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Engaging Girls in Computer Science: Do Single-Gender Interdisciplinary Classes Help?

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***Abstract*—Computing-driven innovation cannot reach its full potential if only a fraction of the population is involved. Without girls and their non-stereotypical contribution, the innovation potential is severely limited. In computer science (CS) and software engineering (SE), the gender gap persists without any positive trend. Many girls find it challenging to identify with the subject of CS. However, we can capitalize on their interests and create environments for girls through interdisciplinary subcultures to spark and foster enthusiasm for CS. This paper presents and discusses the results of an intervention in which we applied a novel interdisciplinary online course in data science to get girls excited about CS and programming by contributing to the grand goal of solving colony collapse disorder from biology and geoecology. The results show the potential of such programs to get girls excited about programming, but also important implications in terms of the learning environment. The startling results show that girls from single-gender classes (SGCs) are significantly more open to CS-related topics and that the intervention evoked significantly more positive feelings in them than in girls from mixed-gender classes (MGCs). The findings highlight the importance of how CS-related topics are introduced in school and the crucial impact of the learning environment to meet the requirements of truly gender-inclusive education.**

***Index Terms*—Diversity, computer science education, interdisciplinary, women, interest, k-12, e-learning, gender inclusive, data science, introductory courses**

I. Introduction

It is not a secret anymore that Computer Science (CS) and Software Engineering (SE) thrives from diversity [1]. Despite many implemented interventions, a notable gender gap persists [2], [3]. There is no need to explain why such a high level of gender imbalance is unsatisfactory. At this point, we all understand that diversity matters greatly, starting from ethical, social, and economic reasons to the observation that SE teams with more diversity, with regard to gender or other, are smarter [4], better performing [5] and achieve better outcomes [6].

When looking at gender diversity, specifically, the age range from 9 to 14 years is understood as being the life-altering period, where the self-selection of girls away from CS/SE and other STEM (Science, Technology, Engineering, and Mathematics) subjects happens [7], [8]. In this age segment, girls, in particular, seem to have a high drop-out risk. Thus, providing early positive experiences with CS and programming is essential as their perception of CS may be better addressed at a younger age than during and after puberty [9]. As a precursor to vocational SE, CS lessons at school are critical during this period in forming their perception of CS; thus, the foundations for a long-term interest in the discipline can be laid here. Especially when learning to program, girls tend to have different expectations, perceptions, and learning outcomes from programming lessons than boys [10], [11]. For many girls, this period is characterized by their first contact with programming lessons in an environment where boys are ahead in their knowledge and tend to monopolize the instructor's time and set the standard pace within the classroom [12], [13]. However, publications that could help teachers in this situation by reporting on practical and actionable implementations or recommendations for girl-friendly classroom designs are scarce [9], [14], [15].

Some studies [16] inform on the factors that shaped girls' choices as regards CS/SE field. A vital inclusion factor among the proposed recommendations [14]–[17] is the creation of welcoming and inclusive environments specifically for girls in CS classrooms in addition to an engaging curriculum incorporating relevant real-world problems into the CS classroom [18]–[21]. An inclusive classroom environment is one where "*all [...] members feel welcomed and valued for who they are and what they bring to the table. All participants share a high sense of belonging and fulfilled mutual purpose*" [22, p. 1].

CS in an interdisciplinary context makes girls believe they can bring more to the table [16], [18], [20], [23]. Girls often experience CS education as dull and purposeless, as well as state their desire to do something that is relevant and makes positive differences in the world [16], [24]. Thus, interdisciplinary learning can be one strategy to address the diversity issue as it offers many possibilities for alternative pathways into CS [14], [25]. This way, students can explore the relevance of the topics for themselves and in relation to later application situations and, therefore, how topics are connected to their interests in other domains [26]. Data science offers many possibilities to work interdisciplinary and thus to address different groups equally [27]–[30]. To this end, we developed and designed an interdisciplinary data science online course, in which students are challenged by research questions in the context of colony collapse disorder, a topic from biology and geoecology about high bee mortality.

However, earlier studies could show that dependent on how students are grouped, they will have different experiences, and this is especially visible in CS classrooms [17]. The gender interaction analysis [31] shows that young children choose to interact with peers of the same sex or peers interested in

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similar types of activities. This tendency tends to strengthen over time, meaning that children become more similar to their interaction partners in levels of engagement in these activities. This process of gender segregation around shared activities and clustering along the educational pipeline is more common for girls than boys [31]. In this context, a homogeneous class is understood as a single-gender class (SGC) and a heterogeneous class as a mixed-gender class (MGC). Female students learning CS in MGCs report on lack of support, feeling as an outsider, and negative experiences that impact their decision to remain in the CS field of study [17], [32]. In contrast, female students from SGCs report significantly greater social connection and comfort and higher intensity of collaborating with peers [17]. Furthermore, some additional studies [33]–[36] suggest that SGCs support the engagement of girls in CS.

In this paper, we present insights gained through the design and delivery of an interdisciplinary data science online course. With those, this paper contributes to the academic debate on the effects of homogeneity and heterogeneity on interactions in CS classrooms and the often ignored consequences of socialization of students with diversity or lack of it. We aim to shed some light on what effects could be observed on the engagement and interest in CS. We especially highlight the critical role of context and agents of socialization, such as peers, in developing students' beliefs and behaviors around CS.

A. *Research Questions*

In this paper, we aim to understand better and further explore the extent to which students are influenced by the environment in which the introduction to CS topics is offered at secondary school and what makes such an introduction engaging and inclusive for all. We examine the impact of an interdisciplinary introductory course to data science and the role of the classroom environment in a *single-gender class (SGC)* and a *mixed-gender class (MGC)* on students' perceptions of CS. Accordingly, our research is guided by the following research questions (RQs):

- RQ_1 Does the course's interdisciplinary context positively impact the perception of CS among secondary students depending on class type (SGC, MGC)? The following sub-questions are addressed here:
  - RQ_1.a Do girls and boys hold on usual stereotypes and gender biases about CS-related topics?
  - RQ_1.b Do girls and boys hold on usual associations with CS-related topics?
- RQ_2 Does the course's interdisciplinary context positively impact the engagement in CS among secondary students depending on the class type (SGC, MGC)? The following sub-questions are addressed here:
  - RQ_2.a Do girls and boys experience the same positive feelings of joy, fun, and flow when working on CS-related topics?
  - RQ_2.b Do girls and boys feel an equally strong interest in CS based on personal relevance, appreciation, and identification with CS-related topics?
  - RQ_2.c Do girls and boys have future solid intentions and self-efficacy perceptions to undertake further CS-related activities?

