Raising self-efficacy in STEM education to provide opportunities for all

Couso Lagarón, Digna *(digna.couso@uab.cat) Centre de Recerca per a l'Educació Científica i Matemàtica (CRECIM)*

Grimalt-Álvaro, Carme *(carme.grimalt@uab.cat) Centre de Recerca per a l'Educació Científica i Matemàtica (CRECIM)*

STANCE ON STEM, A MATTER OF INTEREST

Anyone working on STEM education, either at formal or informal level, has faced the challenge of trying to engage a participant who feels that "STEM is not for them". And this person could be sitting next to someone who shows true STEM enthusiasm even before the activity starts. What is different between these two people in the audience? How the same STEM activity could be perceived so differently? We have coined the term "stance on STEM" to refer to the way a person thinks, feels, talks and acts about STEM, that is, their position on STEM-related topics, agents and activities. Stance on STEM encompasses how students see themselves in this field, including their views on what role STEM plays in their life and what role they play in the STEM field (Couso, 2017). This complex construct is the result of past and present experiences on STEM, including educational ones but not only those. Stance on STEM is also a strong influencer of future expectations regarding the STEM field. In psychological and sociological terms, we consider stance on STEM to be based on and the result of one's interests, aspirations, self-efficacy, capacity and identity about STEM (Figure 1). All these variables are interrelated in complex ways, conforming the stance on STEM that our students hold.

Traditionally the idea of "stance on STEM", despite not coined as such, has been approached through the study of the different variables in Figure 1: interest in STEM topics, identity in STEM, aspirations regarding the STEM work field and capacity and perception of capacity in STEM. These studies have proved the existence of differences and inequalities in young people, according to gender, socioeconomic background and ethnicity, which would ultimately condition their stance on STEM.

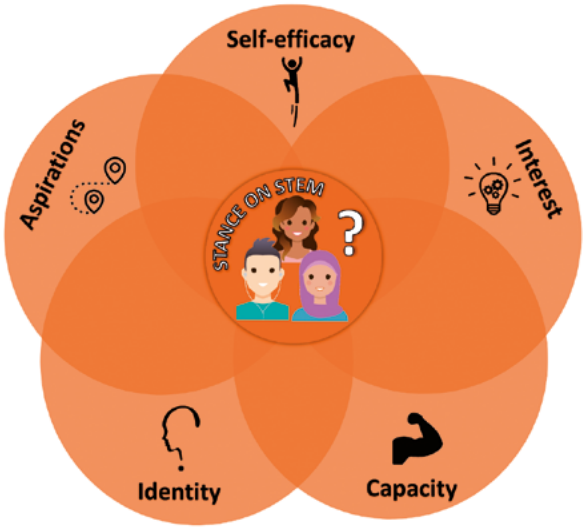

Figure 1. Representation of the factors affecting stance on STEM

For example, regarding interest, although at the age of 10 students' interest in STEM is relatively high with little gender differences (Archer et al., 2010), their interest declines sharply in the following years as they progress through school (Osborne, Simon, & Collins, 2003). This decrease is especially pronounced for girls (Barmby, Kind, & Jones, 2008), which at the age of 14 appear to be generally less engaged by STEM topics (Tytler, Osborne, Foundation, & Forgasz, 2008), especially the ones related with technology and physics (Sjøberg, 2002; Tytler et al., 2008).

Similar results can be found in the literature regarding aspirations in STEM , which appear to be deeply gendered, ethnic and socioeconomic biased: for example, girls envisage themselves as health or biology professionals more than boys do; and boys see themselves as becoming computing (ICT) professionals, scientists (especially physicists) or engineers more than girls do (Bøe & Henriksen, 2013; OECD, 2016b; Sadler, Sonnert, Hazari, & Tai, 2012; Sáinz, 2017); boys in highly deprived schools are more likely to choose mechanics over engineering; among girls, architects, vets and engineers are more popular in less deprived schools, whereas hairdresser, nurse and beauty assistant are more popular professions in the more deprived areas (Chambers, Kashefpakdel, Rehill, & Percy, 2018).

