible about the problem. Students can upload their website to have it embedded into the RockStartIT website and to show it to family etc. After having their website ready for launch, they continue with a data science approach to discover new knowledge in large amounts of data (#3). They learn about suitable data storage strategies such as databases and how they can use SQL to search such datasets for answers. They also learn about possibilities to visualize their findings and critical thinking as a key competence when interpreting visualizations. The "data journey" goals are to find answers to the questions

#	Expedition	CS Topic	Keywords	Interdisciplinary Context
	Save the Bees			
1	Know your Mission	scientific thinking	science, process, critical thinking, problem solving	biology, sustainability, writing, math
2	Expedition into the Internet	web development	internet, browser, copyright, url, html, tags, css	
3	Journey through Data 1 & 2	data science	data, database, sql, visualization, critical thinking	
4	Bee Lore for the AI	artificial intelligence	data, ai, machine learning, image recognition	
5	Team-Challenge	project management	team work, roles, CS jobs	
	In Search of Other Life			
6	Rocket Launch	algorithmn	variables, conditions, loops, scratch	astronomy, physics, photography
7	The Camera Sensor	signal processing	signal, analog, digital, discrete	
8	Take a Photo, Save the Photo	encoding	binary, pixel, color coding, storage	
9	Sending the Photo back	error correction		
	Save the Climate			
10	Climate in danger	computational thinking	decomposition, pattern matching, abstraction	geography, sustainability, biology
11	An Ocean of Legumes	sorting	bucket sort, scheduling, cache, trees	
12	A Question of the Season	encoding	codes, abstraction, binary coding	
	Visual Arts (in development)			
13	Learn the Computer Colors!	encoding	pixel, color coding	arts, color theory

TABLE I
OVERVIEW OF INTERDISCIPLINARY EXPEDITIONS OF ROCKSTARTIT.

of bees are doing badly everywhere and how data about bee behavior can be used to help the bees find food. In the fourth expedition, they investigate if all bees that leave the bee hive also return (#4). They learn how AI can help them count the bees so that they do not have to do this repetitive and tedious work themselves. In the last expedition, students slip into the role of a project manager (#5). They learn about the benefits of teams to approach big problems and what it needs to build a team for a project "saving the bees". Therefore they begin to look for adequate people and recognize that one needs specialists from many different fields, especially from the field of CS as experienced in the expeditions before. They build their team with applications from different fictive people. Those applications simultaneously are a revision of all the different skills they learned that a web designer, data scientist or AI specialist needs.

B. Beyond Physics - In Search of Other Life

In the physics-related courses, students went on expeditions in search of other life. The first challenge students face is how to get into space (#6). Therefore they learn about the basics of rocket science and what they need to consider so that a rocket finds its way into space. They know it is impossible to navigate a rocket by themselves: they need control systems controlled by software. Now it is their turn to write a program for their rocket. Therefore they engage with a scratch project where they try to solve the problem step-by-step, finally having their rocket in space. By doing so, they learn about basic control structures and variables. After successfully launching the rocket into space, the next step is to learn about camera sensors since the camera will be a key feature in discovering space. In another expedition, students explore analogue and digital signal processing using historical time laps (#7). After gaining the required knowledge about the camera sensor, it is time to use it. The next challenge is about how we can store an image in a way that we can send it from space back to earth. Therefore, students learn how a photo can be digitized with a pixel representation (#8). The final step is sending the image back to earth, but students explore the problem of interfering that might damage the image on its way. To solve the problem, they learn about the primary error correction mechanism (#9). Their image can be securely transferred back to earth, raising opportunities for further expeditions.

C. Beyond Geography - Save the Climate

In this series of expeditions, students engage with problems around climate change, a topic from geography. Almost every student has a close relationship with the topic, as it is present in their everyday lives and will play an essential role in their future. Besides the topic- and domain-specific fundamentals, the course primarily focuses on computational thinking concepts, motivating them through real-life impact as approaches for saving the climate. Students join Ida on a journey to find out how they can improve their everyday lives to act climate-friendly and sustainable. Ida is a fictive young computer scientist who thrives on knowledge and is intended to represent an approachable role model for young students and convey the everyday relevance of CS principles in a playful way. The course is designed to be embedded in CS classes and other subjects, depending on how the teacher sets the subsequent emphasis.

In their first expedition (#10), students explore fundamental principles of computational thinking (decomposition, pattern recognition, abstraction, and algorithms) and how they can use them. As a basic idea, students will explore how the principles can be used like tools combined to structure big problems, e.g. by creating a model for causal relationships of the greenhouse effect. In the second expedition (#11), students need to help Ida with her bulk purchase of legumes. Legumes are of rich nutritional value and are best suitable for sustainable nutrition. Now they are challenged by the task of sorting the legumes, which follows the basic concept of decomposition.

As an example, they learn about bucket sorting. The third expedition (#12) is about information coding, which they find, for example, supermarket bar codes that save information about the seasons. This way, students can use coding theory to label fruits and vegetables so that they know when they should by which one to eat seasonally and to contribute to sustainability.

