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Are my technology lessons for girls? The Gender Sensitive Education Checklist (GSEC) for teaching Science and Technology.

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Abstract

In times of shortages in STEM professions, the untapped potential of girls with a STEM talent is a waste on a personal, social and economic level. Childhood is believed to be a very important formative stage in which children develop an early interest in specific occupations and teachers can have an important influence by developing lessons in such a way that girls are getting motivated for technology and/or science. This paper describes an educational design research study, in which we developed a checklist for teachers to screen the gender sensitivity of their STEM lessons and materials. The checklist contains 20 different questions categorised in four main pillars, namely: the fundamental critical attitude, the image of technology, guidance & interactions and didactical methods. Overall, the Gender-Sensitive Education Checklist (GSEC) can be used to tick what is already going well, ensure these roots can anchor strongly and focus on what teachers can do next to act in a more gender sensitive way. Preliminary evaluative findings suggest that the GSEC could potentially be an inspiring tool for teachers to continuously rethink their STEM lessons and materials. Further research is needed to test the effectiveness of the GSEC.

Keyword

Teaching, Gender-sensitivity, Girls, STEM, Checklist, equity

Introduction

> *"But that's not for girls, is it!?" Sam (8y) shouts as he pushes Dunia aside to operate the drone.*

Two problems at the base

Although girls are equally talented in STEM (science, technology, engineering, mathematics), they are noticeably less likely than boys to choose a field of study in which (one of the components of) STEM is a cornerstone (e.g. Blickenstaff, 2005; Ceci & Williams, 2010; Eddy & Brownell, 2016). By the age of twelve, girls show less positive attitudes towards a future in STEM than boys (Denessen, et al., 2015). This untapped potential talent is a waste on a personal, social and economic level (van den Hurk et al., 2019). It is unfortunate that children choose a course of study based on gender expectations and/or norms instead of skills, ambition and personal preferences. The consequences of these imposed choices is that a lot of female and diverse talent is missed. Certainly, in times of shortages in STEM professions, a society cannot afford to neglect professional talent, while a more gender balanced playing field will undoubtedly also lead to a more personal fulfilment on the girls' behalf.

Childhood (age 6 to 12) is believed to be a very important formative stage in which children develop an early interest in specific occupations and in which they increasingly differentiate between occupations and activities they like or dislike (Gottfredson, 1981, 2005). For example, a study by Trice and McClellan (1993) found that as many as a quarter of adults aged 40-55 years surveyed recalled deciding to pursue their current profession as a child.

With this information in mind, another problem arises. Although overt practices of discrimination may no longer be as prevalent as they were in the past, covert and more subtle, often unintentional forms of gender bias and sexism still exist and occur throughout life undoubtedly shaping male/female career choices (Wang & Degol, 2016; So et al, 2020; Ardies et al, 2021). Teachers often work from a so called 'gender-blind' position, meaning they believe they do not take students' gender into account when teaching (Garrahy, 2001). Yet, we know that implicit biases not only shape our thoughts, but also the way teachers set expectations, teach and evaluate their students (Newall et al, 2018; Consuegra, et al., 2016). Teachers must become aware of these implicit biases and ideas, as they do influence their interactions with students. In a study by Newall and colleagues (2018), teachers in a blind test, for example rated 8-year-old girls less academically capable than 8-year-old boys in physical sciences. The adults overall believed that girls were less interested in science and were less likely to enjoy it. This echoes earlier findings from Tiedemann (2000), who found that teachers believe girls benefited less from extra effort in mathematics and believe that mathematics is more difficult for girls than for boys. Such pre-formed beliefs (or biases) about children's abilities and interests are not innocent but have important implications for education. For example, teachers can give less scientific information if they think they are teaching a girl (Newall et al., 2018). Or if teachers believe, implicitly or not that girls have lower ambitions for STEM-oriented education, they can encourage them less, make girls feel that they do not belong or that they are not competent. (Eddy & Brownell, 2016; Wang & Degol, 2013). Furthermore, research shows that the more a teacher believes in the stereotype that mathematics is a male domain, the more strongly their students start to believe this stereotype (Eccles & Wigfield, 2002, Keller, 2010). We have no reason to believe that this would be any different for the education of technology.
Although teachers have a great influence in confirming gender biases and stereotypes, they also have the potential to be important agents in tackling these ideas (Gunderson, et al., 2012).