II. Research Method

In this study, a quasi-experimental design was used to understand the impact of an interdisciplinary intervention on secondary school students' enthusiasm for CS. To this end, an online course in data science was designed, implemented, and delivered with the primary aim of getting girls excited about adopting CS technologies and showing them the benefits of programming. The course is part of the *RockStartIt* initiative (rockstartit.com) and is freely available online (rockstartit.com/data-expedition). The interdisciplinary approach is based on questions in the context of colony collapse disorder, a topic from biology and geoecology about the high bee mortality. The online course was distributed to schools in Germany via social networks, nationwide teacher mailing lists, and other school administration channels. Teachers then could voluntarily choose to use the online course in their own classes. This means, in particular, that the intervention was conducted in regular classes without prior selection of students and without prior instructions for teachers. This distinguishes the study presented here from similar studies on this topic, as the students did not show any initial inclination for the topic (e.g. by being required to sign up for the course initiatively) and were exposed to the course in the regular school setting, in the regular class constellation and by their regular teacher with no additional training in relation to this course. Thus, the participants do not necessarily have a personal affinity to CS, as might be the case with special programs such as workshops for which students actively sign up, e.g. girl-oriented summer camp programs or other after-school activities. At the same time, we had no exchange with the teachers before or during the intervention, except for the short and general advertisement message. Teachers were able to use the course in their classes without prior instructions or explanations. In summary, it can be assumed that our study design reflects the school's reality to a high degree.

We used a pre-test-post-test study design (see Fig. 1) to capture changes throughout the intervention [37]. From 16th September 2021 until 10th October 2021, a questionnaire (in *Google Forms*) was used for data collection. The surveys were directly embedded into the online course. After the study period, the data has been prepared for data analysis. For this purpose, blank submissions and obvious false information, such as 1- or 5-star ratings on all items (controlled by negatively formulated statements), have been removed from the dataset. Data analyses were performed with descriptive statistics (means, effect-sizes), and with t-test, and two-way ANOVA to assess the extent to which the intervention had an impact on students under the consideration of gender and environmental conditions [38], [39].

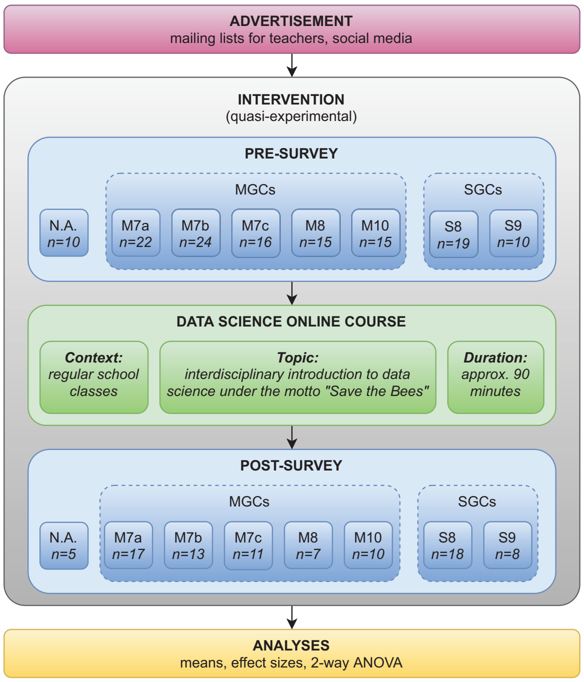

Fig. 1. Study design process. 'MX' and 'SX' refer to MGCs and SGCs respectively where 'X' represents the grade level and 'a,b,c' is used to distinguish classes of the same grade levels. 'N.A.' are responses without any class affiliation. 'n' is the number of responses in the pre-test and post-test survey accordingly to the different groups.

A. Study Area and Curriculum Context

The study was conducted at participating German secondary schools (called *gymnasium*). The German *gymnasium* (grades 5-12) is a school form with the dedicated goal to prepare students (ages 10-18) for higher education at the university. It can be assumed, that most of the participating schools were from the southwest state of Baden-Württemberg. Here, CS is a mandatory subject in grade 7, but only since 2016 and only in that grade. The subject is called 'Informatik' (Engl. informatics) and encompasses different topics from 'data and encoding', to 'algorithms', 'computers and networks', to 'society and security' [40]. After grade 7 until grade 11 there is no dedicated subject to CS that students could choose to continue with. They only have the option to choose CS in a subject combination 'IMP' (informatics, maths, physics) as an alternative to a second foreign language for grades 8, 9, and 10. This brings CS in a competing situation, where students have to choose between a 'people-centered' alternative of learning a second foreign language against the more 'things-related' alternative of the subject IMP that necessarily incorporates maths and physics, which might stress the pathway in CS of especially girls [41]. There is also no separate subject for SE. This is, why it is all the more important to provide suitable early contact to CS in school to promote diversity in CS professions, including vocational SE, in the long term.

B. Participants

In total, we had 131 valid responses in the pre-survey and 89 in the post-survey. Not everyone indicated their gender, but about the same number of girls as boys participated in the study. Specifically, 65 females and 62 males participated in the pre-survey. In the post-survey, we received 45 responses from girls and 24 from boys. For eleven responses from MGCs, no gender information was available in the post-survey. Although it can be assumed that a large proportion of them are male (as almost all girls in the MGCs also indicated their gender in the post-survey), we excluded these cases with missing gender from the gender-based analyses. The ages range from 12 to 15 years, with most participants being 12 and 13 years old.

Based on time stamps, grade information, and feedback from individual teachers, the dataset could be structured and differentiated according to individual classes (see Fig. 1). Both SGCs are from an all-girls school and have been instructed by the same teacher, who was male. Regarding the teachers of the other classes, we do not have any information. Almost all student participants have already had CS as a school subject. Since CS is mandatory only from grade 7 on in the study area, it can be assumed that at least the 7th graders had at most just a few weeks of CS education and, therefore, very little previous knowledge. Participation in the survey study was voluntary and could be canceled at any time. Data collection was completely anonymous and all participants have been advised by their teachers about their rights in taking part of the survey study.

