Ready for Computing Science? A Closer Look at Personality, Interests and Self-Concept of Girls and Boys at Secondary Level

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Abstract. Among school children, the interest in dealing with computing science varies between different age groups and countries, but it can be observed that it tends to decline among young women, and it is mostly men who gain a foothold in this domain. Various programs and activities are meant to increase the interest of all our children, but measurement instruments to collect baseline data and interpret effects of (classroom) interventions are rare.

In this work, we present a framework that allows us for collecting measures (personality traits, interests, and self-concept) from different age groups, and we use it to take a closer look at girls and boys at lower secondary school level. We report on measurable similarities as well as differences and, in the context of our own teaching interventions, we come up with first recommendations and suggestions in order to encourage secondary school teachers and curriculum developers to also address the needs and interests of girls and boys.

Keywords: Gender Issues · Secondary Education · Personality · General Interests · Self-concept · Computing Science

1 Introduction

One of the greatest challenges facing society today is to instill in children and young people an interest in computing science as a skill of the 21st century. Even though starting ages and also the content differs between individual countries [18], computing science (thereinafter we are also using the term informatics instead) has found its way into the different curricula. Clearly, computing science does not appeal to everyone equally, and so many additional support programs were launched [7, 15, 20, 13, 25].

In Austria, among many others, there are now environments like PocketCode [21] in place, free MOOCs teaching computing science and digital literacy [11], but also implementations of CoderDojo or CodeClub [2], and in the field of computational thinking and computing science the Bebras (Beaver) competition [9] attracts more and more young pupils. In Klagenfurt, we are running the "Informatikwerkstatt" (German for "Informatics-Lab" [22]) and, working together with teachers from primary and secondary education, it has attracted more than 13.500 visitors at the Institute for Informatics-Didactics since 2015.

But, a look in the direction of industry or tertiary education makes one rethink. There, you clearly see that, comparable to the situation at the end of the 1990s [12], on the one hand not enough young people have become enthusiastic about a computer science career, and on the other hand, the proportion of young women is still significantly lower compared to young men – a situation that became known as the gender-gap.

The objective of this paper is now to report on a baseline of traits that can inform and steer future research in computing science education at the lower secondary level. Related work (see Section 2) shows that interests and personality do influence the attitude towards computing science, and so we are interested in learning more about the pupils attending our Informatics-Lab and how to cope with gender issues. The analysis for more than 650 pupils attending our workshops was supported by a data collection framework (called KAUA, see Section 3), and the first findings are presented in this work.

The rest of this paper is structured as follows. Section 2 briefly summarizes literature related to personality, interests and self-concept. Section 3 introduces our data collection framework, Section 4 reports on the collected data for pupils aged 10 to 14 years, Section 5 reflects on the data found and derives initial recommendations. Finally, Section 6 concludes with the most important findings and future work.

2 Related Work

As mentioned above, it is well known that women are under-represented in many fields of STEM, but the percentage of women differs in the fields, e.g. women are not under-represented in biological sciences as they are in computer science. A cross-study paper of Cheryan et al. [8] found different potential factors that may result in these differences. They mention, inter alia, stereotypes of STEM fields, lack of role models, insufficient early experience in the field, as well as math ability, math performance and self-efficiency. Their paper also shows that most studies only evaluate one STEM field but lack a cross-study comparison which could give more insight on the influencing factors.

Stout et al. [24] show that female university students can be influenced by role models (like female professors). It increases their self-concept, attitudes and future career ideas.

A study on freshman undergraduate students chose personality, motivation, self-regulation, self-concept, self-estimates of ability as factors to survey on. It showed that men and women show different profiles on these criteria: A decisive factor for women leaving STEM majors are lower scores in Math and Science self-concept. So it can be a factor to predict STEM persistence [1].

Gender differences have been well reported [19, 10, 4], with respect to the RIASEC (Realistic - Investigative - Artistic - Social - Enterprising - Conventional) interests: Women show higher mean scores in the dimensions Artistic and Social. Men show higher mean scores in the Realistic dimension (independently from their background).