Our long-term goal therefore is to support teachers in developing lessons and workshops for pupils in such a way that girls are motivated to deliberately choose to continue to follow in a field of study where technology and/or science occupy a prominent place. Therefore, we wanted to develop a checklist that can help teachers to be aware of their gender-sensitive attitudes and behaviour and how to change their behaviour in favour of more equity in technology and science education.

Methodology

Designing a tool for teachers: educational design research as a means for supporting gender sensitivity in the classroom.

Educational design research (EDR), evolved from design-based research, is an iterative approach to designing, implementing, evaluating, and improving educational interventions (Marej, 2021; McKenney and Reeves, 2018). EDR is both a pragmatic and supportive research design for small teaching and learning projects that can inform and make a difference to both students and staff, and subsequently qualitatively evaluates the change (Jetnikoff, 2015). This methodological approach utilizes collaborative partnerships between researchers and practitioners and mixed methods in the design of programs, curricula, and interventions in real-life contexts like the classroom (Barab and Kirshner, 2001). Educational design research has proved to be an effective approach for research projects focused on the design and evaluation processes of instructor training programs and initiatives (Dede et al, 2009).

The study described in this paper utilizes the EDR model (fig.1) of McKenney and Reeves (2018) to develop a practical tool with the means of creating or deepening gender sensitivity among technology teachers to achieve gender equity in the study choices of their pupils.

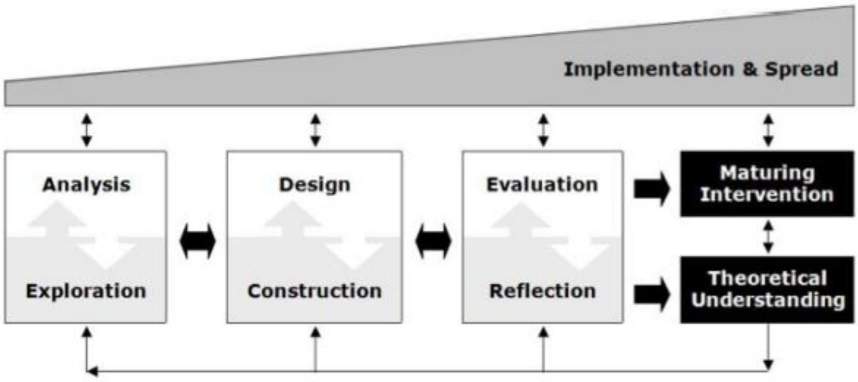

Figure 1: Generic model for conducting educational design research.

In every phase we focused on interventions and strategies that benefit all students and do not exclude anyone (male, female, non-binary). For example, we did not include interventions in the checklist that have a positive influence on the participation of girls at the expense of boys. After all, we advocate for messages and activities that clarify that the STEM field is diverse, inclusive and can present an intellectual challenge for a wide range of people (Diekman et al., 2018).

The **first phase (analysis and exploration)** consisted of a thorough literature review on both explicit and implicit barriers that girls and women experience when (not) choosing for a study or career in technology and proven opportunities to overcome these barriers. We also looked at and screened existing supporting materials, such as checklists or toolkits to support gender-sensitive teaching, such as the checklist of the institute of physics (2019) and the guide for gender sensitive learning materials (Van Tieghem, s.d.). This resulted in the main principles and the overall structure of the checklist.

In addition to literature research, we gained insight into current challenges and good practices regarding gender-sensitive STEM workshops in the Flemish context through both surveys and desk research. During the desk research, we took a critical and constructive look at existing lesson plans from the Technology and Science Academy, which is an organization that provides science and technology workshops for children from the age of 6 to 16. We took a multi-stakeholder perspective by investigating, in collaboration with Finnish and Belgian experts and teachers, how we can (re)design existing technology lessons and workshops to attract girls. Subsequently, the focus was deepened on technology workshops for students aged 10 and up.

In **the second phase (design and construction)**, we developed a first version of the checklist based on insights from the previous phase. We translated the big ideas from the in-depth literature research of the first phase to key points and questions on which teachers could score themselves. This was carried out by the researchers and double-checked by experts.

