RAISING SELF-EFFICACY IN STEM, A WAY TO PROVIDE OPPORTUNITIES FOR ALL (O4)

DESCRIPTION OF THE MAIN STRATEGIES TO RAISE SELF-EFFICACY IN STEAM USED IN THE STEAM4U PROJECT

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YOUNG PEOPLE'S STANCE ON STEM, A MATTER OF INTEREST

By age 14, most children's STEM stance have become well established, with ever diminishing numbers choosing to study science subjects at higher levels (Archer et al., 2010). This imply that at this age, there is a considerable number of students who consider themselves not STEM persons, refusing to engage in STEM activities. This situation has consequences in the STEM literacy of these youngsters, since they will not engage in such activities.

Women, socio-economically deprived students and particular ethnic collectives are under-represented in STEAM careers (especially the ones related with mathematics and technology), compared to the distribution of the population (Macdonald, 2014). This situation implies that only a certain "privileged" group of people (white, male, middle-class and brainy) will mainly have access to the future STEM professional jobs required by the economy, endangering, as well, public scientific literacy for social justice ends.

In a society increasingly STEM, we should guarantee that all students end with a general STEM competencies that allow them to be full-citizens. That means, we have to find a way to make STEM stance of all students positive to STEM, even if they do not want to pursue post-obligatory studies of STEM. Thus, it is necessary to set different actions to change how these URM (Under Represented Minorities) in STEM feel and act about STEM (that is, their stance on STEM), not only as a way of guaranteeing a number of STEM vocations/aspirations, but as a matter of promoting equity among future citizens.

Inequalities in STEM in numbers

- Socio-economically disadvantaged students across OECD countries are almost three times more likely than advantaged students not to attain the baseline level of proficiency in science (OECD, 2016).
    - Nearly one in six adults with a bachelor's degree or higher was a member of an underrepresented minority group (women, ethnic minorities…) (National Science Foundation, 2017).
    - Although in all Member States, there were more women among tertiary education graduates than men (58% of graduates were women at EU level), male dominated education fields are engineering, manufacturing and construction (where men account for 73% of the graduates in this field) and Science, mathematics and computing (58%). On the other hand, four out of five graduates in Education are women (80%). Another field where women are largely overrepresented is Health and welfare, with 75% female graduates (Eurostat Press Office, 2016).
    - While there have been some gains, national data continue to show that the disparity in STEM degree attainment for URM (Under-Represented Minorities) students (i.e., African American, His- panic or Latino/Latina, American Indian, and Alaska Natives) increases at each degree level, compared with white and Asian students (Estrada et al., 2016).
    - At the top 40 college science and mathematics departments, Blacks, Hispanics, and Native Americans represent less than 5 percent of tenured faculty (Lewis, Miller, Piché, & Yu, 2015).

DEFINING STANCE ON STEM

We propose to define stance on STEM as the way a person thinks about and publicly expresses their opinions about STEM-related topics and activities based on their interests, aspirations, self-efficacy, capacity and identity about STEM. In a first analysis of the literature to define which elements or variables were comprised, we identified and classified all factors with a proven impact on students' decisions or opinions about STEM and STEM studies into two big groups: a) contextual factors (which are mostly external to the individual, such as the type of STEM education received at school) and b) personal factors (which directly imply the subject, such as interest in STEM). Many relevant studies consider the relevance of contextual and personal factors, such as the work of Archer, Dawson, DeWitt, Seakins, & Wong (2015) and Wong (2016) defining science capital to predict students' aspirations in STEM, drawing in parental science qualifications among other personal and contextual factors. Although these researches have cast much new light on the issue of under-represented groups in STEM education, in our framework we believe that students' stance on STEM should be narrowed to those factors who can be targeted through direct actions and use contextual factors in a secondary level, as providers of context. However, our aim when defining stance on STEM was to provide an operational definition to facilitate the evaluation of the impact of educational initiatives on students. Thus, although we also acknowledge the influence of contextual factors, in our framework we propose to consider only those ones who could be easily targeted through direct actions with young people.