C. Course Content and Design

Course Design Principles

- *Interdisciplinary* context: colony collapse disorder related to biology and sustainability
- *Problem-based learning*: are bees threatened everywhere the same?
- Programming for *social good*: using SQL in order to explore new knowledge and to help the bees
- *Self-regulated learning*: novice-friendly entry to programming with different levels of difficulty
- *Encouragement* through immediate relevant feedback and continuous articulation of achievements in learning

The primary goal of the course was to excite a more diverse audience for CS. We found previously that linking CS and programming with theory from other disciplines, e.g. biology, has several benefits. First, an interdisciplinary, problem-based approach seems to get girls, in particular, excited about CS by motivating them to code for something "good", intending to help bees. Secondly, students with a more substantial background in biology may link programming to their familiar knowledge base and become more confident with their programming skills. For the students who are less familiar with biology but more familiar with programming, the interdisciplinary context may help them to anchor their knowledge better. Thirdly, the course design may balance the

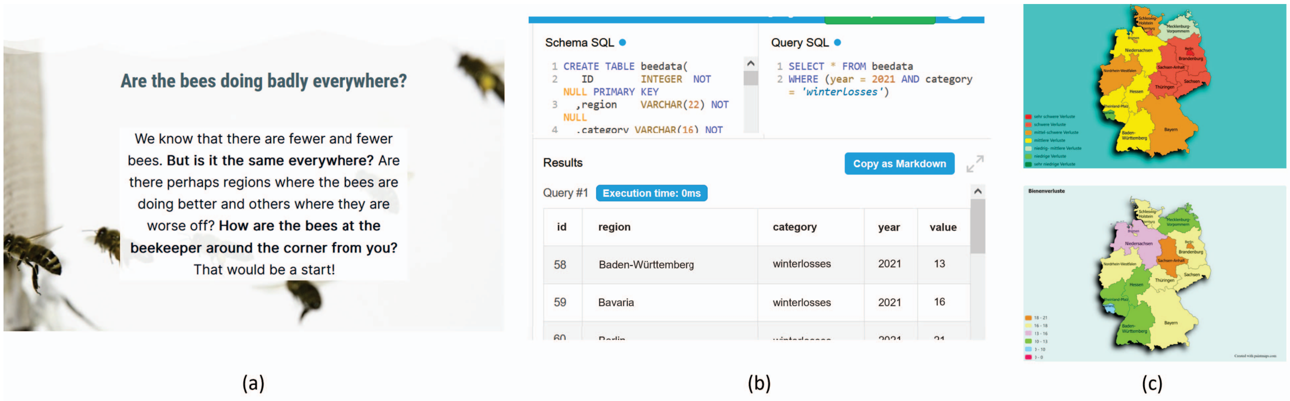

Fig. 2. Screenshots from the online course (translated from German). (a) Start of the course introducing the interdisciplinary problem (b) Students explore SQL queries with an interactive database to investigate bee losses (c) Students' examples of visualizing bee losses in Germany as a result of their own analyses.

students' different skills and experiences. Some may need to improve their CS and programming skills, and others need to work on domain-relevant and interdisciplinary problem-solving skills. In this way, we allow students to excel in certain areas without discouraging experiences that hurt confidence. By allowing them to take up a topic (or interdisciplinary problem) of their interest, we aim to encourage individual initiative, creative thinking, appetite for learning, and the capacity to transfer prior knowledge across domains.

Students start into the course facing a challenging question, e.g. *"Are bees doing badly everywhere?"* (Fig. 2a) , which they will not be able to answer in a sufficient way at the beginning. In the search for answers, they travel on a "data journey". The starting point for the journey is a big dataset with bees-related information that the students received from a fictive organization (translated: "German-Happy-Bee-Association") that also aims to help bees, but yet lacks ideas, on how the data could help. Now, students are encouraged to experiment with the data. In small steps and guided by interactive elements, they learn about techniques to explore new knowledge in big datasets. They have the opportunity to work on an interactive database and use SQL to gain new knowledge about bee losses in Germany (Fig. 2b). In a final project, they can use their findings to provide a visualized answer to the initial problem statement (Fig. 2c). All data they work on are from real sources (e.g. Deutscher Imkerbund e.V.) and thus representative for reality, making them meaningful, and giving the students a feeling of relatedness to promote interest.

Learning about suitable storage, analysis, and representation strategies are vital components in understanding the data science process [42], [43]. Thus, data management and visualization play central roles throughout the course. For the purpose of data management, participants learn about databases and the programming language SQL, which is the most used database technology in data science professions [44]. One design principle was to provide a novice-friendly entry without supporting negative preconditions about programming. So even if the course covers SQL, participants should not feel urged to practice programming at any time. Instead, the SQL-related parts should be self-intentionally motivated by their practical use. One approach was to motivate programming as a valuable tool to achieve something bigger and contribute to something good, that otherwise might not be realizable with human work or would require boring repetitive work. To address the novice-friendliness, all SQL-related parts of the course offer different levels of programming depth ranging from simple drag-and-drop questions via using those SQL queries in the interactive database to modifying and discovering own SQL queries. This approach aims for a self-regulated learning environment where everyone can choose a suitable level of difficulty, progress at a self-paced speed, and has the opportunity to enlarge upon topics of interest. So the course explicitly targets topics in a way that supports a *growth mindset* and motivates CS and SE for *social good* which shows to be, especially for girls, relevant factors for interest development [45], [46].

Relevant and encouraging feedback follows all activities in the course. 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. Most interactive elements are realized with the H5P framework (h5p.org), but there are also activities embedded from external resources such as polls (strawpoll.com), the interactive database (db-fiddle.com), and a map creation tool (paintmaps.com).

D. Instruments

For evaluation, we developed a questionnaire to assess the *enthusiasm* potential of our intervention. We define *enthusiasm* according to Singh et al. and Alpay et al. as a raised thirst for action and willingness to engage with a topic [47], [48]. To measure *enthusiasm* we ground our theoretical framework in the three components of interest in the person-object theory of interest (POI) [49], [50]. Derived from the POI we consider the variables *positive feelings*, *interest*, and *future intents* as key components of the construct *enthusiasm*.

Positive Feelings This component relates to the extent to which an activity is connected to positive emotions such as fun. In the best case, this results in a *flow* momentum [51] in which "time flies by".

Interest This component represents the self-intentionality and self-identification expressed by the extent to which "goals and volitionally realized intentions related to the area of an interest are compatible with the attitudes, expectations, values and other aspects of the person's self-system" [49, p. 11].

Future Intents The third component is reflected in a person's desire, or development of such a desire, to expand their competencies concerning the subject of interest, to increase their knowledge, and to improve their skills.

In addition to the three components, items related to perception and stereotypes are included in the questionnaire. Table I shows the full questionnaire and Cronbach's alpha values for the internal consistency of the three constructs corresponding to our current case study. Items of the questionnaire have been extracted from a comprehensive literature review of studies that evaluated concepts based on our theoretical framework and the study design goals (i.e. interdisciplinarity, stereotypes, self-efficacy, interest, positive feelings, and future intents). Thus, we did not develop the items ourselves but adopted most of them from existing studies (indicated in the source column of Tab. I). The questionnaire itself is structured in such a way that it can be used in a pre-test-post-test design to capture changes throughout the intervention. The first part of the questionnaire consists of 17 Likert-type scale items and one open-ended question. All 18 items of this part were identically repeated in the pre- and post-survey making it possible to compare responses before and after the intervention. The second part contains ten additional Likert-type scale items that evaluated engagement and positive feelings with a direct connection to the course, referred to as post-only items. The survey was conducted in German, and items have been translated into English for the purpose of this paper. For items that have been extracted from an English source, the original notation of it is used. For all other items, no specific standardized process was used for translation. All Likert-type scale items were rated on a 5-point Likert-type scale ranging from *(1) - "Strongly Disagree"* to *(5) - "Strongly Agree"*. In addition to the questionnaire items, the survey included items about the demographical and educational background (such as gender, age, grade level, school type). Gender could be indicated as a choice out of *"female"*, *"male"*, *"not listed"*, and *"prefer not to say"*.