In support of this checklist, we also developed an introductory workshop for teachers to provide more profound and sustainable support to use the checklist. The development of this workshop started from the work of Merchie et al. (2016) to assure ourselves of effective elements, such as a context-bound approach and attention to reflection and practice in practice. Inspired by Van Thienen (2013), in our workshop, we made use of appreciative inquiry. In this strengths-based approach to individual and organizational change, participants arrive at concrete and individual plans and steps, based on a description and reflection of reality (one's current workshop or teaching practice) and by projecting a dreamed future (gender-sensitive STEM activities).

During and after the design phase, we went through **the third phase** of **evaluation and reflection**, with a strong focus on implementation in practice. First, we followed several evaluation cycles by conducting walk-throughs of the design with both the Finnish and the Belgian partners. Second, we ran three small pilots of the introductory workshop, once with four student-teachers who voluntary organised and guided extracurricular STEM-activities for young pupils, once with three students who design STEM activities in the context of their bachelor theses, and once with seven STEM-teachers from a secondary school. Based on their feedback, we finalized the first version of the workshop and the checklist.

Three weeks after the initial workshops, we observed a STEM-activity organised and guided by these participating students to see what did or did not seem to 'stick'. We held a follow up focus group with these students about the perceived effect of and feedback on the workshop and checklist. We conducted a similar in-depth focus conversation with the other participating student-teachers, four weeks after attending the workshop. In these interviews and focus groups the focus was on the experience and efficacy.

Subsequently, we focused on a broad implementation in the educational field and organized three workshops that were promoted through the most popular Flemish teachers magazine (Klasse.be) and newsletters of the partner organisations. Participating was free. During this phase, we refined the workshop and checklist based upon various feedback rounds. Participants in the offered workshops were 58 teachers, teacher-students, counsellors, teacher educators, and technology-experts. After each workshop, the participants were asked to give feedback through a survey about the content, organization and user-friendliness of both the workshop and the checklist, to redesign and optimize the workshop and checklist. This survey consisted of both questions based on a Likert scale as well as open-ended questions.

As a result of the feedback, we added more concrete examples to the workshop and created opportunities to look at our learning materials and teaching behaviour. In addition, we made the introductory workshop longer in duration so that we could discuss those aspects more extensively during the workshop.

Matters that have been adjusted throughout these various cycles, include:

- Using clear language in the statements,
- Eliminating double negative statements,
- Adding a few statements, partly based on other research or other instruments
- Dividing the checklist into one concise and one comprehensive format,
- Add a short guide and mark "yes" and "no" instead of "true" or "wrong" with each statement
- Adding real-life examples and cases

Although we cannot generalize the results due to the limited size of the study, they served their purpose in the study design. After all, participants indicated that they *felt* more aware of the gender-sensitive supervision of STEM activities by using the checklist and after following the workshop, by making sure that they portray women in their teaching materials, pay attention to language use, and so on. Further thorough, systematic evaluation and analysis is needed to follow up on the effectiveness of the GSEC-tool in the field.

Based upon their feedback, this educational design research resulted in a checklist and accompanying workshop which will be described below.

Content of the checklist and workshop: four main principles

The thematic literature review in phase 1 was summarized in four main pillars, that in our opinion, include all the practical and empirically based suggestions.

The starting point is always the teachers' self-reflection to map out their strengths, mindset, and blind spots around gender-sensitive teaching. In this way, we develop a checklist that starts from a solid basis or ground condition, namely self-reflection by the teacher or counsellor about the implicit ideas and (general existing) prejudices about gender in STEM. On this basis of awareness, we further provide more suggestions based on literature. Because this checklist serves as a reflection tool, teachers can mark on a non-numeric scale the extent to which they believe they agree with a statement or question. In this way, we emphasize the possibility of growth within gender-sensitive teaching, rather than see it as a measurable, quantitative subject.

The developed workshop is constructed based on the four principles of the checklist. Optimal conditions for the workshop seem to be a duration of at least 120 minutes in groups of maximum 20 people to ensure sufficient interaction. The workshop starts with enhancing of the sense of urgency of this topic and presents theoretical insights, coming from previous research and evidence. We alternate these facts and figures with interactive exercises which support the transfer to teachers' own practices, such as a screening of their own learning materials in view of gender representation. Ideally, this workshop is given in real life, to optimise the chances for interaction and watch non-verbal cues from participants. Furthermore, the participants are actively engaged in reflection by immediately using the GSEC and thereby linking new insights to own ideas and classroom practices.

