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Gender Differences in the New Interdisciplinary Subject Informatik, Mathematik, Physik (IMP)—Sticking with STEM?

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Abstract: The current state of research in computer science education outlines gender differences in motivation, interest, and elective subject decisions in favor of male students. This study takes an exploratory approach to examine the gender differences in the interdisciplinary STEM profile subject Informatik, Mathematik, Physik (in short: subject IMP), which combines the three subjects of computer science, mathematics, and physics. A survey was conducted involving n = 336 (m = 236, f = 88, o = 12) subject IMP students in the 10th grade attending a Gymnasium in Baden-Württemberg, Germany. The deciding factors for choosing the subject, subject interest, motivation, and more were measured using a questionnaire. Overall, the subject IMP is most chosen by male students. For those students choosing the subject IMP, no statistically significant gender differences in subject interest in IMP, mathematics, and the STEM area or in motivation and vocational orientation in natural science and engineering were found in contrast to the state of research. The interdisciplinary character of the subject IMP could be more appealing to girls than computer science by itself. We conclude that, with a higher participation rate of female students, the subject IMP could be a first step in getting more women into STEM fields.

Keywords: computer science education; gender differences; motivation; interest; IMP; subject specific analyses; STEM education; STEM careers; gender motivation self-concept interests

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1. Introduction

The current gender gap exists in many STEM (science, technology, engineering, and mathematics) fields at different educational levels in Germany. Beginning from subjects in secondary schools—such as computer science (CS) [1], physics, engineering/technology, chemistry, biology, and mathematics—until the university [2], the most prominent fields with a gender gap are CS and engineering [2]. A similar distribution can be observed on the job market [2–5]. The percentages can be as low as 13.7% for women working in computer science professions in Germany [2]. At the same time, there exists a shortage of skilled professionals in many STEM fields (such as computer science, physics, and mathematics) in Germany [5–7]. Combining the two facts mentioned above, education has to adapt. Monitoring those changes to better understand why students choose the subjects they do and to give research-based recommendations to teachers and educators has never been more important. Furthermore, topics such as AI, cryptography, simulation, data literacy, and computational thinking have become more important for today's society and that of the future [8–10]. When dealing with those changes and when seeking to shape the society of the future, the gender gap plays an important role, since the aforementioned topics bring many ethical, legal, and social implications (ELSIs) with them. As one way to address the shortage of skilled professionals and to teach students the basic knowledge needed to understand the fundamentals of CS and acquire future skills, new interdisciplinary subjects, programs, and courses have been created by politicians and educational experts to foster students' interest in STEM at different schools, levels, and countries [11,12]. Nevertheless, in many federal states in Germany, CS and other interdisciplinary subjects related to CS are not compulsory [13]. Overall, the structure of CS as a subject in secondary schools in Germany is diverse [13]. CS is an elective subject in some grades and compulsory in others. In some federal states, it is only an elective subject throughout middle school, while in others it is compulsory, such as in Baden-Württemberg, where CS is taught for one hour per week in the 7th grade. Since 2018, students in the 8th grade at secondary schools called Gymnasien in Baden-Württemberg have been able to choose the new interdisciplinary profile subject IMP. This new subject combines the three subjects of CS, mathematics, and physics as a continuation of the CS profile and, more specifically, a STEM profile [14,15]. As one subject of the four-hour profile, students can choose between a third foreign language, another interdisciplinary natural science and technology subject called Naturwissenschaft und Technik (NwT)—with a focus on technology that complements the natural sciences—and IMP, which is the focus of this article. Students studying IMP can learn the skills of CS, mathematics, and physics, along with the interdisciplinary intersections between those subjects, such as computational physics and numerical methods in mechanics, the physical fundamentals of information systems, and cryptography [15]. In the summer of 2021, the first IMP students reached the end of the three-year-long profile subject. Afterwards, they had the option to continue with CS as a chosen, basic, or performance course (Figure 1) for 2, 3, or 5 h per week, respectively, in the higher grades.

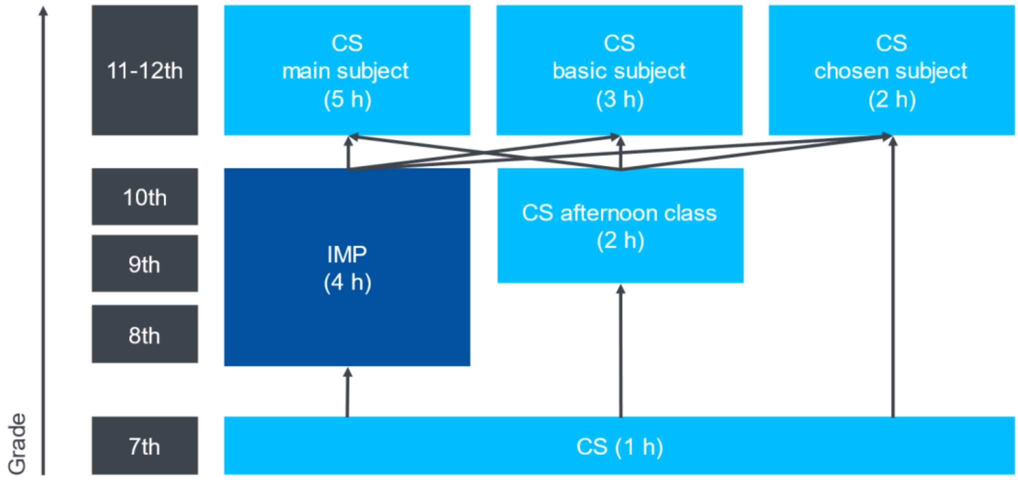

Figure 1. Structure of CS classes in Baden-Württemberg, edited; original by Koch, A. and Mittag, A., licensed under CC BY-SA 4.0 [13].

The course selection in Baden-Württemberg allows for different profiles, with some rules. The students must choose courses totaling at least 32 h per week, including three performance subjects, two courses from German, mathematics, one foreign language, and one natural science (biology, chemistry, or physics), as well as some basic or chosen subjects [16]. CS as a performance subject or basic subject is currently in a school pilot phase, and the subject is only available in some schools. Due to the lack of CS teachers in Baden-Württemberg [17], it is likely that not all of the schools can provide the two new subjects.

1.1. Theory

This study focused on the learning characteristics of IMP students. Learning characteristics are individual prerequisites such as interest, motivation, and self-concept. Starting with the situated expectancy value theory (SEVT) developed by Wigfield and Eccles [18], many empirical studies [19–21] have shown the interdependencies described in models. As in the model described above, learning characteristics influence the course selection and vocational orientation of students.

The theoretical basics of interest, along with the subject-specific interest in IMP for this study, are described by the construct of interest developed by Krapp et al. [22], with reference to the self-determination theory (SDT) of Deci and Ryan [23]. With a situational incentive quality, the attention of the students should be focused on the subject of learning. Objects of learning can be activities, topics, and areas of expertise [24]. Situational interest can be developed through the learning situation or the learning object. Fostering situational interest in the classroom can lead to individual interest as a personality-specific characteristic (e.g., subject interest) in students.

Studies have shown the influence of the academic self-concept on students' career choices and educational decisions, as well as on their performance [25–27]. In addition to other learning characteristics, studies have shown that the subject-specific self-concept is the most significant moderating variable for the variance of the subject interest [28]. As one facet of the academic self-concept, the subject-specific self-concept differentiates the academic self-concept for the specific subjects [25].