III. Findings

Differential analysis of the data collected on the group of girls and boys from the five MGCs and girls from the two SGCs revealed significant differences in their experiences and shed light on the nuances in the emergence of individual engagement and perceptions of CS among secondary school students. In the following, we outline our observations to address the research questions in Section I-A.

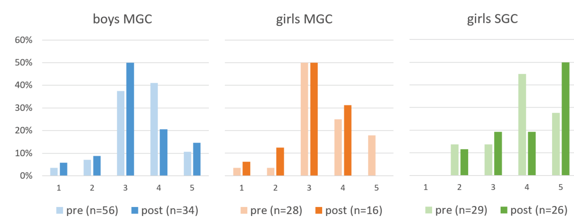

Fig. 3. Results Q1: *"I like to combine knowledge from different domains to solve problems"*

A. Impact on the Perception of CS (RQ_1)

Main Finding: Girls in SGCs strongly prefer interdisciplinary learning and consider CS a gender-independent subject, while girls and boys in MGCs agree much less with both points.

To investigate RQ_1 about the impact of CS teaching in an interdisciplinary context, we included seven items about perceptions of CS in our pre-test and post-test questionnaire (Table I). A simple main effects analysis revealed that gender and class type have a statistically significant impact on interdisciplinary learning preferences ($p<.05$). Girls in SGC show a significantly higher preference for interdisciplinary learning than girls and boys in MGC both before and after the intervention (see Table II, Q1). While the preference for interdisciplinary learning decreased among boys and even more among MGC girls, it increased clearly among SGC girls. Only five boys and no girls from the MGC selected *""Strongly agree"* on the item *"Q1: I like to combine knowledge from different domains to solve problems"* after the intervention (see Fig. 3). In contrast, 50% of the SGC girls agreed, and selected *"Strongly agree"*, with the interdisciplinary preference, an increase of 60% compared to before the intervention.

a) Stereotypes and Gender Bias (RQ_1.a): Our study's sample does not indicate a noticeable gender bias in secondary education regarding the perception of the role of women and men in CS. Across all groups and time points, average agreement with the question *"Q15: Computer science is a suitable subject for boys and girls"* was very high (see Table II, Q15). Nevertheless, the class type shows a statistically significant influence on the students' opinion of whether computer science is a suitable subject for girls and boys or not ($p<.05$). Boys and girls of MGCs are significantly less likely to agree with this item than girls of SGCs, The discrepancy between boys and girls in MGC is not as prominent here as between boys in MGC and girls in SGC, indicating that, on average, students of MGCs are less likely to believe that CS is equally suitable for girls and boys than girls of SGCs. While girls' agreement in SGC was not significantly affected throughout the intervention, the agreement between boys and girls in MGC decreased.

TABLE I
ITEMS OF QUESTIONNAIRE USED FOR SURVEY IN PRE-TEST-POST-TEST DESIGN AND CRONBACH'S ALPHA VALUES FOR CURRENT CASE STUDY

	Construct	No.	Item	Source
PRE-TEST and POST-TEST	Positive Feelings	Q3	I enjoy solving problems with computers	[52]
		Q4	Learning about what computers can do is fun	[53]
		Q10	Computer science is fun for me	[54]
			$\alpha_{pre} = .810\ (n = 130),\ \alpha_{post} = .843\ (n = 81)$	
	Interest	Q5	I am interested in computer science	[55]
		Q9	Computing jobs are boring	[56]
		Q13	Computer scientists deal with interesting topics	[57]
		Q16	What I learn in computer science I know I can put to good use later on	[54]
		Q17	Coding skills can help me in my everyday life	[58]
			$\alpha_{pre} = .725\ (n = 124),\ \alpha_{post} = .747\ (n = 79)$	
	Future Intents	Q2	I do not want to deal with coding in my life	[58]
		Q7	I would be interested in learning more about computer science than I need for school	[59]
		Q18	I can see myself doing something in the field of computer science later on after school	
			$\alpha_{pre} = .600\ (n = 131),\ \alpha_{post} = .704\ (n = 77)$	
	Perception	Q1	I like to combine knowledge from different fields to solve problems	[23]
		Q6	I know I can do well in computer science	[60]
		Q8	I know what computer science is and what computer scientists do	[52]
		Q11	What spontaneously comes to your mind about computer science? Name up to 3 keywords.	[57]
		Q12	Computer scientists mainly deal with programming	[57]
		Q14	Computer science is... rather a very specialized field or just everywhere?	[57]
		Q15	Computer science is an appropriate subject for both boys and girls	[61]
POST-TEST ONLY	Positive Feelings	Q19	School would be more fun if we would cover things like this more often	[62]
		Q22	It was fun to engage with the topics covered in the course	[55]
		Q23	The course has aroused my curiosity	[55]
		Q27	During the course time flew by	[63]
			$\alpha = 0.889 (n = 84)$	
	Interest	Q20	My interest in computer science has increased since I took the course	[62]
		Q21	I felt like I had learned something for myself	[62]
		Q26	I would recommend such a course to others	
			$\alpha = 0.788 (n = 83)$	
	Future Intents	Q24	I would love to do a course like this again	
		Q25	During the course I had an aha moment	[55]
		Q28	I will talk to friends, parents, or siblings about things I experienced in the course	[64]
			$\alpha = 0.639 (n = 83)$	

b) Associations with CS (RQ_1.b): Even though computer- and coding-related terms dominated the responses in the open-ended question, a slight shift was observable. For example, "coding" was mentioned 65 times (19%) in the pre-survey, but only 23 times (13.5%) in the post-survey. In contrast, the term "exciting" was mentioned only once in the pre-survey and three times in the post-survey. Regarding the question *"Q12: Computer scientists mainly deal with programming"* students' opinions varied a lot. Most votes were on *"Neither agree nor disagree"* but also almost as many answers could be found on both sides of the spectrum. For boys of MGCs and girls of SGCs their average opinion in this regard remained about the same (see Table III, Q12). In contrast, the mean agreement of girls of MGCs decreased clearly.