Fundamental critical attitude

Since knowledge and awareness of existing interaction patterns with students is the first step in changing and improving the interaction, a gender-aware basic attitude is indispensable. Teachers needs to be aware of the possible influences of gender (Consuegra et al., 2013) before we can take further steps in the design process of a gender-aware technology lesson that gives girls equal opportunities. Canning et al. (2019) argue for example that beliefs of the instructor about the nature of intelligence can likely shape the way they structure their course, their communication with students, and the encouragement or discouragement of students' persistence.

We, therefore, invite teachers to critically and honestly reflect on their ideas and bias to actively work towards truly inclusive technology and science lessons.

Within this dimension, we offer teachers two reflective questions:

1. Are you aware of the implicit ideas and prevailing prejudices about m/f/x in society? (example: boys are better at engineering than girls)
2. Are you aware of your own ideas and beliefs about m/f/x? (for example: to girls, I need to give feedback more sensitively.)

The image of technology

Children form an early picture of what a scientist or engineer should look like. If they do not recognize themselves in this, their motivation to continue with this study or career choice decreases (Blickenstaff, 2005). Role models are therefore important in arousing girls' interest in technical careers. The use of female role models may increase an important sense of belonging in STEM (Blickenstaff, 2005). The most effective role models are those with similar backgrounds to those of the participants. That resemblance can encourage girls to imagine that one day they might end up in those positions (Martens et al, 2006; Zirkel, 2002).

It is also important for boys to see counterstereotype examples. Children need to see and hear that you do not have to be a 'geek' or an outsider to choose such a direction. Regularly bringing female and stereotyped successful role models into the classroom has a positive influence on the attitudes of girls and boys towards women in technology and ICT (Shin et al., 2016; McGuire et al., 2021). People need not one but several mutually reinforcing examples to see counterstereotypes as evidence of trends (Eagly and Woods 2012; Richards & Hewstone, 2001). Hence, it is crucial that a teacher would not "check off" the diversity box when a female engineer once testifies about her work experience. That box can only be checked when the manuals and work materials for the whole year are being critically screened. Contrary to what we might think recent research shows that much of the learning material and imagery used in STEM classes still confirm the stereotypical idea that science associates with white men (Kerkhoven et al., 2016; McGuire et al., 2021).

One teacher we observed for the project told us that he had added pink paint and glitter to his technology projects to attract and stimulate girls in "their talents". This is described in the literature as 'pinkwashing' (Myers, et al., 2019). Contrary to what this teacher thought, the addition of glitter and pastels does not provide more motivation for technology education. On the contrary, they can reinforce girls in the idea that this is not for them by giving extra attention to their gender, which is associated with negative stereotypes about STEM (Heybach & Pickup, 2017). This may lead to reduced performance through stereotype threat (Steele, 1997; Spencer, et al., 1999). In other studies, the addition of pastel-colored blocks in a game also did not positively affect girls' technical ability but negatively impacted boys' performance (Mulvey et al., 2017).

When designing a gender-sensitive lesson, teachers should consider the image they create in the classroom. After critical self-reflection (pillar one), they should screen teaching materials, videos, posters, and stories: As part of the critical self-reflection (pillar one), they should screen teaching materials, videos, posters and stories using the questions in the checklist below.

In the developed checklist and accompanying workshop, we direct teachers towards online and offline intersectional gender sensitive imagery of science and technology on websites, picture books, biographies, etc. (e.g. the book on Girls and Science by Rachel Ignotofsky, 2016)

Within this dimension, we offer teachers five reflective questions:

1. Is there an equal number of men and women presented in your learning materials?
2. Do the women in pictures play an active role? (For example: plumber Burçu is pictured repairing the faucet)
3. Do you pay attention to the (historical) contribution of female scientists and technicians? (e.g. Edith Clarke, Grace Hopper, Hedy Lamarr, Katherine Johnson, Annie Easley,…)
4. Are the children brought into contact with a female supervisor, scientist, or technician during class or workshop?
5. Do you use neutral-colored material? (Avoid offering pink or purple hammers or work trays to 'attract girls')

Guidance and interaction in the lessons

Our interaction with children potentially has a major influence on, among other things, the self-image of girls and whether they feel like they belong in STEM disciplines. Children actively look for cues about gender in their environment to organize and make sense of their social world (Ruble et al., 2006). Among other things, children seem to use hints in language like occupational titles to categorize occupations along gender lines. In most European languages there is a distinction between the male and female form of scientist for example. The current practice of using the generic masculine form as a so called 'neutral job title' when describing stereotypical male occupations may therefore contribute to the preservation of gender-stereotyped images in adults and children (Vervecken et al., 2013, 2015). This advice can also be relevant in English when repeatedly, and often subconsciously using 'he' rather than 'she' for a technician or scientist.