Personal factors have been approached through the study of different variables like interest, aspirations, identity, capacity or achievement in STEM (Figure 1). Recent researches point out the need to also consider the influence of a new construct: self-efficacy in STEM (Rittmayer & Beier, 2009). This construct allows to re-conceptualize the internal processes that lead to young people to express a particular stance on STEM and to consider different new strategies that can be useful for changing the positioning of young people for STEM.

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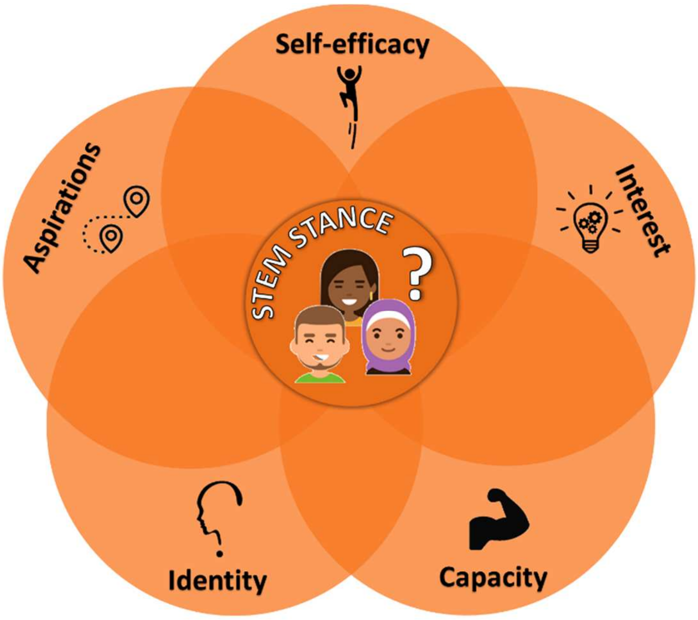

Figure 1. Representation of the considered variables influencing stance on STEM

Althought there is a strong consensus in the field that self-efficacy beliefs can positively act in the stance on STEM of young people, there are few references about how to raise it in 10-14-year-old students. To this aim, the STEAM4U project draws from a desire to contribute to provide opportunities for all by carrying out several actions addressed to change young people's own self-efficacy beliefs in STEM. Towards this aim, the efforts of 7 different organisations from formal and non-formal educational contexts have been addressed.

SELF-EFFICACY IN STEM AS A KEY ELEMENT OF STEM STANCE

Self-efficacy beliefs are part of a broad non-cognitive factors, such as motivation, and support, to which attention has been recently paid for their critical role in student development of their stance on STEM (Williams & George-Jackson, 2014). Self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to manage prospective situations (Bandura, 1995). Thus, self-efficacy in STEM refers to beliefs in one's capabilities to accomplish a particular STEM task at a one designated level, which it is different that the real capacity for accomplishing this particular STEM task. In this sense, students can value their own abilities to perform a particular STEM task despite having demonstrated the same achievement, and these self-efficacy beliefs deeply configure their perceptions about their personal value for STEM or not. In other words, self-efficacy influence students' behaviour in engaging and pursuing STEM activities. The higher students' perceived their own efficacy, the greater the interest they have in STEM activities, and the wider the career options they seriously consider pursuing (Bandura, 1993). Thus, having a strong sense of self-efficacy results in people having the capacity to deal with challenges they encounter, which is highly relevant to have an actual success (Williams & George-Jackson, 2014).