A study [10] on school students (n = 247, age cohort 12-19 years) shows also that students with high scores in self-concepts (verbal and mathematics) as well as students with higher interest in the subject Math show higher interests in all dimensions of the RIASEC model.

A study [4] in middle school students (n = 627, age 13) shows that boys have more interest in STEM occupation and activities (this is also confirmed by the participants in our Informatics-Lab) — with the highest difference to girls in technology and engineering. All correlations between RIASEC interests and STEM interest were observed as being positive but highest in Investigative, showing similarities between boys and girls. It can also be seen that the students differ in their interests in science technology, engineering, and mathematics. They do not see these fields uniformly.

A study [23] on high school students (n = 3023), tracked 10 years after graduating school, observed RIASEC interests and personality traits. It shows that the interests can predict many life outcome factors of work, health, and relationship. It does not show a significant difference by gender on influence of these measures in the life outcomes concerning work and health. It shows that specific interests at school can predict later working life and success, which makes them particularly interesting for further research and justifies the research in terms of a possible influence on students' interests.

The characteristics that benefit life outcomes are similar for female and male students. But, the characteristics differ between the gender cohorts. This makes a more detailed observation of these characteristics (and the evaluation of possible interventions to influence these factor) important for progress in educational processes.

3 Data Collection Framework

In 2016, we intensified our efforts to improve our teaching in Klagenfurt but also at our partner University in Košice. We also looked for ways to measure the sustainability of our classroom interventions. As our school systems differ, but as we also wanted to learn more about the characteristics of our pupils and (future) students, we implemented a framework called KAUA, which is an online survey system that supports anonymous, longitudinal studies.

From the very beginning, KAUA was designed with the General Data Protection Regulation of the European Union[1] in mind, guaranteeing that personal data is not stored while still being able to allow for tracing changes in participants' characteristics. To enable this, a KAUA survey works as follows:

[1] http://data.europa.eu/eli/reg/2016/679/2016-05-04

1. In a first step participants supply personal information (name, birthday) and answer a security question (where the answer is likely stable over lifetime) from a list compiled by us. This personal information is then used as input to compute a SHA-512 hash that identifies the participant. With this setup, participants are anonymous, but will generate the same hash in longitudinal study designs.
2. In the second step, participants are authorized with their hash and complete the survey. The survey results are only linked to the anonymous hash.

KAUA was already used in a small-scale study to investigate the personality, self-concept, and general interests of pupils participating in informatics competitions (Bebras, Coding Contests) in Austria [3]. Since then, the survey has been expanded, additionally eliciting specific interest in computing science and study interests, and it has been adapted to be also usable by children. In its current version, it takes about 20 minutes to register and fill out a KAUA survey.

Table 1 provides an overview of the dimensions, the individual traits and corresponding scales collected by KAUA. The items for *I1) General Interests* follow the six dimensions of interests (RIASEC) established by Holland [14] and formulated by Bergmann and Eder [6]. The items for *I2) Personality* cover two dimensions (Dominant / Easygoing, Formal / Informal) of the Five-Factor and Stress Theory [17, 27]. The items for *I3) Self-Concept* are formulations used in the PISA surveys [16] that elicit the verbal and mathematical self-concept with three items each. The item for *I4) CS Interest* is formulated by us and elicits interest in computing science specifically. The items for *I5) Study Interests* are formulated by us and are presented as check boxes of fields of study the participants might be interested in (now or in the future).