Regarding identity, research has proved the existence of a negative and biased stereotype of STEM professionals which depicts them as white and brainy males,

who come from middle-class backgrounds and who are geek, socially awkward and singularly obsessed with their chosen STEM field, which makes them have an almost non-existant personal life (Archer et al., 2013; Kim, Sinatra, & Seyranian, 2018). This stereotyped image has changed little since the 70's well-known study "Draw a scientist" project, and affects negatively students when considering their choices to become STEM professionals. Of course, there are few students who in spite of not identifying with this image, can manage to build their own identity in STEM regardless of this shared and well-known stereotype. However, it is the existence and the strong presence of this STEM stereotype that can explain why very few students, particularly girls and students from socially deprived areas, do not contemplate becoming a STEM professional, despite expressing their liking for STEM topics and themes during school years (Archer et al., 2010). In these authors' research ideas such as " I am not brainy enough" or "this is not for girly girls like me" are powerful messages that emerged often and explained the non STEM career choices of many girls.

Finally, in relation to capacity and believes regarding own capacity (self-efficacy beliefs), there is also consistent evidence that, regardless of their actual capacities, students from underrepresented groups in the STEM field tend to undervalue their own performance and STEM competences (OECD, 2008). For example, although international tests such as PISA show small differences in boys' and girls' competences in STEM, especially for Science (OECD, 2016a), it has been extensively reported that girls assess their science and mathematical abilities much lower than do boys with similar achievements both at school level (Bøe & Henriksen, 2013; Hill, Catherine, Corbett, & St. Rose, Andresse, 2010) and at career or more advanced level (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011). In other words, boys and men tend to be more confident than girls and women in their capacities in the STEM field (Schunk & Pajares, 2002). A similar situation happens regarding students with low socio-economic status: research consistently report a strong relationship between low level of socioeconomic background and lower feelings of self-efficacy, in comparison with counterparts with high-socioeconomic level (Archer, Dawson, DeWitt, Seakins, & Wong, 2015; Bandura, 1993; Becker, Kraus, & Rheinschmidt-Same, 2017). In relation to ethnicity, there are no concluding studies whether this variable affects separately to students' self-efficacy, since much of the research has confounded ethnicity with social class by comparing white children of middle socioeconomic levels with ethnic minorities from lower socioeconomic levels (Schunk & Pajares, 2002). However, what research has already shown is that ethnicity would reinforce the negative effect of other variables such as gender and/or socioeconomic level on self-efficacy. In other words self-effi-

cacy among Black undergraduate women is significantly lower than those of their White women peers —a finding not evident for Black men (Ro & Loya, 2015).

SELF-EFFICACY: A CRUCIAL FACTOR FOR A POSITIVE STANCE ON STEM

In the last decade a growing attention has been paid to the critical role of self-efficacy believes in the students' development of their stance on STEM. Research has provided evidence that self-efficacy beliefs deeply configure students' perceptions about their personal value for STEM or not, affecting not only their interest and aspirations, but also their actual capacity. In this sense, we consider self-efficacy believes to be a crucial factor for a positive stance on STEM.

What are exactly self-efficacy believes in STEM? As defined by Bandura (1995), self-efficacy believes refer to the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations. When focused in STEM, we use self-efficacy in STEM to refer to beliefs in one's capabilities to accomplish a particular STEM-related task at a designated level. Self-efficacy believes in STEM, like in other areas, have shown to be different that the real capacity for accomplishing a particular STEM task.

Self-efficacy believes in STEM have an strong impact: the higher students' perceive their own efficacy, the greater the interest they have in STEM activities, and the wider the career options they seriously consider to pursue (Bandura, 1993). This is not surprising considering the strong effect that self-efficacy believes can have in actual performance. In this sense, literature shows that self-efficacy beliefs are a strong predictor of academic performance (Aurah, 2013).

Despite self-efficacy believes can be affected by social stereotypes, self-efficacy beliefs, which are future-oriented (i.e. I know I will be able to do it), are personally built through experience. In other words, these expectations are in large part results of self-schemes that are created from earlier experiences (i.e. I know I will be successful because I have successfully carried out similar tasks before) (Bong & Skaalvik, 2003). Since they are the result of the self-interpretation of multiple past experiences, self-efficacy beliefs tend to be deeply rooted in one's own mind and are difficult to be changed, pointing out a need to undertake and combine multiple strategies and experiences of achievement to successfully change them. Moreover,

these features also highlight the need to undertake these actions at early ages in which self-schemas are in initial stages of formation. The older a student is, the more informed and rooted their self-schemas will be and the more difficult it will be to change their perceptions about their own capacities.