To measure the students' motivation (amotivated, extrinsic, introjected, identified, intrinsic, or interested), we fell back on the known scales described by Prenzel [29], based on the SDT of Deci and Ryan [23], according to which motivation can vary with respect to the self-determination aspects of learning. Students who identify with the subject of study and take pleasure in learning more about it are intrinsically motivated. "Interested" is the state where the students themselves want to learn more about the subject of study [24].

The vocational orientation and the influencing factors of the vocational choices were assessed in this study. To better understand the reasons behind the vocational choices, the quantitative results of the influencing factors of educational choices from the questionnaire (adapted from [30,31]) were supplemented with the analysis of the qualitative results from the open questions asking about the influencing factors of the choice of IMP and CS courses in the higher grades. In the best case, the qualitative analysis can explain and indicate trends or add information to the results of the questionnaire items [32].

1.2. State of Research

According to the current state of research, there is no systematic method to collect data on the learning characteristics of IMP students. Therefore, the only option is to view the state of research for each individual STEM subject or comparable interdisciplinary subject. In this subsection, the gender differences in learner characteristics in STEM subjects in Germany are presented. Gender differences occur in some countries but not others, due to differences in educational systems, interventions, programs, influences from the social background, etc. For the state of research, studies regarding the gender differences in the learning characteristics of students from Germany were viewed.

The subject interest in CS [33], physics [28,34,35], and mathematics [36] in different grades of the school is higher for male students than for female students, while the subject interest in biology is higher for female students than for male students [37]. The state of research on chemistry education in Germany does not show an unambiguous preference towards one gender, and Krapp and Prenzel reported the importance of the differentiation of thematic fields within all STEM subjects with respect to the subject interest [38]. Hence, the state of research in STEM education regarding subject's interest can also be seen through a critical lens, as the interest might not be the same for all topics within a subject and different interest profiles can be measured [28,38,39].

The state of research regarding the academic and subject-specific self-concept is mostly homogeneous for the STEM subjects, with the exception of biology. In CS, gender differences appear as early as primary school [40] and in the programming-related self-concept [41]. They can be found in secondary schools [33], universities [42], and even among computing professionals [43]. In physics and chemistry, the same gender differences are prevalent in middle school [25]. Especially in mathematics, large-scale studies such as PISA and TIMSS have reported gender differences in the math-related self-concept as well as the STEM-related self-concept [26,44,45]. The gender differences mentioned thus far are stereotypically all in favor of male students, whereas the biology self-concept favors female students [44].

Another aspect to consider is students' negative associations with STEM stereotypes as well as role models in STEM fields [1]. The latter could influence women's implicit STEM cognitions [46], foster a sense of belonging and raise their expectations of success [47]. Maybe regardless of their gender [48,49], teachers could apply strategies to foster girls' interest in CS [1,49], introduce students to positive role models and programs, or be a role model themselves [1,46,50].

To extend the scientific discourse on CS and STEM education and gender, the focus of this study is on the following two research questions:

(RQ1) By which self-concept, motivation, interests, vocational orientation, and factors influencing educational choices can IMP students in the 10th grade be characterized?

(RQ2) What gender-specific differences in the self-concept, motivation, interests, vocational orientation, and factors influencing the educational choices of IMP students exist between male and female IMP students?

2. Materials and Methods

2.1. Participants and Procedure

The study was conducted from 27 April 2022 to 4 July 2022 via an online survey in Baden-Württemberg, Germany. Overall, n = 336 (*male* = 236, *female* = 88, *other* = 12) IMP students at the end of the 10th grade with an average age of 16 years (*Min* = 15.0, *Max* = 19.0, *M* = 15.98, *SD* = 0.70) attending a Gymnasium participated in the study. In total, 20% of the IMP students in the 10th grade during that period of time participated in the study (information from September 2022 from the Ministry of Education, Cultural Affairs, Youth and Sports of Baden-Württemberg). From all 99 Gymnasien (information from September 2020 from the Ministry of Education, Cultural Affairs, Youth and Sports of Baden-Württemberg) that introduced IMP in the school year 2019/2020 or earlier, 31 from the different administrative districts (Freiburg n = 5, Karlsruhe n = 9, Stuttgart n = 12, Tübingen n = 5) of Baden-Württemberg participated. The Gymnasien received an e-mail with a link to the online survey and a declaration of consent for the parents. The participation in the online survey was anonymous and voluntary, as explained in the covering letter to the schools, parents, and students.

2.2. Instruments

The original version of the questionnaire, in German, can be found in the Supplementary section of this article. We assessed demographic data, such as a code for re-identification if a participant wished to revoke their participation, along with age, gender (male, female, other), and their school. To measure the students' motivation (amotivated, extrinsic, introjected, identified, intrinsic, or interested), we adapted the known scales described by Prenzel et al. [24]. The chosen subjects and their interest in them, along with the subject-specific self-concept (adapted from [27,51,52]), academic self-concept (adapted from [53]), and performance-related expectations associated with CS in higher grades (adapted from [27]), area-specific interest (adapted from [22]), subject interest in IMP (adapted from [54]), factual interest, vocational orientation (adapted from [30,31]), and factors influencing their educational choices [31,55] were also assessed. At the end of the questionnaire, we asked the IMP students about grades and some open questions. As indicated in Table 1 below, the Cronbach's α values to measure the internal consistency of all applied instruments were reliable ($\alpha > 0.75$ [56]), except for extrinsic motivation ($\alpha = 0.684$ [56]). This result was to be expected, as we used tested and validated instruments. Not a single item was excluded. We analyzed the results using SPSS 28.0.0.0 and R 4.3.1.

Table 1. Test quality criteria of the applied scales.

Scale	Subscale	Cronbach's α	Number of Items	M	SD	n
Subject-specific self-concept		0.950	10	3.05	0.78	321
Academic self-concept		0.964	11	3.43	0.93	331
Performance-related attitudes towards CS in higher grades		0.945	7	2.71	0.88	225
Motivation	Amotivated	0.820	3	2.38	1.17	333
	Extrinsic	0.684	3	2.28	1.04	333
	Introjected	0.751	3	3.22	1.05	332
	Identified	0.757	3	3.37	1.08	331
	Intrinsic	0.816	3	2.70	1.15	332
	Interested	0.886	3	2.84	1.20	333
Area-specific interest	Linguistic–literary–artistic	0.893	4	2.27	0.85	331
	Social science	0.884	4	2.74	0.79	329
	STEM	0.890	4	3.18	0.77	330
Subject interest in IMP		0.916	18	2.37	0.67	299

The answers to the open questions such as "name the three most important reasons for choosing the profile subject IMP?" and "name the three most important reasons why you decided to take or not to take the CS course in higher grades?" were analyzed using the systematic, rule-guided, qualitative content analysis described by Mayring [57]. The deductive categories (see the Supplementary) were the course selection and deselection motives described by Eitemüller and Walpuski [55]. The only two inductive categories were added after 25% of the analyzed answers were coded, since many students named "Programming" and "Future relevance" among their reasons for choosing IMP or CS in higher grades. After adding these categories, the answers were analyzed again. Programming, as one aspect of the CS part of IMP, was therefore excluded from the categories "Subject and factual interest" and "interest in working methods". If the students did not explicitly mention the importance for their future career or study and only stated that the content of the subject and/or the subject itself would be relevant in the future, the answer was assigned to the category "Future relevance". No answer was coded in more than one category. In addition to the factors influencing the educational choices within the questionnaire, the open questions provided the IMP students with the option to state their own reasons without being restricted by the questionnaire. The answers to the open questions have the benefit of being more specific with respect to the selection of IMP and CS courses in higher grades. The interrater agreement between the first rater (i.e., the first named author of this article) and the second rater (i.e., a trained student assistant) was 88% for the motives for selecting IMP, 81% for the motives for selecting CS in higher grades, and 80% for the motives for dropping CS in higher grades. The Cohen's kappa values for the three categories were substantial [58,59]. We used MAXQDA 20.4.2 for the data analysis.