4 Traits of Lower Secondary Pupils

4.1 Methodology

In this publication, we describe differences in traits of lower secondary school pupils, aged 10 to 14, with regard to their personality, self-concept and interests. Our goal is to report on a baseline of traits, which can inform and steer future research - for example the design of classroom interventions to mitigate gender gaps. In a two-year span, we used the data collection framework KAUA to collect 676 survey responses (303 girls and 373 boys) from pupils attending computer science workshops at our Informatics-Lab. The pupils were from regional schools without any focus on computer science - their class teachers voluntarily decided to attend our workshops with their classes. The survey was conducted before each workshop. To better gauge differences in traits, we divide the cohorts by gender (female and male) and by age (5 groups from 10 to 14 years). For the mentioned traits, we investigate intra-gender progression (how the traits change with the pupils' age) and inter-gender differences (conditional to the pupils' age). The sizes of the different cohorts and age groups $\{10y/o, 11y/o, 12y/o, 13y/o, 14y/o\}$ are distributed as follows: n_{Female}=$\{15, 75, 106, 69, 38\}$, n_{Male} =$\{11, 53, 110, 130, 69\}$.

Table 1: Dimensions and items collected by the KAUA framework.

Dimension	***Items***	***Scale***
***I1) General Interests** [14, 6]*	Realistic, Investigative, Artistic, Social, Enterprising, Conventional	9-level Likert [-4; 4]
I2) Personality [27, 17]	Dominant / Easygoing, Formal / Informal	13-level Likert [-6; 6]
I3) Self-Concept [16]	3x Verbal Self-Concept, 3x Mathematical Self-Concept	4-level [1; 4]
I4) CS Interest	Computing Science Interest	6-level [1; 6]
I5) Special Interests	History, Art, Music, Literature, Language, Economy, Law, Social fields, Health, Natural sciences, Informatics, Math, Engineering, None	yes / no [0; 1]

4.2 General Interests

In the study of Bollin et al. [3] it turned out that pupils interested in computing science seem to be more interested in the investigative and artistic area, and, with the exception of the social dimension, they are more interested in all the other fields of interest. Figure 1 depicts the responses of interests of our cohorts and dimensions and shows relevant differences. Interests change and slightly decrease over time, but two features stand out. First, according to the realistic (a,b) and artistic (e, f) interests there is a notable difference between boys and girls. Secondly, while the interest in the social domain decreases for boys (h), it stays, with some exceptions, stable at a quite high level for girls (g).

4.3 Personality

Personality plays an important role when working together in teams [17], and pupils interested in Computing Science tend to be (significant) more easy-going compared to control-groups and not so formal as expected [3]. Figures 2 (a) and (c) depict the differences between the two cohorts and show that girls are "moving" from dominant to easy-going, whereas boys are "moving" the other way round. Concerning formal/informal, both cohorts tend to be slightly more formal than informal. But, it is interesting to see that the age of 12 years seems to be a point where the personality tilts over for both, boys and girls.

4.4 Self-Concept

The mathematical and verbal self-concept plays an important role when deciding for (or staying in) a STEM field. Figure 3 shows the answers to the questions "How well do you rate yourself in German?" and "How well do you rate yourself in mathematics?". There are no statistically significant differences between girls and boys; girls start at a slightly worse level (in our grading system 1 is the best grade) but are then overtaking the boys. In all the cases, the mathematical self-concept is better than the verbal self-concept, but both, verbal and mathematical self-concept are getting worse by nearly one grade over the time.