B. Impact on the Engagement with CS (RQ_2)

Main Finding: SGC girls have a much more open attitude towards CS and generally are more willing to engage more with CS topics. The main findings were:

- SGC girls enjoyed working on CS topics significantly more than girls and boys of MGC.
- SGC girls are significantly more interested in interdisciplinary CS-related topics than girls from MGC.
- SGC girls manifest significantly higher self-efficacy in CS than girls of MGC.

To investigate RQ_2 about the impact of the classroom environment on engagement with CS topics, we included eleven pre-test and ten post-test items about perceptions of CS in our questionnaire (Table I). The analysis of the responses allowed for the following observations.

a) Positive Feelings (RQ_2.a): Prior to the intervention, there was a statistically significant difference between positive feelings towards CS of girls and boys ($p<.05$) with a medium effect size (see Table II). This difference and significance disappeared after the intervention. While the positive feeling of girls remained about the same, boys' feelings towards CS seem to be damped relatively strongly. The post-test items indicate that boys enjoyed the data science course much less than girls, which explains the effect. A differentiated comparison of SGC to MGC highlighted unexpected insights here. Girls of SGC

TABLE II

MEANS (M_1, M_2), STANDARD DERIVATIONS (SD_1, SD_2), EFFECT SIZES (COHEN'S D) AND 95% CONFIDENCE INTERVALS (CIS) BY GENDER AND CLASS TYPES ON RESPONSES IN PRE- AND POST-SURVEY.

	Construct		M_1	SD_1	M_2	SD_2	Cohen's d	95% CI Lower	95% CI Upper
girls (1) to boys (2)	interdisciplinary preference (Q1)	pre (n_1=61, n_2=61)	3.72	0.97	3.49	0.91	−0.25	−0.60	0.11
		post (n_1=26, n_2=43)	3.74	1.00	3.35	1.06	−0.39	−0.87	0.10
	self-efficacy (Q6)	pre (n_1=66, n_2=61)	3.68	0.98	4.08	0.78	0.45*	0.10	0.80
		post (n_1=45, n_2=26)	3.64	1.10	3.62	1.06	−0.03	−0.51	0.46
	stereotypes (Q15)	pre (n_1=66, n_2=61)	4.68	0.66	4.33	0.93	−0.43*	−0.78	−0.07
		post (n_1=45, n_2=26)	4.65	0.69	4.19	1.06	−0.54	−1.04	−0.05
	positive feelings	pre (n_1=61, n_2=55)	4.00	0.91	4.36	0.70	−0.43*	−0.80	−0.06
		post (n_1=37, n_2=26)	4.05	0.91	3.86	0.72	−0.04	−0.54	0.46
		post-only (n_1=41, n_2=25)	3.66	0.95	3.22	1.31	0.40	−0.10	0.91
	interest	pre (n_1=57, n_2=53)	3.80	0.79	3.98	0.57	−0.26	−0.64	0.11
		post (n_1=38, n_2=25)	3.86	0.72	3.79	0.65	0.10	−0.41	0.60
		post-only (n_1=40, n_2=25)	3.36	0.92	2.80	1.20	0.54*	0.03	1.05
	future intents	pre (n_1=62, n_2=55)	3.32	0.96	3.60	0.94	−0.31	−0.67	0.06
		post (n_1=38, n_2=25)	3.30	1.03	3.47	0.79	−0.18	−0.68	0.33
		post-only (n_1=39, n_2=25)	3.03	0.94	2.53	1.05	0.50	−0.01	1.01
girls MGC (1) to girls SGC (2)	interdisciplinary preference (Q1)	pre (n_1=28, n_2=29)	3.50	0.96	3.86	0.99	−0.37	−0.89	0.12
		post (n_1=16, n_2=26)	3.06	0.85	4.08	1.10	−1.01*	−1.66	−0.34
	self-efficacy (Q6)	pre (n_1=33, n_2=29)	3.48	1.03	3.93	0.75	−0.49	−1.00	0.02
		post (n_1=19, n_2=26)	3.26	1.10	3.88	1.03	−0.59	−1.19	0.02
	stereotypes (Q15)	pre (n_1=32, n_2=29)	4.47	0.84	4.90	0.31	−0.66*	−1.18	−0.14
		post (n_1=17, n_2=25)	4.41	0.87	4.88	0.33	−0.77*	−1.41	−0.13
	positive feelings	pre (n_1=32, n_2=29)	3.74	1.05	4.26	0.59	−0.61*	−1.12	−0.09
		post (n_1=15, n_2=26)	3.62	0.99	4.26	0.72	−0.76*	−1.42	−0.10
		post-only (n_1=18, n_2=26)	3.29	0.95	3.93	0.86	−0.71*	−1.33	−0.09
	interest	pre (n_1=29, n_2=28)	3.68	0.86	3.92	0.70	−0.31	−0.83	0.21
		post (n_1=15, n_2=26)	3.75	0.61	3.93	0.75	−0.26	−0.90	0.38
		post-only (n_1=18, n_2=26)	2.93	0.69	3.65	0.99	−0.83*	−1.46	−0.19
	future intents	pre (n_1=33, n_2=29)	3.20	0.99	3.48	0.95	−0.29	−0.79	0.21
		post (n_1=17, n_2=26)	3.19	1.17	3.37	0.94	−0.18	−0.81	0.45
		post-only (n_1=12, n_2=25)	2.69	0.55	3.19	1.07	−0.56	−1.18	0.06

*$p<.05$

TABLE III

MEAN AND STANDARD DERIVATION (SD) FOR SELECTED ITEMS AND BY GROUPS BOYS MGC (N_PRE=53, N_POST=29), GIRLS MGC (N_PRE=25, N_POST=13) AND GIRLS SGC (N_PRE=28, N_POST=24).

Item	Group	Mean pre	Mean post	df	SD pre	SD post
Q3	boys MGC	4.32	4.03	-0.29	1.05	1.02
	girls MGC	3.96	3.62	-0.34	1.26	1.27
	girls SGC	4.54	4.50	-0.04	0.59	0.58
Q5	boys MGC	4.30	3.93	-0.37	0.80	0.82
	girls MGC	3.72	3.62	-0.10	1.12	1.10
	girls SGC	4.14	4.21	0.07	0.98	0.76
Q12	boys MGC	3.09	3.10	0.01	1.01	0.82
	girls MGC	3.04	2.69	-0.35	0.94	0.95
	girls SGC	3.11	3.21	0.10	0.96	0.88
Q13	boys MGC	3.75	3.66	-0.09	0.96	0.93
	girls MGC	3.40	3.54	0.14	0.96	0.66
	girls SGC	3.79	3.79	0.00	0.74	1.02
Q18	boys MGC	3.38	3.21	-0.17	1.32	0.98
	girls MGC	2.76	3.08	0.32	1.48	1.55
	girls SGC	3.21	3.12	-0.09	1.17	1.15