3. Results

To answer RQ2, the following subsections cover the gender differences in the motivational and affective determinants of the IMP students in this cohort.

3.1. Gender Differences

The significance of gender differences in the subject-specific self-concept in IMP ($U = 7803$, $p = 0.030$, $Z = -2.165$) and academic self-concept ($U = 7263$, $p < 0.001$, $Z = -3.768$) was assessed using the Mann–Whitney U test. There was homogeneity of the variances as assessed by Levene's test for the subject-specific self-concept ($p = 0.887$) and the academic self-concept ($p = 0.179$) (Table 2). None of the populations were normally distributed according to the Shapiro–Wilk test ($p < 0.001$). The analysis of the effect size r indicated that female IMP students had a slightly lower subject-specific self-concept in IMP ($r = -0.124$) and academic self-concept ($r = -0.211$) than male IMP students in this cohort. Instead of computing Cohen's d, it is recommended to report the effect size r for non-parametric tests such as the Mann–Whitney U test [60,61]. The analysis showed that for this cohort of IMP students, gender-related differences in the self-concepts were prevalent, as also shown in other STEM fields in secondary schools in Germany [25,26]. As with other STEM subjects [28,34,35], male IMP students in this cohort were more interested in physics ($U = 8018$, $p = 0.002$, $Z = -3.131$, $r = -0.175$) and CS ($U = 7303$, $p < 0.001$, $Z = -3.531$, $r = -0.200$), while female IMP students were more interested in biology ($U = 7413$, $p < 0.001$, $Z = -3.930$, $r = -0.219$) and in the linguistic–literary–artistic areas ($U = 5570$, $p < 0.001$, $Z = -6.193$, $r = -0.348$), as assessed by the Mann–Whitney U test (Table 2). None of the populations were normally distributed according to the Shapiro–Wilk test ($p < 0.001$). Considering the unequal sample sizes, the group differences were assessed by the Mann-Whitney U test [62–64].

Table 2. Differences between male and female IMP students.

	Shapiro–Wilk Test	Levene's Test	Mann–Whitney U Test/ t-Test/Chi-Squared Test	Gender n (Male, Female)
Subject-specific self-concept	$p < 0.001$	$p = 0.887$	$U = 7803$, $p = 0.030$, $Z = -2.165$, $r = -0.124$	226, 83
Academic self-concept	$p < 0.001$	$p = 0.179$	$U = 7263$, $p < 0.001$, $Z = -3.768$, $r = -0.211$	232, 87
Performance-related expectations towards CS in higher grades	$p < 0.001$	$p = 0.120$	$U = 2758$, $p = 0.006$, $Z = -2.733$, $r = -0.186$	172, 44
Amotivated	$p < 0.001$	$p = 0.241$	$U = 9055$, $p = 0.155$, $Z = -1.422$	234, 87
Extrinsic motivation	$p < 0.001$	$p = 0.158$	$U = 9189$, $p = 0.253$, $Z = -1.143$	235, 86
Introjected motivation	$p < 0.001$	$p = 0.227$	$U = 8554$, $p = 0.050$, $Z = -1.961$	234, 86
Identified motivation	$p < 0.001$	$p = 0.442$	$U = 9801$, $p = 0.855$, $Z = -0.182$	233, 86
Intrinsic motivation	$p < 0.001$	$p = 0.675$	$U = 9272$, $p = 0.286$, $Z = -1.066$	233, 87
Interested	$p < 0.001$	$p = 0.775$	$U = 8855$, $p = 0.091$, $Z = -1.693$	234, 87
Interest in linguistic–literary–artistic areas	$p < 0.001$	$p = 0.392$	$U = 5570$, $p < 0.001$, $Z = -6.193$, $r = -0.348$	231, 88
Interest in social science areas	$p < 0.001$	$p = 0.045$	$U = 7600$, $p = 0.001$, $Z = -3.275$, $r = -0.184$	231, 87
Interest in STEM areas	$p < 0.001$	$p = 0.406$	$U = 8888$, $p = 0.135$, $Z = -1.495$	231, 87
Subject interest in IMP	$p = 0.122$	$p = 0.733$	$t\ (287) = 1.794$, $p = 0.074$	210, 79
Interest in CS	$p < 0.001$	$p = 0.186$	$U = 7303$, $p < 0.001$, $Z = -3.531$, $r = -0.200$	266, 87
Interest in mathematics	$p < 0.001$	$p = 0.996$	$U = 10176$, $p = 0.864$, $Z = -0.172$	236, 88
Interest in physics	$p < 0.001$	$p = 0.050$	$U = 8018$, $p = 0.002$, $Z = -3.131$, $r = -0.175$	235, 88
Interest in biology	$p < 0.001$	$p = 0.512$	$U = 7413$, $p < 0.001$, $Z = -3.930$, $r = -0.219$	235, 88
Interest in implementing code	$p < 0.001$	$p = 0.917$	$U = 7802$, $p = 0.002$, $Z = -3.065$, $r = -0.172$	230, 86
Interest in algorithms	$p < 0.001$	$p = 0.187$	$U = 6948$, $p < 0.001$, $Z = -4.074$, $r = -0.229$	231, 87
Interest in requirement analysis	$p < 0.001$	$p = 0.359$	$U = 7814$, $p = 0.002$, $Z = -3.029$, $r = -0.170$	231, 87
Interest in software projects	$p < 0.001$	$p = 0.917$	$U = 7151$, $p < 0.001$, $Z = -3.845$, $r = -0.217$	231, 86

Table 2. *Cont.*

	Shapiro–Wilk Test	Levene's Test	Mann–Whitney U Test/ t-Test/Chi-Squared Test	Gender n (Male, Female)
Vocational orientation: pursuing a career or study in mathematics or CS	$p < 0.001$	$p = 0.130$	$U = 8264$, $p = 0.018$, $Z = -2.360$, $r = -0.133$	230, 87
Vocational orientation: pursuing a career or study in science or engineering/technology	$p < 0.001$	$p = 0.189$	$U = 8700$, $p = 0.088$, $Z = -1.706$	229, 87
Factors influencing the educational choice: career prospects	$p < 0.001$	$p = 0.148$	$U = 9146$, $p = 0.038$, $Z = -2.079$, $r = -0.118$	225, 86
Choice of CS in higher grades	$p < 0.001$	$p = 0.008$	$X^2(1, n = 313) = 6.278$, $p = 0.012$, $\phi = -0.142$, $p = 0.012$	231, 86