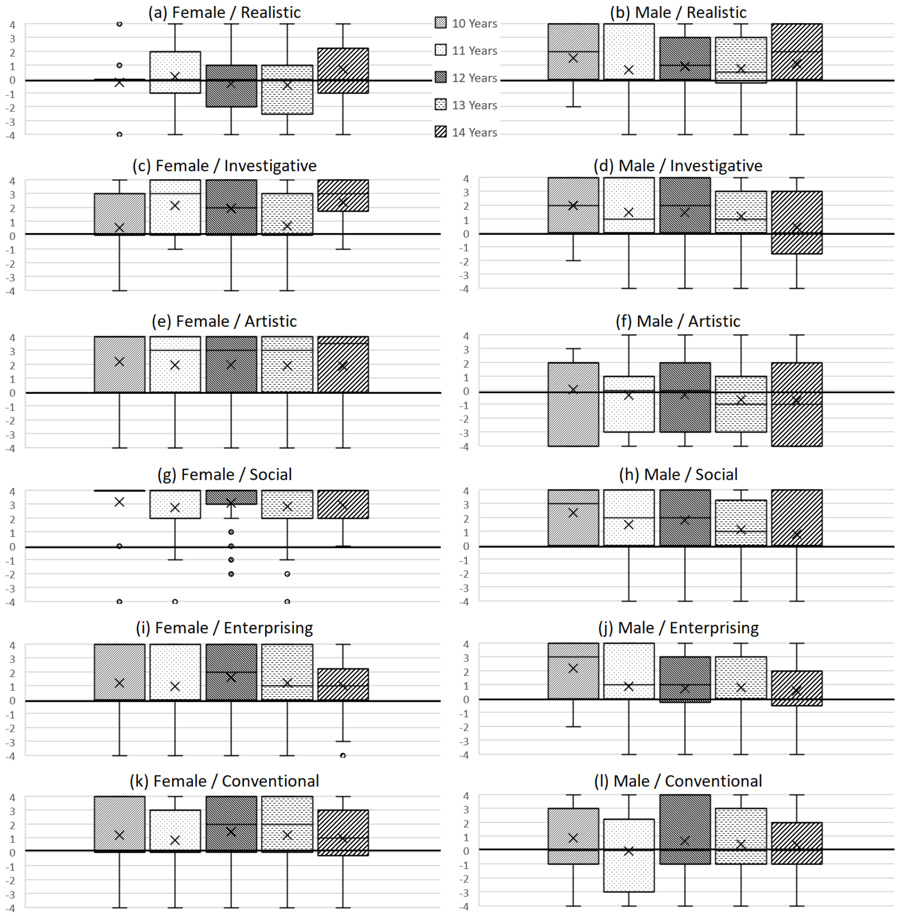

Fig. 1: Interests for female and male pupils. Values range [-4 .. not at all interested up to 4 .. very interested].

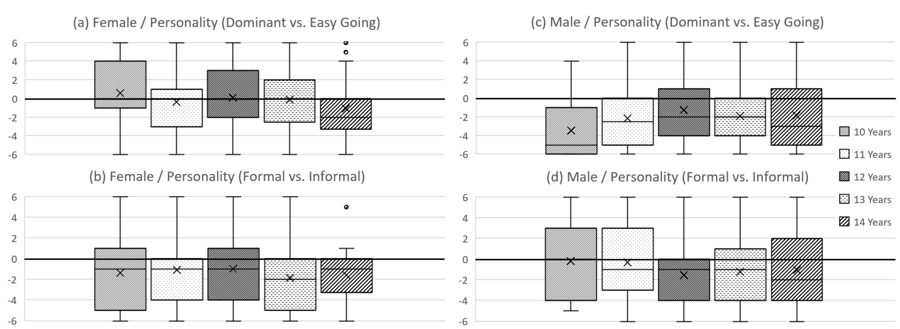

Fig. 2: Personality traits for male/female pupils. Scales in (a) and (c) are Dominant [-6] up to Easy-Going [6], (b) and (d) are Formal [-6] up to Informal [6].

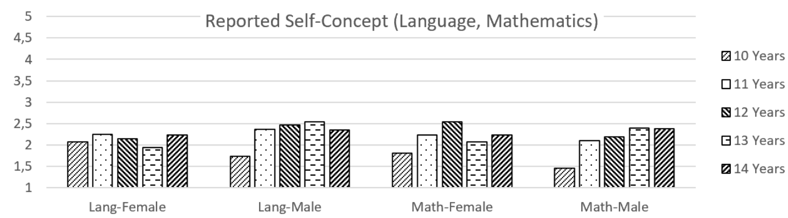

Fig. 3: Mean of reported grades (1 .. very good up to 5 .. insufficient) in language skills and mathematics for female and male pupils. Numbers and standard deviation are $(n_{Female}, \sigma_{lang}, \sigma_{math})$={(10y/o, 1.03, 0.94), (11y/o, 0.93, 0.93), (12y/o, 0.81, 0.89), (13y/o, 0.83, 1.00), (14y/o, 0.71, 0.81)}, and $(n_{Male}, \sigma_{lang}, \sigma_{math})$={(10y/o, 0.64, 0.68), (11y/o, 0.92, 1.09), (12y/o, 0.93, 1.05), (13y/o, 0.90, 1.03), (14y/o, 0.87, 1.05)})