Again, people from underrepresented groups in STEM and those not aligned with the STEM stereotype tend to systematically underestimate themselves in STEM-related tasks, compared to their peers. This is related with feeling less interested, holding fewer aspirations and actually performing worse, so it is not surprising that they consider they are not good enough for STEM and that STEM is not for people like them. The consequence is a negative stance on STEM that causes their progressive detachment from STEM activities, which ultimately would imply to drop out of compulsory STEM education at the very first opportunity, and avoiding STEM-related tasks, leisure and information. This affects not only their future prospects in the STEM work force but, more importantly, their likeability to acquire an adequate STEM literacy. In the post-truth knowledge-based, global and post-industrial society in which these students will become full citizens, a poor STEM literacy will act as a severe agent of social exclusion.

4 STRATEGIES TO RAISE SELF-EFFICACY: PROVIDING OPPORTUNITIES FOR ALL IN THE STEAM4U PROJECT

As any deeply rooted belief, self-efficacy believes cannot easily be changed with short-term and superficial actions. This is not to say that self-efficacy cannot improve: we can help all students think they can successfully participate in STEM activities and that they are the right people for doing so. Following this line of reasoning, the STEAM4U project (https://steam4u.eu) draws from a desire to contribute to provide opportunities for all. In the project, we have carried out several actions addressed to change young people's self-efficacy beliefs in STEM, joining the effort of 7 different organisations in formal and non-formal educational from 5 EU countries: (Belgium, Italy, Poland, Spain and Ireland). In STEAM4U, different actions addressed to 10-14-year-old students were undertaken, serving as examples of the bringing into practice of the different strategies that can be used for having a positive impact on self-efficacy. The framework used to justify these actions proposes four families of strategies to address self-efficacy believes in STEM (Figure 2). These four main families of strategies have been constructed combining the previous works of Pajares, (2006), Barry J. Zimmerman & Campillo (2003),

Barry J. Zimmerman & Cleary (2006) and choosing the most relevant results and ideas for formal and informal STEM education. They include:

- Facilitating the self-regulation of students before, during and after the STEM activity
- Ensuring that all students can be successful learners in a STEM activity
- Building up a good STEM classroom environment
- Stimulating positive influences in the STEM learning community

Figure 2 also shows how the 7 different organisations participating in the STEAM4U project relate with different families of strategies. These organisations used the project framework to reflect on, rethink and re-design their initiatives in light of promoting a positive stance of STEM and raising self-efficacy. In this sense, they used a myriad of strategies and instruments to measure their possible impact, and focused in a particular family of strategies for research purposes. In the next chapters, the concrete experiences of these organisations during their 2 years of work within the project can be found. In the following paragraphs each of these families of strategies and how STEAM4U participants have made used of the strategy in their initiatives will be briefly presented.

Facilitate the self-regulation of students before, during and after the STEM activity

Actions included in this type of strategy are aimed at:

- Providing guidance to students to help them to be aware of their progresses throughout the activity (e.g. help them to know where they are in relation to the learning objective of the activity).
- Assisting students to develop more efficient strategies to carry out a task (e.g. help them to make a problem resolution scheme).
- Promoting students' emotional education (e.g. help them overcome anxiety before an exam)
- Persuading students about their own capacities before start and throughout an activity.