People differ in the areas in which they cultivate their efficacy and in the levels to which they develop it even within their given pursuits (Bandura, 2006): One can believe that he or she will be very capable of solving a particular math problem but not able to solve another one, or to explain to a big audience how he or she has managed to solve it. For this reason, self-efficacy beliefs in STEM need to be tailored to a particular domain and task (Bandura, 2006), although in this article we consider them as a group, to simplify the reading. However, it is worth to note that when different spheres of activity are governed by similar sub-skills, some interdomain relation in perceived efficacy has been observed (Bandura, 2006). From these perspective, educational interventions emphasizing these common competences or practices between disciplines, such as the new framework K-12 Science Education of the National Research Council (2012), would hold promising effects in stablishing positive synergies in the development of self-efficacy in STEM.

Finally, although self-efficacy beliefs are inherently future-oriented -they refer to my beliefs in my own success or failure when doing a particular task-, these expectations are in large part results of self-schemas that are created from their earlier experiences -I know I will be successful because I have successfully carried out similar tasks- (Bong & Skaalvik, 2003). These results highlight the need to provide students with not one, but multiple experiences of success when participating in STEM activities as a key strategy to shift and improve their self-efficacy in STEM (Bryant, 2017; B J Zimmerman, 2000). Moreover, it also points out 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 will be to change their perceptions about their own capacities.

Main findings related with gender, socio-economic background and ethnic minorities

- Students' self-efficacy beliefs in STEM are lower than their real capacity, especially for girls and disadvantaged students (Bandura, 1993). Girls assess their mathematical abilities lower than do boys with similar achievements in STEM subjects (Bøe & Henriksen, 2013; Hill, Catherine, Corbett, & St. Rose, Andresse, 2010). At the same time, girls hold themselves to a higher standard than boys do in subjects like math, believing that they have to be exceptional to succeed in "male" fields (Hill, Catherine et al., 2010). In other words, boys and men tend to be more confident than girls and women in academic areas related to mathematics, science, and Technology. Boys tend to be more self-congratulatory in their responses whereas girls are more modest (Schunk & Pajares, 2002). These beliefs about their own competence, in turn, influence their real capacity in STEM
- Differences in self-efficacy begin to emerge following children's transition to middle or junior high school, with girls typically showing a decline in self-efficacy beliefs (Schunk & Pajares, 2002).
- Ethnic minorities generally have low sense of efficacy for STEAM careers, which also is related with avoiding these kind of professional path (Bandura, 1995). However, much of the research has confounded ethnicity with social class by comparing middle-class white children with lower class minority children (Schunk & Pajares, 2002)
- Scholars have found self-ratings of engineering learning out- comes among Black undergraduate women to be significantly lower than those of their White peers—a finding not evident for Black men (Ro & Loya, 2015).
- Economic hardships can alter parents' perceived efficacy which, in turn, affects how they raise their children (Bandura, 1995). However, collective efficacy can also compensate the influence of socioeconomic status (Pajares, 2006).

STRATEGIES TO PROMOTE SELF-EFFICACY IN STEM IN EDUCATIONAL CONTEXTS

Being aware of the challenging limitations of changing such deeply rooted beliefs, the STEAM4U partnership has undertaken different actions to try to raise 10-14-year-old students, by carrying out one type of strategies, which are described below[1] (). These type of strategies have been defined from the combination of the previous works of Pajares, (2006), Barry J. Zimmerman & Campillo (2003), Barry J. Zimmerman & Cleary (2006) and the STEAM4U results, and are described below. These strategies are summarised below (

Figure 2), although they can be found in an on-line tool through the link: https://view.genial.ly/5b6031c8088c650ee536fc78/strategies-to-promote-self-effic.

[1] In order to simplify the classification, we have considered the main strategy of the action been carried out by the organisation.