4.5 Interest in Computing Science and Special Interests

Figure 4 summarizes the differences in the interest in computing science between the two cohort of girls and boys. Whereas the interest of boys is quite stable across the different age groups, it declines a bit for girls. With the exception of age 10, the interest of boys is always higher than that of girls.

In addition to the RIASEC dimensions and the question about the interest in computing science, we also asked for additional fields of interests. Figure 5 shows the percentages of boys and girls who voted for one or more items. On the first sight, girls seem to be interested a bit more in art, music, literature, language, social sciences, health and nature, and boys are more interested in informatics, mathematics and the engineering domain. However, it is noticeable that for girls, with the exception of art and language, the interest is growing by time, whereas with the exception of history, economy and informatics the interest decreases for boys in general. It also shows that, when not asking for computing science (Informatics) directly, interest of girls is still there, but just at a lower percentage as for boys.

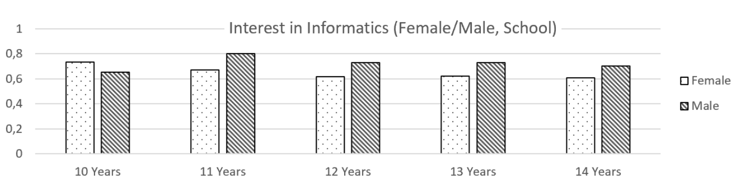

Fig. 4: Reported interest in computing science. Scale between [0 .. not interested to 1 .. very interested]. Numbers and standard deviation are: (n_{Female}, σ)={(10y/o, 0.26), (11y/o, 0.23), (12y/o, 0.28), (13y/o, 0.26), (14/yo, 0.27)} and (n_{Male}, σ) ={(10y/o, 0.36), (11y/o, 0.22), (11y/o, 0.26), (13y/o, 0.25), (14y/o, 0.30)}

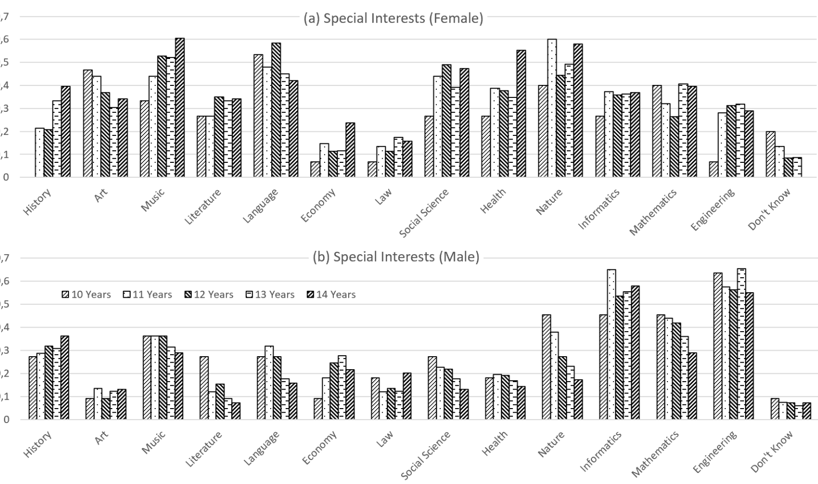

Fig. 5: Percentage of items reported for special interests for (a) female and (b) male pupils. n_{Female}={15, 75, 106, 69, 38}, n_{Male} n={11, 53, 110, 130, 69})

5 Discussion

When pondering over the results of this study, one has to be careful as there are quite some threats to validity. Among them is the currently small size of the cohort of the 10-year-old pupils (26 in total). As at the current stage we are using descriptive analysis only, we decided to include them in the description to cover the full secondary I level. The good news is that, apart from the realistic and social RIASEC score and the interest in history, the results do not contradict findings in literature, e.g. higher results for Artistic and Social dimensions for girls [4].