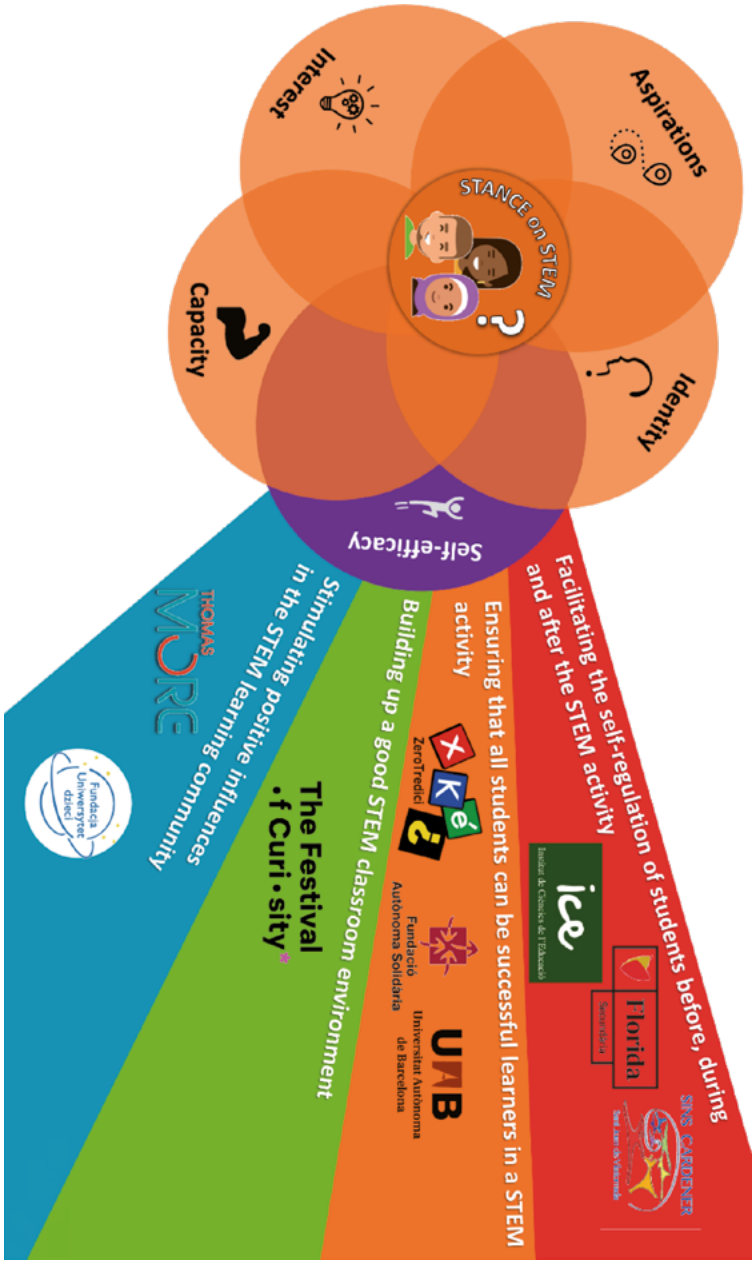

Figure 2. Representation of the 4 main type of strategies to raise self-efficacy in STEM carried out within the STEAM4U project by the organisations implementing them in their initiatives.

The secondary schools Florida Secundària and SINS Cardener, as representatives in the STEAM4U project of the network of innovative schools[1] of the ICE (Institute of Educational Sciences) of the Autonomous University of Barcelona (UAB), have been carrying out actions mainly addressed to these types of strategies. In particular, these schools have included different actions to promote the self-regulation of students in the implementation of a STEM school project.

Ensuring that all students can be successful learners in a STEM activity

Actions included in this type of strategy are aimed at:

- Classifying and sequencing the learning objectives and/or the key ideas of the activity in increasing order of difficulty, establishing an initial level suitable for all students
- Customizing the activity at the various learning rhythms (e.g., propose different ways in which the same activity can be carried out)

In the STEAM4U project, Xké? has been carrying out actions mainly addressed to these types of strategies by providing resources to teachers to carry out engaging activities in formal school contexts. The Solidarity Autonomous Foundation (FAS) of the Autonomous University of Barcelona (UAB), together with the Research Centre for Science and Mathematics Education (CRECIM), have developed a model of workshop for volunteers in an out-of-school project working with 12-14-year-old students with less opportunities.

Building up a good STEM classroom environment

Actions included in this type of strategy are aimed at:

- Change and challenge the roles of students in the classroom promoting positive exchanges between peers (e.g. review how roles are shared in a project to break negative associations between students and roles)
- Carry out cooperative activities instead of competitive activities to promote peer learning and reduce the activity stress

1 The network of innovative schools are formed by educational centres (primary and secondary schools) which would like or are implementing global projects taking care to all students. Schools participating in this network have integrated innovative aspects at the organisational and curricular levels and regarding the use of ICT and cooperative learning platforms.

- Review your verbal and non-verbal judgments to emphasize positive messages (e.g., promote optimism)

In the STEAM4U project, The Festival of Curiosity has been carrying out actions mainly addressed to these types of strategies. This organization has specially trained their volunteers to revise the key messages they deliver to participant families and kids, making an explicit effort to foster positive and empowering messages.

Stimulating positive influences in the STEM learning community

Actions included in this type of strategy are aimed at:

- Engage students in positive exchanges/experiences with STEM professionals
- Involve families in STE(A)M activities so that their children can show their successes to the family and feel they are valued positively
- Develop confidence of teachers in their own capacities to influence students

In the STEAM4U project, Fundacja Uniwersytet Dzieci and Thomas More have been carrying out actions mainly addressed to these type of strategies. These actions have promoted positive, informed and supported exchanges with adequately trained STEM professionals and between members of the family, respectively.

TO KNOW MORE

You can find more information on the STEAM4U framework to raise self-efficacy in STEM, the concept of stance on STEM, instruments to measure impact on this stance and the participating institutions of the STEAM4U project in the web: www.steam4u.eu

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