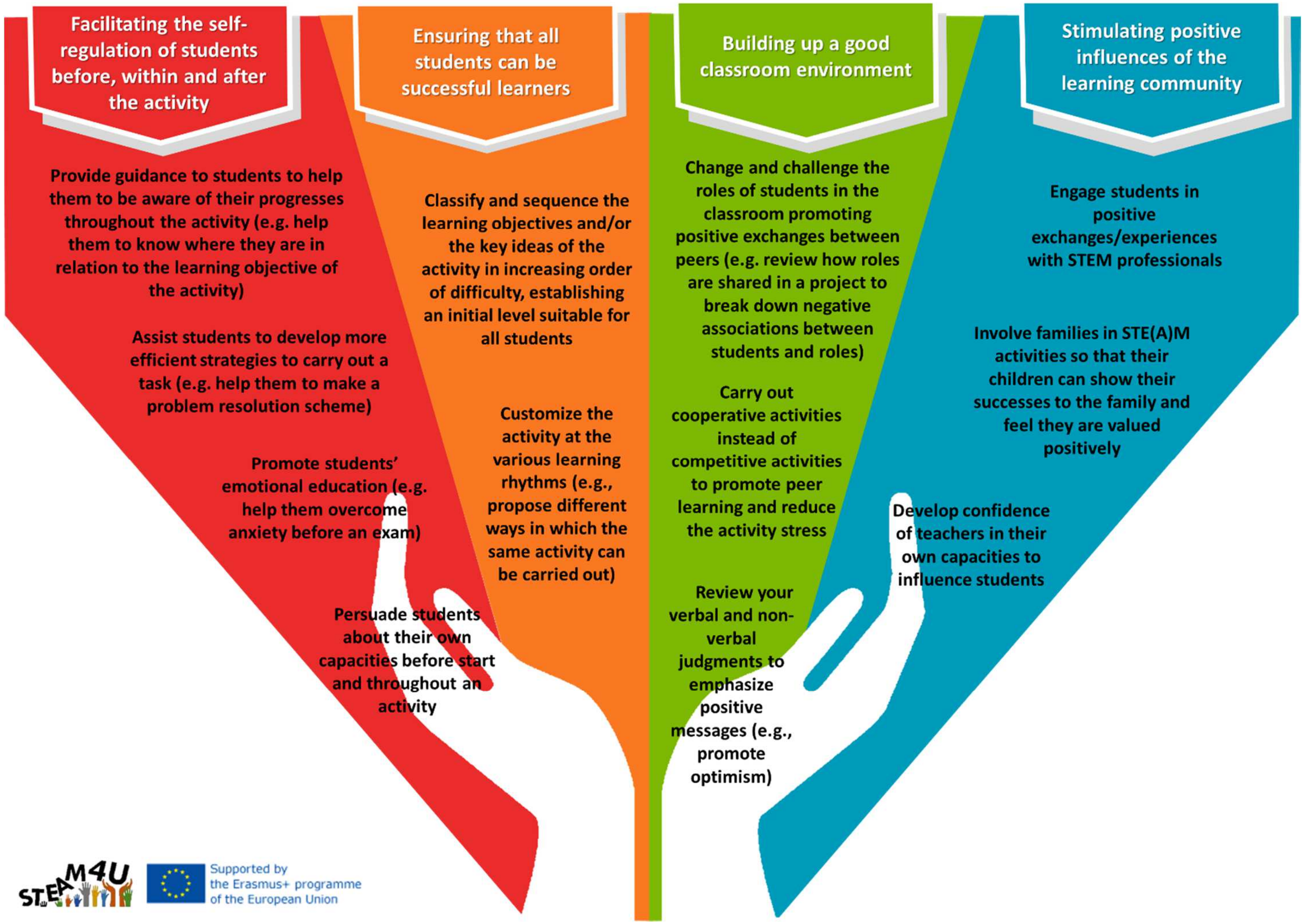

Figure 2. Representation of different strategies to raise self-efficacy in STEM

FACILITATE THE SELF-REGULATION OF STUDENTS BEFORE, DURING AND AFTER THE ACTIVITY

4 strategies have been grouped within this type.

Provide 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)

Young people invariably interpret their mastery experiences. This can lead to situations in which inappropriate interpretations can diminish the very self-efficacy beliefs required to push on in the face of adversity (Pajares, 2006). Ensure that students' interpretations of their successes are adaptive (Pajares, 2006).