3.2. No Gender Differences

In contrast to the state of research in other STEM subjects [28,33,36], there were no significant gender differences in any of the six facets of motivation [65–67], the interest in the STEM area, or the subject interest in IMP and mathematics, as assessed by the Mann–Whitney U test and *t*-test (Table 2). The subject with the highest interest was mathematics, with no gender difference. As the IMP students chose a STEM profile subject with four hours per week in the 8th grade, it was not a big surprise that there were no gender differences in interest in this area and subject. Mathematics is one of the key subjects comprising the theoretical background of the interdisciplinary topics mentioned in Section 1, as well as being a central part of the subject IMP. This could explain why, in contrast to the state of research in mathematics education [36], there were no gender differences in the interest in mathematics. The interdisciplinary context of IMP, which is built around CS, could be more appealing to female students, and this could explain why there were no gender differences in any of the six facets of motivation—even intrinsic motivation and interest (Table 2). Looking at the vocational orientation, there were no significant gender differences for the item "pursuing a career or study in science or engineering/technology", as assessed by the Mann–Whitney U test ($U = 8700$, $p = 0.088$, $Z = -1.706$). The sample size of only 336 (20% of all IMP students in the 10th grade at that time) could be a limiting factor, but the fact that there were no gender differences stands in contrast to the current gender gap in universities (24.2% female students in the first semester studying CS, 21.5% female students with bachelor's degrees in CS, and 23.5% female students with master's degrees in CS at German universities in 2021 [68]) and on the job market [1,2,5]; however, the overall lack of a gender difference could imply that the IMP students tend to choose an education or career in science or engineering/technology (Figure 2).

Overall, most of the IMP students tend to choose an education or career in the fields of science, engineering/technology, mathematics, or CS (Figure 2). Since IMP is the only way for students in Baden-Württemberg to continue with a subject in the field of CS, we also examined the gender differences in the choice of CS in higher grades.

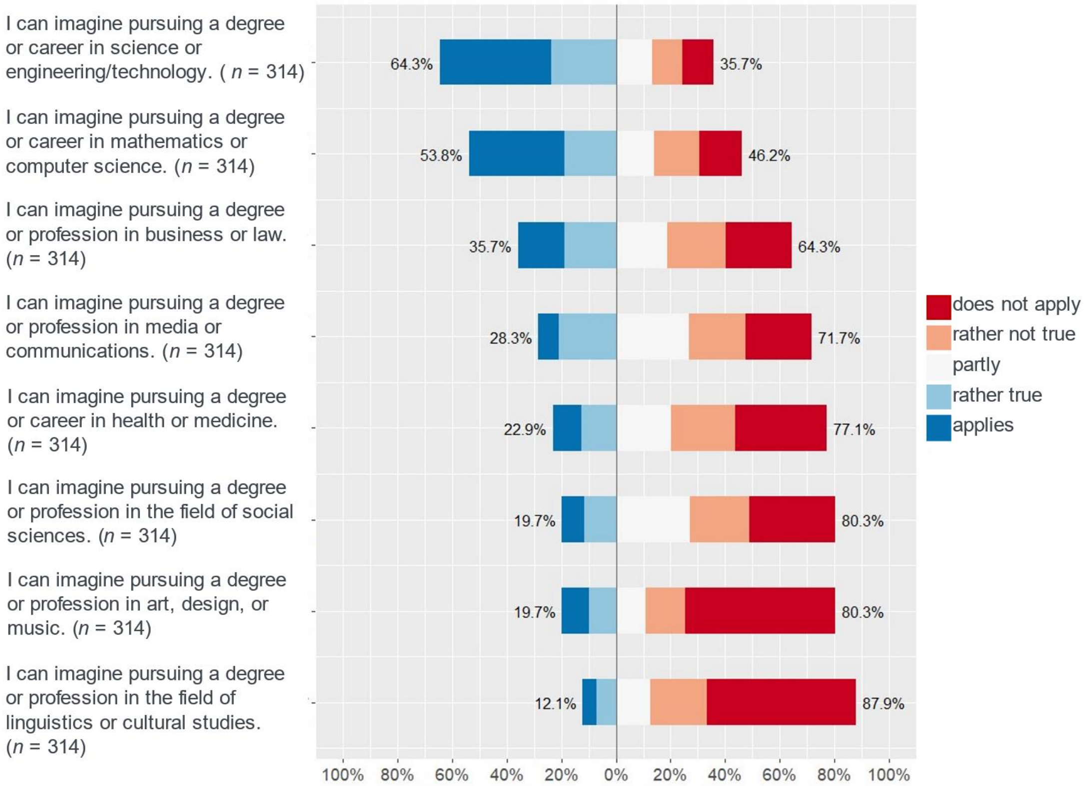

Figure 2. Vocational orientation of IMP students.

3.3. Gender Differences in the Choice of CS in Higher Grades

Overall, 40.7% of IMP students who chose CS in higher grades in this cohort had higher intrinsic motivation, a higher subject-specific and academic self-concept, better IMP grades, higher performance-related expectations towards CS in higher grades, were more interested, and had a higher subject interest in IMP than IMP students who did not choose CS in higher grades, as assessed by the Mann–Whitney U test (Table 3). There was a small but significant gender difference ($X^2(1, n = 313) = 6.278$, $p = 0.012$ [69]) in the choice of CS in higher grades. Consistent with the state of research in CS education, female IMP students were less likely to select CS as a subject in higher grades ($\phi = -0.142$, $p = 0.012$). However, while female students usually drop out of CS with increasing age, 30.7% of the female IMP students in this cohort did not drop out of the CS field after IMP. Since the IMP students choose a STEM profile for 4 h per week very early on, a positive selection bias occurs. Even so, the fact that female students who choose IMP tend not to drop out at the same rate as in other subjects is an interesting trend.

On the other hand, the analysis of the performance-related expectations towards CS in higher grades showed a significant gender difference according to the Mann–Whitney U test ($U = 2758$, $p = 0.006$, $Z = -2.733$, $r = -0.186$) in favor of male IMP students. The results show that male IMP students had slightly higher performance-related expectations towards CS in higher grades. We also analyzed the influencing factors of the choice of CS in higher grades named by the IMP students in the open items, so as to provide an in-depth description of the factors influencing the educational choices according to the questionnaire. A total of 115 ($m = 86, f = 27, o = 2$) IMP students named the three most important reasons for choosing CS in higher grades. In accordance with the SEVT [18], subject and factual interest, vocational orientation, and a positive self-concept were the most commonly mentioned influencing factors for choosing CS in higher grades (Figure 3). Included in the subject interest, "programming" was also named as an influencing factor by the IMP students. The third most frequently mentioned reason was "contribution obligations". Students chose CS because they "Did not want to select other subjects in higher grades". Due to the rules regarding the profile choices for students in Baden-Württemberg, as mentioned in the Introduction, the students have to choose at least 32 h of courses per week. The contribution obligations (i.e., the obligation to choose one of the profile subjects) could also be influenced by the expectation of success [18], which could be higher in CS than in other subjects, with CS being seen as the “lesser evil” (54 Pos. 2). Another reason for choosing CS in higher grades was the relevance of the topics or the subject CS itself for the future. The IMP students also named several individual reasons for choosing CS, such as CS being a “young science” (303 Pos. 2) and “[I] had the chance through IMP, so I took it” (266 Pos. 2).