It seems that when both the male and female professional titles are being used in pair-form, boys and girls feel equally addressed, this boosted children's self-efficacy regarding traditionally male occupations and increased the interest of girls in stereotypical male professions (Vervecken et al., 2013, 2015). Both boys and girls also believe more strongly that women can also be successful in these professions. The use of pairing in job titles supports women to envision more successful peers (other women) thereby also increasing their interest in STEM careers (Vervecken et al., 2013, 2015).

Other research shows that naming science as behaviour or action ('we are going to do science'/'you can work well independently') rather than as a fixed identity ('we are scientists'/'you are independent') contributes to the interest of young girls (4 to 9 years old) in technology. These effects are especially true for children who are targeted by stereotypes that suggest that they may not be the kind of person who is successful in STEM, in this case, girls (Rhodes et al., 2019).

Many girls and those around them think that for technology or science you need to have an innate and fixed talent (Hill et al., 2010, Ardies et al, 2015a). Therefore, it is important for teachers to give students explicit appreciation for their learning process, approach, commitment, and creativity. Teacher should clarify that everyone can develop and improve STEM skills through practice. Providing feedback and language that is growth-oriented and not just about the result can help. Teachers also need to correct misbeliefs and myths like these and clarify the skills in the workshop are not 'innate' but can improve with practice (Wang & Degol, 2016).

Boys are more likely to overestimate their qualities while girls are more likely to underestimate themselves, especially for science and technology subjects (Correll, 2001; Nagy et al., 2010). Van der Heyden et al., 2016). Extensive research confirms that for example low math self-efficacy plays a major role in girls' or women's underachievement in math (Durik et al., 2006). In other words, girls who estimate themselves lower will also perform lower in mathematics as a result. This self-assessment is important because both girls and boys who rate their mathematical competence highly are more likely to enrol in a mathematical field and start a STEM career (Dweck, 2007).

Fortunately, teachers can make a difference. After all, teacher expectations can influence students' self-esteem and performance (Metheny et al., 2008). Teacher expectations differ for individual students and are related to differences in treatment and performance (Hattie, 2009; Jussim & Harber, 2005; Turner & Patrick, 2004). Indeed, girls are more likely than boys to be disadvantaged by teachers' low expectations of math achievement (McKown & Weinstein, 2002; Wang, 2012). This is very closely related and stems from the basic attitude we discussed in pillar one.

It follows that teachers often tend to ask girls less direct and open questions and to give them fewer compliments (Becker, 1981). Teachers should deliberately oppose this and try to critically examine their own interactions.

Within this dimension, we offer teachers seven questions:

1. Do you use the masculine and feminine form (or he/she...) for professions, if possible, in your native language?
2. Do you use active language? (For example, 'we are going to design mini-robots', instead of 'we are going to be technicians')
3. Do you use growth-oriented feedback? (For example: 'I admire your perseverance, even if it doesn't work right away. Are there any other ways?')
4. Do you address students on gender stereotypes statements? (For example: compliment girls on being strong and good in maths and boys in being caring)
5. Do you limit gender-oriented tasks? (For example: avoid asking the girls to clean the tables and asking the boys to replace the tables and chairs)

6. Do you actively monitor student turns? (Do you make sure that a (male) student is not dominating in an activity or lesson? Do you wait long enough after asking a question for all (m/f/x) equally?)
7. Do you ask all students the same type of questions?

Didactical methods

Girls generally seem to prefer a contextualized curriculum, in which technology is seen as a means to solve social problems or to enrich human experiences (Ardies et al, 2015a). In other words, it's important to clarify the social, human relevance of your technology or science activity or place the assignment in a broader context where teachers clarify its relevance. "We are now programming robots, which can also be used to provide companionship to lonely people", for example. Or "design a solution in your group for the plastic waste in the local stream". Or "with such a formula you build a solid bridge that gives people from the village the chance to get their food on the other side".