Another issue is that the results form some kind of baseline for pupils in our region. It therefore cannot (and will not) be easily generalizable for other locations. On the other hand, the results are along with results of existing studies (which is valuable) and this also confirms the applicability of the KAUA survey to some extent.

One should also note that the ”development over time” of interests, self-concept or personality is not the ”development” of a single child - it is really just a baseline that is meant to be the starting point. Investigative, Artistic, Enterprising and Conventional are reported to be more stable over time [26]. As we are continuing to collect this data, by time we will be able to trace these measures back to an individual Level and can compare them to results in literature.

Additionally, there might have been problems with the honesty in filling out the questionnaire, but we had trained student assistants and the classroom teachers taking care of filling out the online survey and also explaining the importance of it. There might also be a bias in the interests and attitudes that we were not able to control as the teachers decided to make use of the offer of our Informatics-Lab by their own.

Apart from the above-mentioned threats, the results do have implications on the program that we offer at our Informatics-Lab. The overall assumption is that, according to the findings in literature and in order to achieve a lasting interest in computing science, self-concept, interests and personality should be considered when teaching. The most important recommendations, stemming from our observations above, are summarized hereinafter.

One insight is related to the fact that general interests (Figure 1) are in a state of constant flow and can be influenced. Attractive materials and classroom interventions (appropriate to the current living environment) should stimulate realistic interests for girls and artistic interests for boys, and the investigative domain should always be included. This should reduce the gap reported in interests [19, 10, 4] as well as support interest that are important for the study interests.

Concerning personality development (Figure 2), it is noticeable that especially girls tend to get less easy-going the older they are. Taking care of it and also reflecting on it when enacting teamwork in the classroom might be helpful. Apart of this, there are training tools like PlayBenno[2] that help developing personality.

Now let's not dwell on the regularly poor results of the Austrian school leaving exams in mathematics and German, but it is astonishing that the verbal and mathematical self-concept (Figure 3) are at a really low level. We thus already started to include (and updated) interdisciplinary materials in our Informatics-Lab to train these skills but also to strengthen the pupils' self-confidence in these fields. Working together with teachers from other subjects also seems to be very beneficial here. These can be a factor to predict STEM persistence [1], especially for girls.

Concerning the interest in computing science in general (Figure 4) and special interests (Figure 5) it means that our teaching needs to be highly attractive to the learning brain [5]. Arousing a wide interest is one thing and can be done by working together in an interdisciplinary manner, but when e.g. the interest in music or languages is rising (as with girls), it is advisable to also touch these topics in ones' own classes. We already included such materials in our lab and a teacher education student is currently working on the relation between crocheting and computing science.

6 Conclusion

In order to make a maximum out of classroom interventions, every teacher should respond appropriately to the needs of her or his pupils. When trying to motivate

[2] https://inventures.eu/game-with-a-mission-wins-innovation-award/4539/

for computing science, personality, interests, the verbal and mathematical self-concept and the gender gap do play an important role, but all too often these aspects are not looked at closer.

In this paper we thus introduce a framework called KAUA that allows for collecting such measures from different age groups with just a small time-overhead (about 20 minutes) in the classroom setting. We then take a closer look at 676 girls and boys at the lower secondary school level and report on measurable similarities as well as differences.

In the context of our own teaching interventions, we then try to come up with recommendations and suggestions. Even though the results might not be generalizable to other locations, the work demonstrates that with not much effort, (secondary school) teachers are able to learn more about their pupils and might thus be able to support the interests of girls and boys in computing science appropriately.

The work presented here is ongoing work and in the winter term 2020 we will be able to roll out the survey more widely, reaching about several thousand pupils in Austria. For the next couple of years, we also plan to collect more data from University students (of different fields), and as we changed the rhythm of collecting the feedback from returning visitors we will soon be able to analyze changes in the scores on an individual level.

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