Accomplishments are interpreted in light of one's self-regulatory processes, such as self-evaluations, attributions, strategy use, and goal setting. For example, self-efficacy precepts depend on how an individual evaluates the circumstances and factors surrounding the accomplishments (Barry J. Zimmerman & Cleary, 2006). Help students interpret their own failures & successes adaptively.

Decriminalise the mistake by giving it a formative meaning (e.g. provide formative evaluation/ feedback to participants & use revised exercises to identify the mistakes and learn how to solve them) (Pajares, 2006).

Provide memorable moments by making private feedback. Providing private feedback in a personal encounter can be a powerful way of engendering attention and making a moment memorable (Pajares, 2006).

Assisting students to develop more efficient strategies to carry out a task (e.g. help them to make a problem resolution scheme)

Tran students in self-regulation processes, and make self-regulatory practices automatic and habitual (Barry J. Zimmerman & Cleary, 2006). For example, help them to set their goals, self-monitoring and be more strategic planners. These practices can increase their confidence levels to perform specific tasks in school and their chances to succeed resulting in stronger self-efficacy and achievement in various areas (Pajares, 2006). Some of these practices can be grouped into (Barry J. Zimmerman & Campillo, 2003):

- Task strategies: students' abilities of reducing a task to its essential parts and reorganizing them meaningfully.
- Imagery: students' abilities of forming of vivid mental pictures which assist encoding and performance.
- Self-instruction: students' strategies of overtly or covertly describing how to proceed as one executes a task, such as "thinking aloud" when solving a mathematics problem.
- Attention focusing: students' strategies of improving one's concentration and screen out other covert processes or external events during problem solving. For example environmental structuring to eliminate diversions or slow-motion executing to assist motor coordination. Volitional methods of control, such as ignoring distractions and avoiding ruminating about past mistakes, are effective in enhancing problem solving.

Promoting students' emotional education (e.g. help them overcome anxiety before an exam)

Help young people learn to "read" their feelings / emotional education (Pajares, 2006). Help young people read their own emotional feelings and teach them strategies to overcome anxiety. Children interpret their stress reactions and tension as signs of vulnerability to poor performance. In activities involving strength and stamina, people judge their fatigue, aches, and pains as signs of physical debility (Bandura, 1995). If a student gets extremely anxious during math activities, she may interpret her rapid heart rate or sweating palms as indicators of personal ineffectiveness (Barry J. Zimmerman & Cleary, 2006).

Persuading students about their own capacities before start and throughout an activity

Value and praise students about their work emphasizing skill development, effort, perseverance and persistence rather than simply self-enhancement (Pajares, 2006), mastery absolute achievements or social achievements. Most children and adolescents will inevitably compare their skills and abilities with those of their friends and peers regardless of what well-meaning adults try to do to minimize or counter these comparisons (Pajares, 2006). Young people should be helped to develop their own internal standards for evaluating their own outcomes.

Self-efficacy theorists shift the emphasis from self-enhancement to skill development—to raising competence through genuine success experiences with the performance at hand, through authentic mastery experiences. People who are persuaded verbally that they possess the capabilities to master given activities are likely to mobilize greater effort and sustain it than if they harbour self-doubts and dwell on personal deficiencies when problems arise (Bandura, 1995). Although encouraging comments (e.g., “I know you can do it”) and reassuring statements from a teacher (e.g., “You will do better next time”) may help struggling students sustain their motivation in the short-term, the effects of such statements will be short-lived if the student is consistently unable to attain perceived successes (Barry J. Zimmerman & Cleary, 2006).

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ENSURING THAT ALL STUDENTS CAN BE SUCCESSFUL LEARNERS

2 actions are included in this type of strategy

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

Fragment difficult assignments into attainable challenges & sequence the learning objectives according to these levels of difficulty. Set proximal rather than distal goals (Pajares, 2006). As well, make a good progression of the key ideas addressed in class according to their difficulty.