Table 3. Comparison of IMP students who chose CS in higher grades (a) and those who did not (b).

Constructs	Shapiro–Wilk Test	Levene’s Test	Mann–Whitney U Test	*n* (a, b)
Subject-specific self-concept	$p < 0.001$	$p < 0.001$	$U = 5507$, $p < 0.001$, $Z = -8.038$, $r = -0.455$	129, 183
Academic self-concept	$p < 0.001$	$p = 0.494$	$U = 5934$, $p < 0.001$, $Z = -8.071$, $r = -0.450$	133, 189
Performance-related expectations towards CS in higher grades	$p < 0.001$	$p < 0.581$	$U = 1787$, $p < 0.001$, $Z = -8.653$, $r = -0.586$	129, 89
IMP grade	$p < 0.001$	$p < 0.001$	$U = 8481$, $p < 0.001$, $Z = -5.438$, $r = -0.300$	133, 194
Intrinsic motivation	$p < 0.001$	$p = 0.466$	$U = 6038$, $p < 0.001$, $Z = -8.010$, $r = -0.445$	131, 193
Interest	$p < 0.001$	$p = 0.030$	$U = 7202$, $p < 0.001$, $Z = -6.631$, $r = -0.368$	132, 192
Subject-specific interest	$p = 0.432$	$p = 0.791$	$U = 4630$, $p < 0.001$, $Z = -8.117$, $r = -0.474$	122, 171

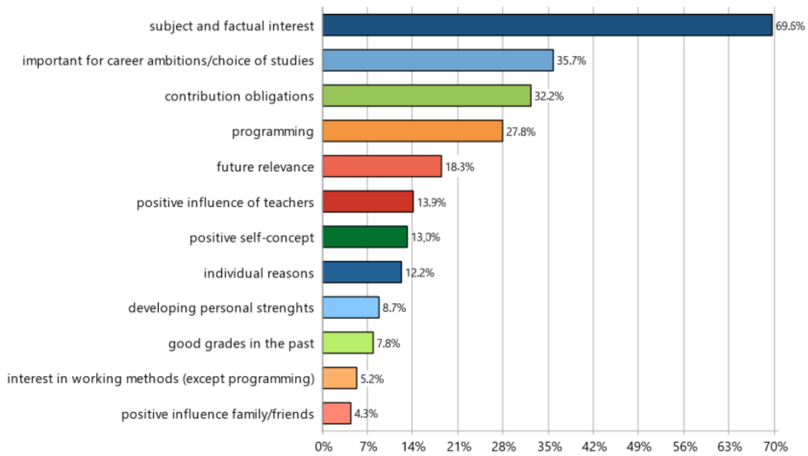

Figure 3. Motives of IMP students for selecting CS in higher grades.

According to the questionnaire, from the factors influencing the educational choices of the IMP students, two gender differences were identified, with “career prospects” being slightly more important for male IMP students in this cohort according to the Mann–Whitney U test ($U = 8164$, $p = 0.038$, $Z = -2.079$, $r = 0.118$), while “teaching” was slightly more important for female IMP students in this cohort according to the Mann–Whitney U test ($U = 8427$, $p = 0.037$, $Z = -2.086$, $r = 0.118$). For “teaching”, there was no normal distribution as assessed by the Shapiro–Wilk test ($p < 0.001$) and no homogeneity of variance according to Levene’s test ($p = 0.029$), but there was a homogeneity of variance for “career prospects” according to Levene’s test ($p = 0.148$). Therefore, it could be beneficial to examine gender differences in the choice of CS in higher grades (Figure 3). Both male and female IMP students named subject interest and factual interest as their most important reasons for choosing CS (Figure 4). Career ambitions were as important for male IMP students as they were for female IMP students in the choice of CS in higher grades ($X^2(1, n = 321) = 0.002$, $p = 0.966$). The quantitative results show that the positive influence of teachers was mentioned significantly more frequently by female IMP students; however, there were no gender differences in this respect as a reason for choosing CS in higher grades ($X^2(1, n = 321) = 0.921$, $p = 0.337$). Hence, these two gender differences in the influencing factors did not apply for the choice of CS in higher grades in the same way as they did for general educational choices. Female students did not choose CS more due to contribution obligations ($X^2(2, n = 321) = 5.148$, $p = 0.075$). There were also no gender differences in the influence of future relevance with respect to the choice of CS in higher grades ($X^2(1, n = 321) = 0.048$, $p = 0.872$).

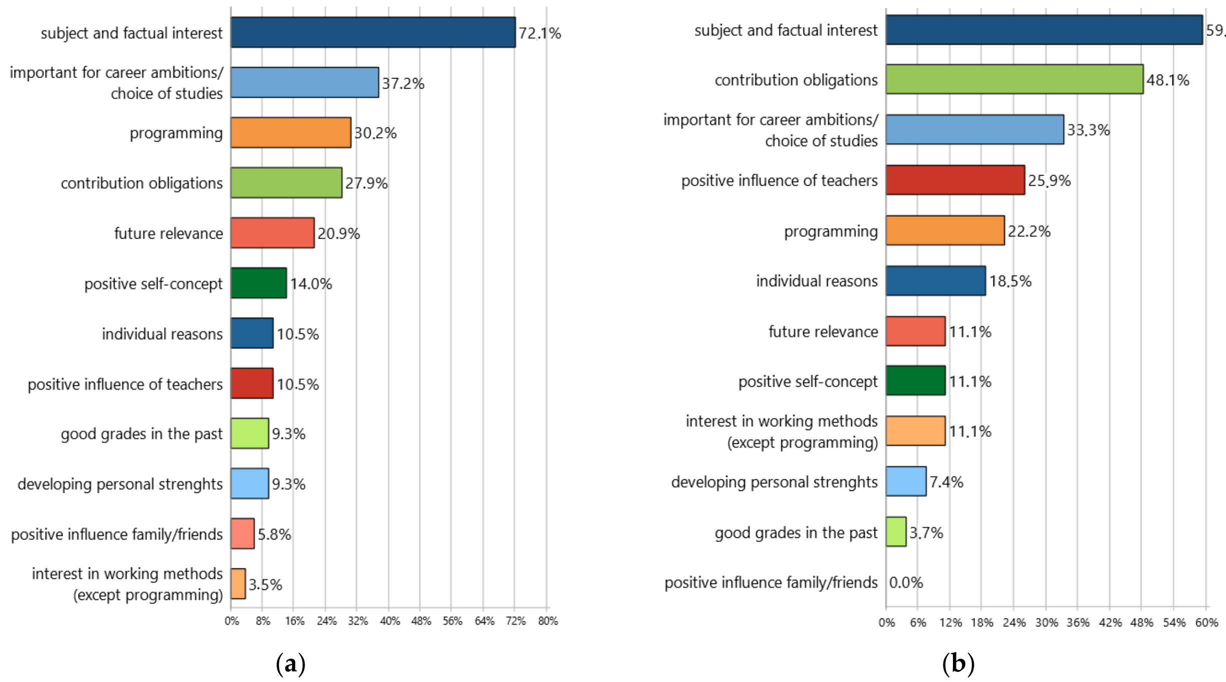

Figure 4. Motives of IMP students for selecting CS in higher grades: (**a**) male IMP students; (**b**) female IMP students.