V. Impact on Participating Students

A. Running Programs

Courses of RockStartIT are already in use of several different programs (see Table II). Until now, more than 300 students of secondary school have enrolled in the project courses. This allows us to collect evaluation data and feedback from many different sources, making optimising our project for both informal and formal education.

Program	Type	Participants	
		female	male
Gender Equity (KIT)	research project	14	32
IT Mission (KIT)	research project	50	51
Girls Day (KIT)	workshop	14	0
Science Camp (KIT)	workshop	12	0
MINT Feriencamp (Cyberforum)	workshop	14	10
Burg Liebenzell (ZLB)	workshop	28	0
Secondary schools	lessons	65	62
Total		197	155

TABLE II
Participants on courses of RockStartIt in duration of January 2022 to September 2022

B. Evaluation Approach - First Insights

For evaluation, we use in most of the programs a pre-test-post-test design [15] to measure the impact of our project and to collect feedback. The instrument we use is a self-developed questionnaire that consists of 28 items extracted from a comprehensive literature review [16]. Eighteen items are repeated identically in the pre-test and post-test context to assess interest and attitude changes. Without going into detail here, Fig. 1 and Fig. 2 show example items of the questionnaire and responses from female students on how they have experienced the expeditions. The responses shown indicate that most girls have much fun engaging with the topics and activities of RockStartIT. On the one hand, participating students show an increased curiosity for CS, and on the other hand, they also clearly state that school would be more fun if they would do things as they do in the course more often. At the same time, responses on item *"I like to combine knowledge from different fields to solve problems"* clearly indicate that students in high school enjoy interdisciplinary learning.

Participating in courses of RockStartIT even seems to increase the preference for interdisciplinary learning. In a recent study on the *Save the Bess Expeditions* we also found evidence, that the interdisciplinary nature of the expedition does not only show potential to have a positive effect on girls' attitudes but also to engage a more diverse audience

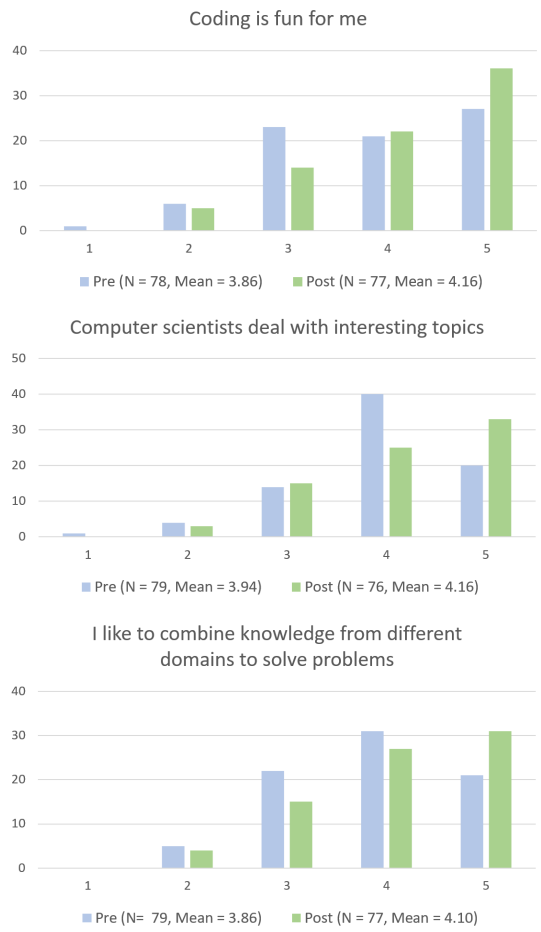

Fig. 1. Responses from female participants to selected items on a likert-type scale (1) - Strongly Disagree to (5) - Strongly Agree

in general including students of all gender, students with less self-confidence in CS, and students that showed programming aversions [17]. So the courses might be an excellent opportunity to enrich traditional school lessons, giving new possible connection points to identify with the subject and get curious about what one can do with CS. This is also reflected in the survey feedback we get from students. One student said, *"It's always fun and it's nice to learn here."*, and another *"I love the website. You learn a lot of new things. It is very interesting and great design."*, which are just examples of the overall opinions. Participants also appreciate the free space the courses give them to progress at their own speed, as this feedback illustrates: *"I liked that we could work very freely"*.

VI. Conclusion

It is crucial for girls to have equal access and opportunities to engage in the field of computer science. The lack of representation of women in the field not only perpetuates stereotypes and biases, but also diminishes the potential for innovation and creativity in the field. In a technology-driven world and rapidly changing economic environment, it is vital to diversify the computing workforce and provide all students