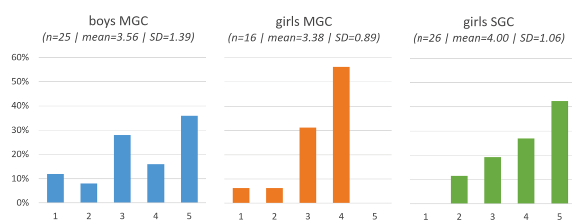

Fig. 4. Results Q22: *"It was fun to engage with the topics covered in the course"*

express strong positive feelings towards CS before and after the intervention and show to have enjoyed the course a lot more than girls (and boys) of MGC (see Fig. 4). They strongly expressed that engaging with the course topic was fun and that school would be more fun if they would work on things as they did in the course more often. Responses on the item *"During the course time flew by"* (see Fig. 5) suggest that at least some girls seem run into a *flow momento* [65] during the course, especially on the side of SGC. In all evaluation dimensions, the effect of class type was medium to large and statistically significant ($p<.05$). Especially the items *"Computer science is fun to me"* and *"I enjoy solving problems with computers"* do illustrate that effect (see Table III, Q5 and Q3). The SGC girls'

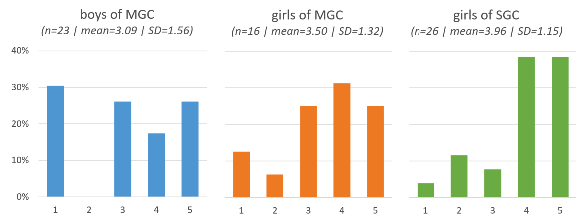

Fig. 5. Results Q27: *"During the course time flew by"*

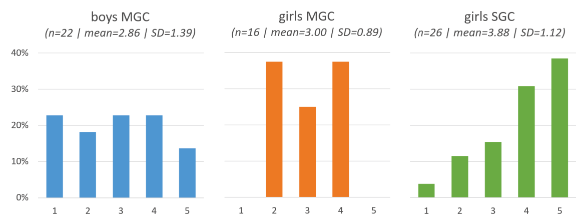

Fig. 6. Results Q21: *"I felt like I had learned something for myself"*

feelings remain on a high level throughout the intervention, while those of girls in MGC remain on a low level or even drop for boys.

b) Interest (RQ_2.b): There is no statistically significant difference between boys and girls in respect of their general interest in CS (see Table II). Descriptive statistics show that before the intervention, the average interest of boys was higher than that of girls. Afterward, boys' and girls' interest in CS was about the same on average. However, while the intervention barely affected girls' interest, boys' interest recorded a relatively substantial decrease. This observation matches the post-only interest results specifically related to activities in the online course used during the intervention (biology-related context). Here, the effect of gender on interest is medium (d=0.54) and statistically significant ($p<.05$). Girls could better identify themselves with activities of the intervention resulting in a higher personal relevance of the intervention for them, as is the case for boys. The item *"I felt like I had learned something for myself"* (see Fig. 6) explains this effect very well, and at the same time, the item indicates that girls of SGC mainly cause the effect. Indeed, class type shows a large effect on interest (d=-0.83) that is statistically significant ($p<.05$). The interest of girls from SGC is significantly higher than the interest of girls from MGC, which is merely higher than boys' interest. Even though girls' interest in MGC was relatively low, their overall interest in CS seems not to be negatively affected by the intervention. In contrast, the data show a positive tendency towards CS.

c) Future Intents (RQ_2.c): Future intents for CS of secondary school students do not statistically significantly differ among gender and class type. Although, we can still draw some tendencies from descriptive statistics. In general, boys' intent to do something in the field of CS is before and after the intervention higher than is the case for girls (see Table II). At the same time, boys are very divided in their feelings

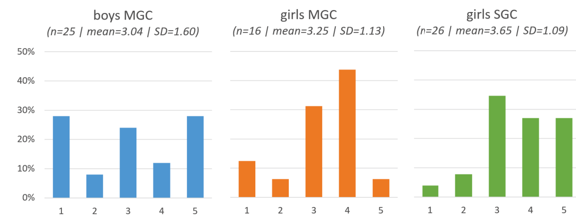

Fig. 7. Results Q24: *"I would love to do a course like this again"*

about doing an interdisciplinary course such as the one of the intervention again (see Fig. 7). On the other hand, girls show a slightly higher willingness to repeat such a course which might relate to their interdisciplinary learning preference. Just as the girls of SGCs had more fun doing the online course, they also show higher motivation to retake a similar course than it is the case for girls of MGCs. Independent of the intervention (i.e. pre and post), girls of SGCs are more open to CS-related activities as they are also more likely to imagine doing something in the field of CS later on (see Table III, Q18). Nevertheless, mean values on the item *"I can see myself doing something in the field of computer science later in after school"* indicate a positive impact of the intervention on the future intents of girls from MGCs.

Furthermore, girls of SGC manifested remarkably higher self-efficacy in CS than girls of MGC (see Table II, Q6). Surprisingly, boys' self-efficacy decreased significantly throughout the intervention. In the pre-survey, boys showed the highest self-efficacy, closely followed by girls of SGC. Throughout the intervention, the average self-efficacy of boys dropped a lot so that after the intervention the self-efficacy of girls in SGC increased even higher than boys' average self-efficacy. Girls in MGC showed the lowest self-efficacy overall, which is remarkably lower than the self-efficacy of girls in SGC. Still, self-efficacy decreased compared to the beginning of the intervention for all three study groups (girls in MGC, boys in MGC, and girls in SGC). While for girls it was just a slight decrease, the drop was a full 0.5 points on average for boys.

C. Additional Findings: Individual Observations

Main Finding Individual results indicate enthusiasm potential of interdisciplinary learning, but repeated occurrence might be necessary.

We wondered whether the intervention positively affected students who were initially less interested in CS-related activities. However, this question could not be answered adequately due to the limited sample size. Instead, an exploratory analysis of students who initially showed less interest in CS-related activities led to new findings at the individual level. This section focuses on two individuals who show interesting results that could be representative of different types of enthusiasm effects of introductory interventions on students' attitudes towards CS.

a) Individual Pattern - "There was a Spark": The first student, MJ04, is a 15-year-old 9th-grade female student in