After looking at the motives of IMP students in choosing CS in higher grades, we analyzed their deselection motives as well (Figure 4) in order to answer the question of why IMP students do not select CS in higher grades after choosing IMP. In total, 187 ($m = 123$, $f = 54$, $o = 10$) IMP students named their three most important reasons for not choosing CS in higher grades. Consistent with the state of research on the course selection motives of students [55], the students named a lack of subject interest or factual interest and a negative self-concept as their main reasons for not choosing CS in higher grades (Figure 5).

When looking at the gender differences in the students' deselection motives, it appears that there were no major differences between female and male IMP students. Only the categories "high workload/complexity of the topics" and "contribution obligations" differed in the order in which they were named by female IMP students, but there was no significant gender difference. Hence, there were no significant associations between gender and the deselection motives "high workload/complexity of the topics" ($X^2(1, n = 321) = 0.194$, $p = 0.660$) and "contribution obligations" ($X^2(2, n = 321) = 5.184$, $p = 0.075$). Individual reasons such as "Basic knowledge from IMP is enough for me" (34 Pos. 2) and "Three years are enough" (45 Pos. 2) indicate that some of the students were already satisfied with their knowledge or did not want to pursue a career in CS. Furthermore, there were gender differences in the item "pursuing a career or study in mathematics or CS" (Table 2), supporting the theory that the choice of CS in higher grades depends on the career choice.

Since female IMP students have a high interest in biology, for example, CS could also be a tool for them to later professionalize in their main field of interest. In summary, female IMP students in this cohort mainly dropped out of CS in higher grades due to their lack of interest, having already picked too many other courses, having a negative self-concept, the high workload, and the complexity of the topics associated with CS. Therefore, it could be interesting to see the paths in other STEM subjects so as to get an idea of which STEM areas the IMP students choose in higher grades and to provide a broader view of the educational choices of the IMP students in this cohort.

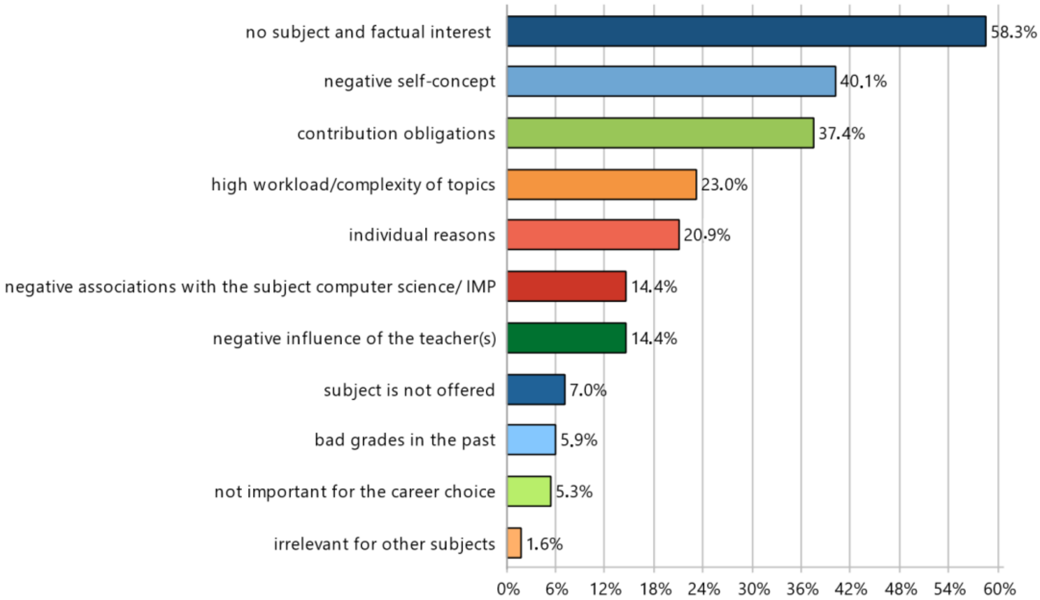

Figure 5. Motives of IMP students for dropping CS in higher grades.

3.4. *Educational Choices of IMP Students*

To answer RQ1, after taking a closer look at the gender differences in the subsections above, we summarize the data collected in this study in the following two subsections.

Figure 6 gives an overview of the educational choices of the IMP students in this cohort. Gender differences are marked with superscript 1. Male IMP students in this cohort tended to choose CS (basic and performance subjects) (Table 2) and the performance subject physics ($X^2(1, n = 317) = 6.203$, $p = 0.013$) in higher grades significantly more frequently than female students. However, there were no significant gender differences for the performance subjects of biology ($X^2(1, n = 316) = 1.478$, $p = 0.224$) and chemistry ($X^2(1, n = 316) = 0.955$, $p = 0.328$). There were no gender differences for IMP students choosing CS in higher grades in terms of vocational orientation, nor for the fields “science or engineering/technology” ($U = 1170$, $p = 0.328$, $Z = -0.978$), mathematics, or computer science ($U = 1048$, $p = 0.052$, $Z = -1.940$). Of the IMP students choosing a STEM subject other than CS, 62–85% said they could imagine pursuing a career in science or engineering/technology, with no significant gender differences for the IMP students who chose physics ($U = 561$, $p = 0.337$, $Z = -0.960$), biology ($U = 178$, $p = 0.622$, $Z = -0.494$), or chemistry ($U = 182$, $p = 0.193$, $Z = -1.302$). For the field “mathematics or computer science”, there were also no significant gender differences for the IMP students who chose physics ($U = 504$, $p = 0.127$, $Z = -1.524$), biology ($U = 195$, $p = 0.978$, $Z = -0.027$), or chemistry ($U = 213$, $p = 0.645$, $Z = -0.461$).