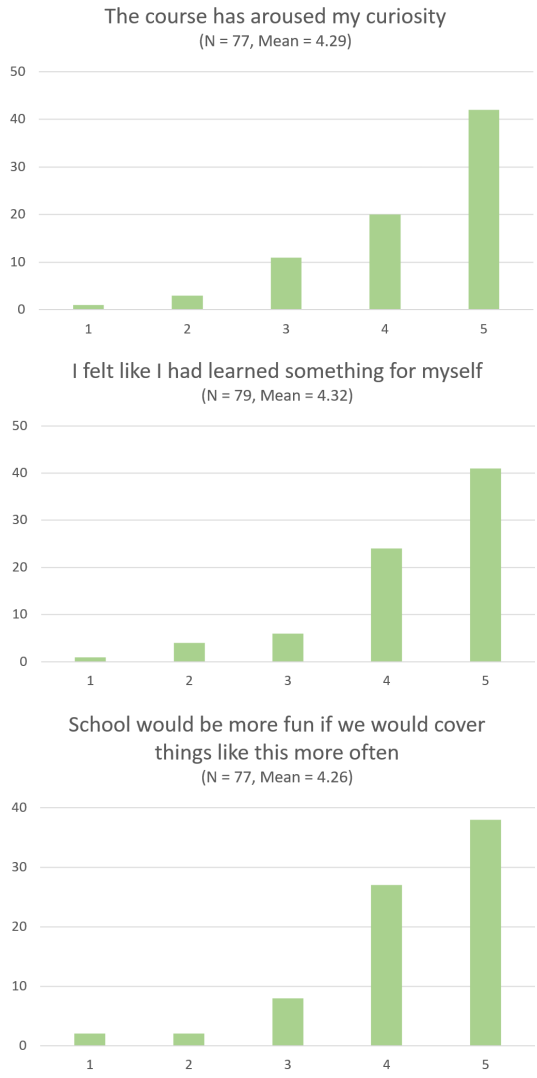

Fig. 2. Responses from female participants to selected post-test-only items on a likert-type scale (1) - Strongly Disagree to (5) - Strongly Agree

equal access to computer science. By providing interdisciplinary, authentic and inclusive learning experiences, we can encourage girls to explore and pursue careers in computer science, and in turn, increase diversity in the field. This will not only help to break down stereotypes and biases, but also tap into a larger pool of talent and ideas, ultimately leading to a more innovative and dynamic computing industry.

This research study delved into the impact of incorporating interdisciplinary computer science education in high school curriculums as a means to enhance accessibility and engagement for students. By reflecting on our experience in creating authentic interdisciplinary programs, we were able to evaluate the benefits of such programs for high school students studying computer science. Furthermore, through the analysis of students' experiences, we were able to understand the extent to which these programs successfully shaped a more inclusive and diverse perception of computer science among female students.

In order to achieve the benefits of authentic interdisciplinary learning experiences, we recommend that programs targeting similar goals should aim to achieve the following learning outcomes:

- Developing a holistic, interdisciplinary understanding of complex problems and challenges.
- Integrating knowledge and skills from computer science and at least one other discipline to approach problem-solving.
- Providing hands-on, real-world experience in tasks and methods relevant to existing software engineering roles.
- Fostering transferable problem-solving, interpretation, and other skills that can be applied across disciplines.
- Encouraging the development of collaboration and communication skills that can be applied in diverse contexts.

While long-term learning experiences may not always be feasible in an educational setting, shorter-term, immersive workshops or self-study sessions can still provide valuable opportunities for students to explore computer science and gain a deeper understanding of the field. These types of experiences can be incredibly impactful in raising students' awareness of the possibilities and potential impact of computer science, and can also serve as a catalyst for further study and exploration in the field. By providing students with opportunities to immerse themselves in computer science in a shorter-term format, educators can help to foster a deeper understanding of the field, increase students' interest and motivation, and ultimately pave the way for a more diverse and skilled computing workforce.

To summarise an immersive learning experience that provides opportunities for girls to fully engage, enjoy, and identify with computer science should allow students to experience:

1) Relevance and Authenticity: The material should be relevant to the students' lives and interests, making the material more engaging and meaningful. This can be achieved by incorporating real-world problems and applications that are directly connected to the students' passions and interests.
2) Experiential and Hands-on Learning: The learning experience should provide opportunities for students to apply their knowledge and skills in real-world settings. This can be achieved through project-based learning or hands-on activities that allow students to see the relevance and practical application of the material and gain valuable experience and skills. Additionally, experiencing it can help to break down stereotypes about who can succeed in the field of computing.
3) Diverse Representation and Perspectives: The learning experience should be diverse in terms of the representation of different perspectives and experiences. This can be achieved by including a diverse range of voices in the curriculum, readings, and discussions, and by making sure that the curriculum reflects the experiences of different groups of people. Additionally, it is important to provide positive role models and representation of

successful female engineers, computer scientists and in the field of technology to show girls that they can succeed in the field and to help them envision themselves in those careers.

By incorporating these elements, an immersive authentic learning experience can provide opportunities for girls to fully engage, enjoy, and identify with computer science. Furthermore, interdisciplinary approaches can further enhance formal education by incorporating other sciences and humanities and promoting versatility for future jobs and real innovation. By breaking down the barriers between disciplines, we can tap into a wider range of skills and perspectives, leading to more effective solutions to real-world problems. It is crucial for education to respond to this need by introducing computer science in an interdisciplinary context and application, in order to increase diversity and innovation in the field.

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