Hands-on activities in which children actively get to work have a positive effect on the motivation of boys and not negatively for girls and we would therefore generally recommend it. Girls feel even more motivated if they can design and conduct their research (Ardies et al., 2015b). There are rich opportunities in formulating a research question, devising a solution route, making mistakes, and formulating an answer. Making a connection between students' life and STEM lessons can also increase interest and outcomes, especially for students with low success expectations (Hulleman & Harackiewicz, 2009).

Many extra and after-school activities offer experiential learning with problem-solving, creativity, and design skills, and offer research opportunities in scientific areas that are often not part of the regular school day. These extracurricular activities have the potential to play an integral role in creating interest in STEM fields and careers.

In their study of after-school activities, Anderson and Gilbride (2003) found that participation in a STEM-focused program can significantly increase girls' interest in pursuing engineering as a career. Therefore, there are rich opportunities in such workshops and refresher courses for students to achieve equal opportunities. We, therefore, work closely with these organizations to convert the screening tool into gender-aware STEM workshops.

Within this dimension, we offer teachers six questions:

1. Do you promote collaboration in the classroom as well as competition?
2. Do you divide groups based on characteristics other than gender? (For example: not 'boys against the girls' but 'red and blue shirts against the others'?)
3. Do you place the activity in a broader context to clarify the relevance? (Are you starting from an authentic problem or a real question, like 'how can we display all the drawings from the children in such a way all parents can see them?')
4. Are you clarifying the social, human relevance of STEM in your activities? (For example: 'In the future, these robots will be able to offer the elderly company' or 'drones will also be used to clean the oceans')

5. Do you give enough space to experiment and get started with problem-solving? (For example: the students do not always have to follow a step-by-step plan for every activity)
6. Do you let the students design and carry out research based on their own choice?

Discussion and conclusion

This research and the developed tool started from the teacher's role in promoting girls' interest in STEM activities. Of course, the dropout of girls in STEM courses and careers is not a direct result of what the teacher alone is doing (Çınar, 2022). For example, stereotypes about gender and STEM affect not only teachers and tutors, but also the student and her/his friends, family and future employers (Kelly, 2016). Cultural and social beliefs, policies, and economic and work-related developments also, directly and indirectly, influence student behaviour. A teacher can only do so much. Nevertheless, teachers and their wider school team must take responsibility for this and do everything possible so that students can make a choice of study that starts from genuine interests and talents and is not based on what the student thinks is expected of her/him/them, based on gender, for example.

To support teachers in organizing gender-sensitive STEM activities and interactions, we developed a checklist and accompanying workshop. This checklist may seem like a collection of many trivial pointers, or maybe it all might seem obvious to many. Yet, as we have read throughout our thematic literature review, the road to gender equity in STEM and the broader society is not paved on big projects, grand gestures or expensive professional development. It is the small changes in our everyday language, the implicit and unintentional biased expectations and textbooks we use in our classes that will need to make the change for a more gender equitable society. When teachers start reflecting on societal and personal ideas about gender and how these affect their class activities, teachers are taking very important steps in the direction of gender-sensitive education. The Gender-Sensitive Education Checklist (GSEC) can be used to tick what is already going well and ensure these roots can anchor strongly. Next, teachers can pick a few points for improvement that they want to work on first. It is not necessary nor possible to give equal attention to all four principles at the same time. By reaching out to teachers and give bite-sized evidence-based advice and questions in our checklist, we aim to bridge the gap between research and teaching.

However, the evaluation phase presented in this paper is limited in terms of effectivity. As expected withing an EDR-study, our research focused more on participants' experience with the GSEC, with the aim of refining and improving the tool, rather than studying the effectivity of the tool itself. Further research might focus on the learning gains and effectivity of the tool and accompanying workshop on teachers' gender sensitivity. Thereby, future studies can focus on the impact on students' ideas of gender.

We are convinced that all teachers can make a difference for their students. With that in mind, the GSEC provides teachers and teacher-students with a robust tool to support gender sensitive teaching, that is grounded in both literature and user experience. By summarizing practical suggestions from recent research in a practical tool and workshop for teachers, we hope to be able to support teachers in working on a gender-sensitive technology or science lesson. Such lessons ultimately ensure that all children feel motivated and addressed and can make a truly free study and career choice, regardless of their gender.

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