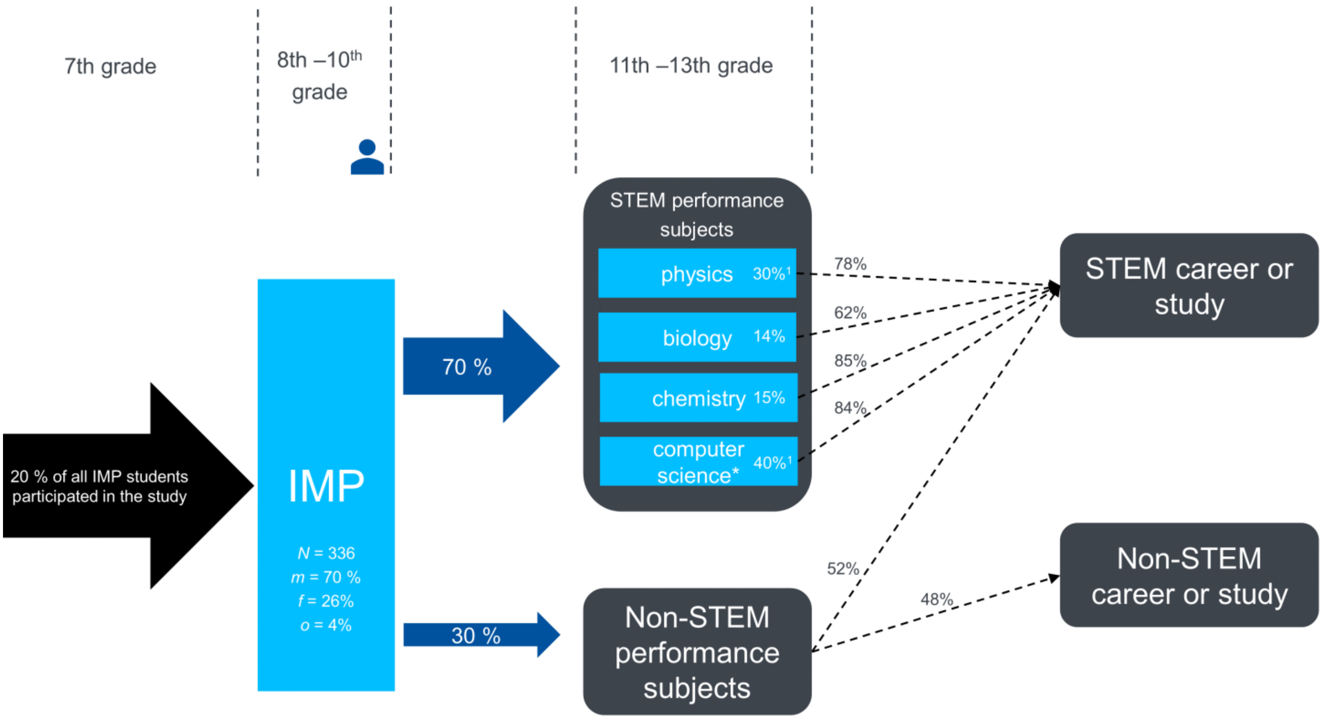

Figure 6. Educational choices of IMP students. [1] significant gender differences * computer science basic and performance subject current vocational orientation course selection of IMP students participating in the study percentage of IMP students in the 10th grade participating in the study amount of 14% IMP students choosing a subject in higher grades.

At first glance, Figure 6 might appear to suggest that the IMP students in the non-STEM performance subjects group did not choose any STEM subject. Since this is not the case, we wish to refer to the structure of the educational system in Baden-Württemberg, as mentioned in Section 1 (Figure 1). First and foremost, we did not assess whether students picked mathematics as a performance subject in this study since some schools told us after their participation that they could not yet choose the courses for the higher level; therefore, the students only stated which courses they were currently taking, and mathematics is the only STEM performance course that the students can take when they are in middle school. Due to the rules limiting the course selection—as students must choose two subjects out of German, mathematics, a foreign language, and natural science—it is likely that many IMP students chose mathematics as a performance subject because it was the subject in which they had the highest interest. In addition to the performance subjects, IMP students can also choose NwT or one of the other STEM subjects as a basic subject for 3 h per week, in which case they would not be "out" of the STEM field. This could also explain why 52% of the IMP students did not choose one of the aforementioned STEM performance subjects (Figure 6), saying that they were considering a career or education in science or engineering/technology. Only 8.5% of the IMP students chose the performance subject, CS. Due to the subject being in a pilot phase in many schools and the shortage of CS teachers in Baden-Württemberg, as well as the fact that the subject was only introduced in 2021, it is expected that not many students will choose it. Since the basic subject CS is also new and in the school pilot phase, we added CS in Figure 6 without considering it a performance subject. Another factor influencing the choice of CS was the performance-related expectations with respect to CS in higher grades (point-biserial correlation $r = 0.588$, $p < 0.001$), with male IMP students assessing themselves more highly than female IMP students in this cohort (Table 2), which could explain the gender difference in the choice of CS in higher grades. In addition, small gender differences were found in the factual interest within the areas of "implementing code", "algorithms", "requirement analysis", and "software projects". Since those areas are explored in greater depth in CS in higher grades, it is more likely that students who are not interested in these areas will not choose the subject.

The educational choices shown in Figure 6 also visualize the current metaphor of educational choices in the STEM field as a "highway" [70] rather than a "leaky pipeline", since students have the option to go in and out of the STEM field at multiple points in their lives and do not have cumulative disadvantages by dropping out of the STEM field [70].

3.5. Motivation and Interests of IMP Students

The most frequent motivational characteristics of IMP students were introjected and identified (Figure 7). Hence, the motivation of most IMP students in our cohort was mostly without any identification or external goal of their actions [29]. An exception were the IMP students who chose CS in higher grades. Considering that "contribution obligations" were mentioned by 43.9% of the IMP students as their second most important reason for choosing IMP, many of these students chose IMP because they did not like the other profile subjects, as explained by the qualitative data.

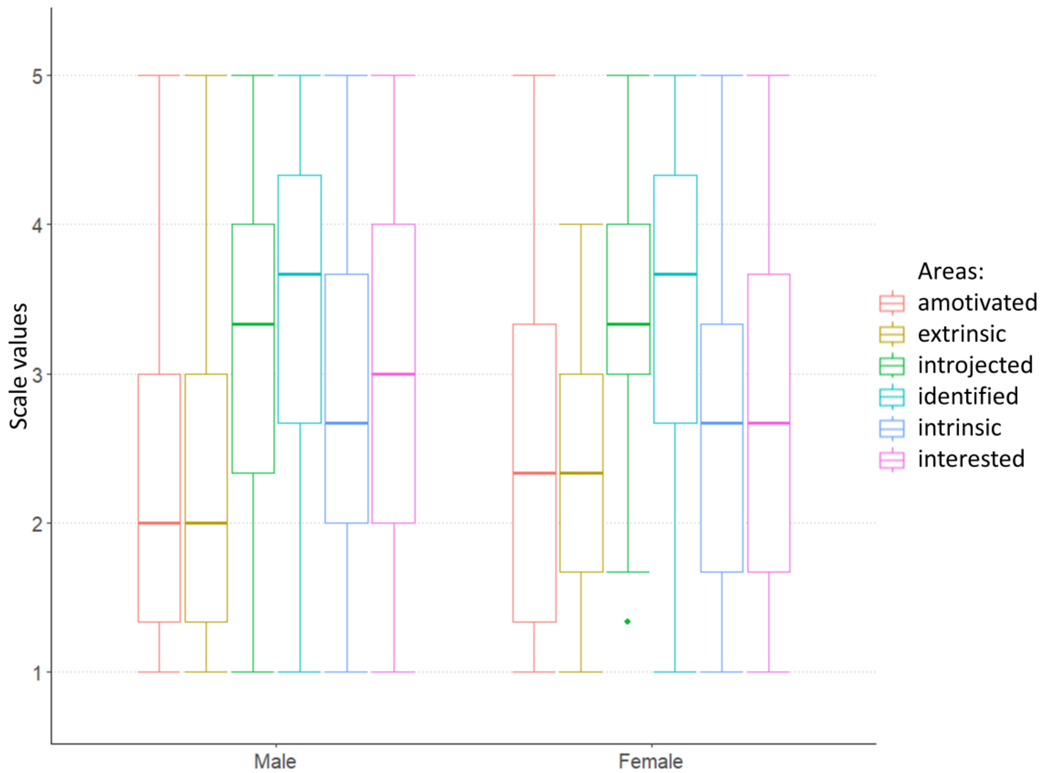

Figure 7. Motivation of IMP students.