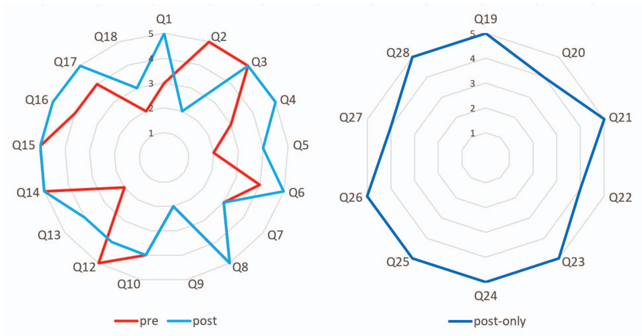

Fig. 8. Spiderweb diagrams for student MJ04

a SGC. She is a prime example of the effectiveness of interdisciplinary learning. Fig. 8 shows MJ04s' responses in the survey as a spiderweb diagram. The spiderweb diagram scale corresponds to the items' Likert-type scale. Without any exception, the blue line trajectory (post) in the left diagram moved towards an "optimum" trajectory or at least remained at the same level as the red line (pre). This means that student MJ04 rated each element at least as positively after the intervention as before, with a positive overall improvement. This includes a significant interest increase in CS (Q5) and a clearly increased willingness to engage with programming (Q2). While in the pre-survey, she already clearly expressed her preference for doing tasks on the computer (Q3), her interest in learning more about the possibilities of the computer (Q4) was still very reserved. After the intervention, she then stated that she would very much like to learn more about computers, which at the same time is a much stronger expression of interest towards CS than it is just with Q3. It is also interesting to note that at the beginning of the intervention, she did not indicate interdisciplinary thinking as a preferred learning method (Q1), but in retrospect, she was entirely in favor of it. At the same time, she did associate CS less with programming-only activities afterward, indicating an arising of a wider application picture of SE which could have positively impacted her overall feelings towards programming-related activities. Such a spiderweb diagram best indicates the intervention's ability to inspire enthusiasm for CS.

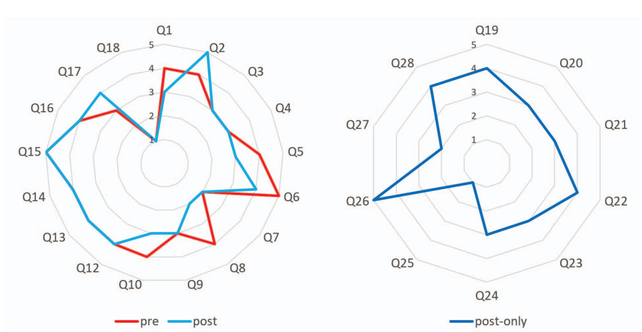

Fig. 9. Spiderweb diagrams for student SS02

b) Individual Pattern - "It Needs a Little more": Student SS02 is a 13-year-old girl from an 8th-grade MGC. She is an example of a group of girls for whom the right stimulus has been given, but the positive effect is still missing. Fig. 9 shows the spiderweb diagram for SS02 that compares pre-test and post-test results and a spiderweb diagram for post-test-only items. Comparing the pre- and post-responses shows that the intervention hardly affected the student's perception, and some items were answered in a declining manner. Nevertheless, the intervention-related post-only items indicate that the student had a noticeable degree of fun with the online course. One possible explanation for this could be the novelty effect of the introduced online course, as it might just have been a pleasant change from regular lessons for her. However, she showed high agreement, especially with the items that specifically asked about the attitude towards the topics covered in the course (Q19 and Q22). She would also recommend such a course to others (Q26) and can also imagine talking to others about the topics covered in the course (Q28). At the same time, she needs to make clear that she does not want to deal with anything related to programming (Q2). One possible interpretation of these results is that this student still has a very strongly preconceived image of CS, which could have a negative impact on her perception and readiness for new things in this field. For this student, the intervention topics might not have an objective relation to CS; if they do, she might treat them only as an exception. It is possible, that repeated access to CS via interdisciplinary scenarios originating in the areas of her interests could have a lasting effect on such students.

IV. Discussion

A. Suitable First Contact

Recommendation 1 *Teach diverse. Teach interdisciplinary.* Think about topic-specific implications and alternatives. Interdisciplinary has excellent potential to offer students different opportunities to explore points of connection and personal relevance to an area of study.

The findings in [14] provide evidence for the hypothesis that interdisciplinary learning units have the potential to get girls excited about CS and this paper supports the effectiveness of such strategies for girl-friendly CS education. The way how topics are introduced and embedded in a context can have a big impact on the motivation of students (e.g. introductory game development as a motivation for CS does not resonate with students new to computer games [16], [66]). Therefore, the teaching should be supported by alternative and varying material for motivating CS [67] connected to students' everyday life [42], to social good [46], and to people and their impact instead of things as an end in itself [41]. There is an opportunity to create alternative and different entry points into the CS field by simply building on individual interests and relatable problems [16]. This helps students to feel more comfortable exploring and experimenting with CS, to have the stability of a familiar knowledge base, and to be able to self-identify with relevant problems. Interdisciplinary-driven CS education might be a promising alternative to traditional introductory courses [25]. At the same time, our data demonstrate how sensitive interest and enthusiasm can be affected depending on the learning topic, how the topic is embedded, and the nature of the learning environment, which in total can result in polarizing effects as we could observe in our case study. While one design goal of the intervention was to attract girls in particular, it was not intended that boys would feel less attracted. We observed that our course initiated questioning of boys' perception of CS, their stereotypes as well as their CS competencies. In this respect, that this effect occurred relatively clearly in this study need not be a bad sign. It could be seen positively as sensitizing boys to the wrong perceptions (e.g. CS is only about programming) or stereotypes (e.g. girls bring less to the CS table) and as broadening of perspective for them. It does, however, highlight the need to reflectively examine CS instruction at school with regard to gender-specific preferences in order to be able to ensure a balanced learning environment in which girls and boys feel equally included.

B. Influence of the Learning Environment

Recommendation 2 *Teach with awareness of character and gender needs.* Create a learning environment where girls can feel safe and free to develop their own ideas. Be aware of the monopolization of the class by advanced learners, who are often the boys in CS classes.

We found that girls from SGCs have much more open attitudes towards CS and generally are more willing to engage with CS topics than girls from MGCs. Many studies claim not to differentiate between SGCs and MGCs in STEM education, finding no significant differences between class types that would support the benefits of gender-segregated education [68]–[70]. Some studies even find positive effects for boys-only schools, but not for girls [71]. However, most of these studies are not directly related to CS teaching. Studies that have directly examined the effect of class type on girls' attitudes towards CS teaching have found positive effects of SGCs that are consistent with our findings [33], [72]. This suggests a unique role and benefit of class type for CS instruction. Our observations show that the learning environment can significantly impact behavior, cognition, and interest development. It is hardly possible to speculate on the specific causes, as there could be many boundary conditions of the learning environment, such as the teacher, the age of the students, certain class constellations, etc., which can have an impact on the students' experiences. However, for example, a study by Wieselmann et al. [73] showed that girls in heterogeneous groups, especially in the subject CS, often orient themselves on how the boys approach a matter. Moreover, in our study, we could observe that especially boys have more stereotypical perceptions about CS than girls. One of our speculations for explaining the differences between MGCs and SGCs is, that boys might tend to smile at the learning unit in the interdisciplinary context of biology with an undertone such as "that's not really CS", which might have an impact on girls' feelings in MGCs and create a situation where it is "uncool" to show enthusiasm for the subject. With our preliminary findings, we do not claim this as an as-is state but we see a potential research gap here, where we want to encourage further investigations and discussions.

At first glance, our results regarding SGCs might seem contrasting to the benefits of having diverse software development teams in companies, and to the higher-ordered goal of promoting diversity in education (without segregation). But, we argue, that it might not be necessary to have gender-segregated classes throughout the whole educational pipeline. It is especially the first contact with the subject, that will or will not trigger situational interest, which in turn is a requirement for long-term interest [74]. So, before a diverse team constellation can unfold all its potential, it is necessary that underrepresented groups have the opportunity to identify themselves with the subject and build solid self-confidence. This is more likely when students find themselves in a welcoming, safe space when having their first experiences with CS [14]. Here, our findings indicate, that all-girls activities seem to be a potential solution, among others.

V. Threats to Validity and Limitations

Due to the nature of quasi-experimental studies and the unique role of our intervention as part of regular school lessons, many factors may influence the results, which we are unaware of. Uncertainties are, for example, how the teacher did introduce the course and how well the teacher could support the students during the intervention. Also, we know nothing about the concrete settings and if there have been any constraints such as time constraints that could have negatively impacted the immersion feeling. We also had no control over the questionnaire conducted. Answers from the students are subjective and could be influenced by the surroundings and therefore not reflect the actual situation properly. Due to the small sample size, different ages, class sizes, the drop-off rate from pre-test to post-test, and the varying effect sizes, the findings can only be generalized to a limited extent. While the interdisciplinary data science intervention clearly showed the potential to motivate individuals for CS significantly, the overall significant and "overwhelming" effect stayed out. In addition to the limitations described above, there are also some other factors that might contribute to this. For example, the average interest in CS was already at the beginning at a surprisingly high level, making it more difficult for the intervention to cause a significant change. Indeed, the difference between a four and a five on a 5-point Likert-type scale is a more cognitively significant change than, for example, between a three and a four [75], so that a change from a five- to a four-point rating is, in general, more likely than it is the other way around. It is also possible, that minor bugs and user interface intricacies occurred during the intervention affecting the immersion effect negatively, even though we carefully developed the content and design of the course in respect of the target audience and iterative discussed and revised the result. This is a known challenge in educational e-learning designs [76]. Another limitation of our study is that results are very limited to situational interest; nevertheless, situational interest is one key component for the development of individual interest [77]. Lastly, although we are aware of the importance of considering the whole gender spectrum [1], we did not include non-binary answers in the gender-related evaluation because of their low occurrence. We had only four participants in the pre-survey and two in the post-survey that explicitly chose *"Prefer not to say"* at the gender-related question. One of those responses belongs to a student of a SGC at the all-girls school.

VI. Conclusion and Future Research

We presented the results of an interdisciplinary intervention in which students of secondary school could explore basic CS concepts in a biology-inspired and problem-based online data science course. With this intervention, we wanted to give girls, in particular, the opportunity to explore programming as a valuable tool for achieving greater goals in the context of their interests, thus providing an alternative to the traditional motivation for introducing SE concepts, e.g. through game development.

a) Did the interdisciplinary intervention positively impact the girls' engagement with CS?: The results suggest that the course has the potential to spark enthusiasm for CS, yet at the same time, we found that the girls' experiences varied greatly depending on the classroom context they found themselves in. The degree of homogeneity and heterogeneity in the classroom affected the effectiveness of the intervention, as well as the extent and the nature of the classroom interactions. We found significant differences between girls from SGCs and girls from MGCs. Girls in SGCs show a much more open attitude towards CS-related topics in general. They clearly prefer interdisciplinary learning and generally express significantly more positive feelings about CS. Evidence from regular school classes suggests that interaction with the learning environment strongly influences girls' attitudes towards CS. Conversely, SGCs can serve as an incubator for the emergence of interest and a positive first experience of CS for female learners. It may not be necessary to create completely homogeneous classes if this is not feasible; some alternatives for CS teachers could be girls-only CS lab sessions, recommending extracurricular CS experiences for girls, long-term groupings of girls for collaborative CS tasks, and mentoring for girls to overcome their novice status in the CS classroom. Our findings suggest that improving girls' experiences in regular CS classes can enhance their interest in the subject. It appears that girls-only interventions can support girls in developing a more stable interest in the subject.

b) Did the intervention positively impact the girls' perception of CS?: In contrast, the boys' feelings about the intervention were very mixed, and to our surprise, the intervention had a rather challenging effect on the boys' perception of CS. We observed a broadening of the boys' perspective and sensitizing them to misperceptions (e.g., CS is all about programming) or stereotypes (e.g., girls contribute less to the CS table). Our experience has taught us that to make MGCs a success; we need to reach out not only to girls but also to boys. Many boys have misconceptions about CS and programming, so it might be helpful to convince them that CS is more than programming and that it is beneficial for everyone if girls contribute authentically and candidly. Our findings show that by co-educating MGCs in CS, the school can try to fulfill its role of socializing students with diversity, but the positive or negative outcome of this experience depends heavily on the teacher's ability to create a friendly and positive classroom climate. This is the crucial difference between regular CS classes in school and extracurricular CS activities for students who have already shown a positive attitude towards the subject through enrollment. In regular classrooms, teachers must actively promote positive and healthy relationships in CS classes and act as role models for beliefs and behaviors in various contexts.

The extent of these effects needs to be discussed and evaluated in more depth in future studies that consider a broader view of user characteristics and include qualitative methods to understand the individual's role in a complex system of the class constellation and social environment. In both constellations, SGC and MGC, there is a need for long-term studies to understand the effects of both types, i.e. whether interest in the first case remains at a high level and whether repeated interventions can positively influence interest in the second case. In respect of the threats to validity, the presented case study might not allow a generalization of our findings yet, in the future we plan to combine results from an increasing number of case studies so that we can derive a theory by similarity [78]. In our case, the interdisciplinary intervention illustrated the potential of polarization of CS topics and possible implications of the learning environment, such as class constellation, which needs to be verified in follow-up research. Although we see the setting of our intervention as part of regular classes at school as a unique strength of our study, in the future we want to conduct studies with more control over the setting and external influences.

Nevertheless, our case study highlighted the need to think about how CS topics are introduced in the context of an inclusive classroom where boys and girls are equally given the opportunity to identify with the subject. The intervention presented offers an alternative first contact with programming in response to a survey participant's quote in [16]: "*Why would I write a game I don't want to play? Waste of time...*" - we have shown that this is definitely not necessary.

Acknowledgment

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