The subject-specific interest in IMP (M = 2.37, SD = 0.67) was relatively low compared to the interest in the STEM area in general (M = 3.18, SD = 0.77). This result can be traced back to other findings since the IMP students choose various performance subjects in higher grades, with mathematics being the subject with the greatest interest among the IMP students (Table 1).

4. Discussion

Consistent with the state of research on CS education, male IMP students had a slightly higher self-concept (subject-specific, academic, and gender-specific) than female IMP students in this cohort (Table 2). Thus, even when choosing IMP and going through the profile subject for four hours per week, female IMP students—especially in the direct gender comparison to male IMP students—had a lower estimation of their own abilities.

As many literature reviews state, the lack of gender-sensitive CS [1,71–75] could explain the findings in this study.

The gender differences in the choice of CS in higher grades can be explained by the students' reasons for not choosing the subject (Figure 4). Apart from the two previously mentioned influencing factors—interest and self-concept—48% of female IMP students named the curricular requirements and elective options mentioned in Section 1 as limiting factors [16]. Thus, these IMP students did not choose CS on top of their normal schedule. Additionally, 35% named the high workload and complexity of the subject as a reason. This could be because the IMP students associate CS with a high level of effort and an accompanying high workload, as well as because of their rather minimal prior knowledge as they only study CS for one hour per week in the 7th grade. Finally, 13% of the female IMP students named their personal preferences with regard to the teachers as a reason for not choosing CS in higher grades, but without elaborating further.

In this study, we found the relative lack of gender differences interesting, as the new interdisciplinary profile subject IMP might provide an opportunity for more gender equality within the STEM area if more female students choose the subject in the future [75]. After three years, the IMP students in this cohort showed no significant gender differences in motivation (all six facets) or in their subject interests in IMP, mathematics, and the general STEM area. Additionally, 64% of the IMP students said they could imagine pursuing a degree or career in the fields of science or engineering/technology. The second most commonly named field was "mathematics or CS". With 40.7% of the IMP students continuing with CS in higher grades, 30.9% of the IMP students choosing the performance subject physics, 14% choosing the performance subject chemistry, 14% choosing the performance subject biology, and only 30% not choosing one of the aforementioned subjects, IMP could provide a new opportunity for students to choose a STEM profile early on and stick with it (Figure 6). With only 26% of the IMP students being female, there is more work to be done in advertising the subject to female students and creating a gender-sensitive environment in IMP.

4.1. Limitations

Limitations of this study include the lack of a comparison group, the sample size of 336 IMP students (20% of the possible population), and the fact that only 31 schools (31.31% of the total number of schools that have IMP as an option) participated in the survey. Due to the low participation of IMP students who categorized their gender as "other" (3.6%), we only analyzed gender differences for the male and female subgroups. This results in the limitation that not all genders are represented in this study. Since the IMP students chose a STEM profile very early on, a positive selection bias also occurs. The sampling may be a positive selection since 10 schools declined the offer to participate in the survey due to their resources, and 58 did not respond at all.

4.2. Research Desideratum

Different research desiderata exist after taking a closer look at the learning characteristics of IMP students. The use of a comparison group could be an interesting method to add information to the descriptive knowledge of the learning characteristics of IMP students and the students in secondary schools in Baden-Württemberg. Another research desideratum is to assess the subject knowledge in CS as one of the key facets of competence in order to see which factors moderate the CS competence of IMP students and add more information to the learning outcomes regarding the utilization of learning opportunities [76]. Assessing more than the choice of CS in higher grades to see how many students stick with STEM after IMP—and especially, how many female students stick with STEM after IMP—is another topic for future research. The interdisciplinary character of the subject IMP might be more interesting to girls than CS itself; whether this factor has an influence on the course selection in higher grades, and whether it has an impact on motivation and subject interest is another topic for future research. In accordance with the SEVT [18], we assessed the subject-specific interest in IMP, the subject-specific self-concept, the IMP grade, and the educational choices and their motives for choosing IMP and CS in higher grades, as well as the motives for dropping CS in higher grades, and took a look through the lens of gender to describe the current status of gender differences among the IMP students in this cohort. Another research desideratum is to use the aforementioned data for cluster analysis to further characterize the IMP students in this cohort and to better foster the enrolment of different students on the IMP course, along with a research-based recommendation for IMP teachers and school development experts to enhance the IMP classes for everyone.

5. Conclusions

In this section, implications for STEM education and—more specifically—IMP education and didactical implications are presented.

The findings of some studies on the state of research in STEM education can be implemented in the classroom. Teachers building a growth mindset and self-efficacy in STEM subjects in middle school [77] and gender-sensitive CS classes [1] are currently the most prominent recommendations. Male students also benefit from measures to increase the recruitment of female students, as shown in physics by the study of Häußler and Hoffmann [78]. Starting points to increase the attractiveness of IMP could include more woman-oriented teaching contexts or (female) teachers as role models [46–49]. The findings of this study, despite its limitations, indicate no gender differences in the motives for dropping CS in higher grades. Therefore, addressing the lack of subject interest and the negative self-concept through teachers building a growth mindset and self-efficacy in IMP could encourage female and male IMP students alike and make the selection of CS in higher grades more appealing.

Contribution obligations, as the third most significant influencing factor for not selecting CS in higher grades, could be addressed by changing the selection rules in the educational system in Baden-Württemberg. For instance, addressing the shortage of skilled professionals in CS with middle school subjects such as IMP is a first step. Students in higher grades should then be able to continue on the STEM path consistently with performance subjects beyond the natural sciences (i.e., biology, chemistry, and physics). Extending the educational rules so that the interdisciplinary subjects Naturwissenschaft und Technik (NwT) and CS are added to the cluster of what students can choose could bring more students into the STEM area or—more specifically—into CS and engineering in higher grades.

Another area that can be addressed is the subject interest of IMP students and the interdisciplinary content. Since the subject with the third highest interest among female IMP students is biology, followed by chemistry in fourth place, while physics and computer science lag behind, more interdisciplinary STEM topics—such as bioengineering, environmental engineering, and interdisciplinary topics between chemistry and CS—could be integrated into the IMP class to better address the interests of female IMP students. Considering that the fourth most frequently named deselection motive was high workload and the complexity of the topics (Figure 5), the already full schedule should not be further expanded but rather refined. The subject was only selectable in 99 out of the 457 Gymnasien in Baden-Württemberg, and in those 99 Gymnasien, students could choose at least between two and sometimes four profile subjects. Due to the shortage of CS teachers in Germany, IMP is not yet implemented throughout Baden-Württemberg. The aforementioned suggestions can be implemented in the process of expanding the subject throughout Baden-Württemberg.

To conclude, this study provides a first description of the learning characteristics of IMP students and the gender differences among them in the Baden-Württemberg context. The initial trends show no gender differences in the motivation, subject interest in IMP, or interest in the STEM area except in the choice of the performance subjects, physics and CS, and no gender differences in the vocational orientation in the fields of natural science and engineering/technology, in contrast to the state of research in other STEM subjects. The new interdisciplinary profile subject IMP, with a higher participation of female students, could be a first step in getting more people—and probably more female students—into STEM.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci13050478/s1, Document S1: Questionaire of the study; Document S2: Category system.

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Data Availability Statement: Because the data used in this study are currently being analyzed as part of a doctoral thesis, the dataset will be available from the corresponding author upon request after the completion of the dissertation.

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