It is important to set an initial goal that every student can achieve. Many times, the first goals are still too far away for some students, making them feel alienated from the activity at the very beginning.

Customizing the activity at the various learning rhythms (e.g., propose different ways in which the same activity can be carried out)

Personalize the activity to students' capabilities and tailor instruction to the student's capabilities (Pajares, 2006) by considering different working paces in the activity. Personalised activities and structures are more likely to increase academic self-efficacy than are traditional structures, since enable the student to feel confident about their success. (E.g. adjusting the pace and/or adjusting the approach of an activity according to the learner's interests).

BUILDING UP A GOOD CLASSROOM ENVIRONMENT

3 actions included in this type of strategy

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 down negative associations between students and roles)

Challenge students' roles in the group by, for example, revising which roles they take in a project (Pajares, 2006). Give new opportunities to students having negative roles.

Develop participants' own internal standards for critically evaluating the inputs of peers (Pajares, 2006). Most children and adolescents will inevitably compare their skills and abilities with those of their friends and peers regardless of what well-meaning adults try to do to minimize or counter these comparisons. Young people should be helped to develop their own internal standards for evaluating their own outcomes.

Promote exchanges between students, considering at least one of them as a peer model (e.g. Promote activities in group, mentoring…). This strategy imply the selection of appropriate peer models (Pajares, 2006), which is important so as to ensure that students view themselves as comparable in learning ability to the models. The verbal and nonverbal judgements of others can play a critical role in the development of a young person's self-confidence (Pajares, 2006).

Discussions between friends influence participants' choices of activities, since friends often make similar choices. For example, students who begin high school with similar grades but who become affiliated with academically oriented crowds achieve better during high school than do students who become affiliated with less-academically oriented crowds (Schunk & Pajares, 2002).

Peer pressure rises during childhood and peaks around grade 8 or 9 but then declines through high school. A key time of influence is roughly between ages 12 and 16, a time during which parental involvement in children's activities declines (Schunk & Pajares, 2002).

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Carry out cooperative activities instead of competitive activities to promote peer learning and reduce the activity stress

Lower the competitive orientation of the activity and ensuring a good work environment (Pajares, 2006) (E.g. Development of cooperative activities, freeing the development of the activity, allowing participants to use a big range of materials... Non-competitive activities and schools are more likely to increase academic self-efficacy than are traditional and competitive structures (Pajares, 2006).

Moreover, cooperative activities develop the collective efficacy of the school/classroom/group (Pajares, 2006), since the group has to work together to achieve the same thing. A low classroom's, school's or group's sense of collective efficacy in STEAM can undermine or enhance teenagers' own sense of efficacy in STEAM. The collective efficacy of a school is also related to the personal teaching efficacy of its teachers, as well as to their satisfaction with the school administration.

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

The verbal and nonverbal judgements of others can play a critical role in the development of a young person's self-confidence (Pajares, 2006). Foster optimism (Pajares, 2006). A good environment of work can less students' stress (Pajares, 2006). Take care as well of other classmate's judgements. A good environment of work can less students' stress (Pajares, 2006).

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STIMULATING POSITIVE INFLUENCES OF THE LEARNING COMMUNITY

3 actions included in this type of strategy

Engage students in positive exchanges/experiences with STEM professionals

Engage in effective exchange practices with social models (Pajares, 2006) (e.g. exchange with adults who good-naturedly admit their errors when they are pointed out, help teenagers understand that missteps are inevitable, that they can be overcome, and that even authority figures can make them…). Students experienced the benefits of seeing other girls who are interested in math and science as well as meeting female researchers and scientists who are doing work in the STEM fields of their interest (Kim, Sinatra, & Seyranian, 2018).

Seeing people similar to themselves succeed by perseverant effort raises observers' beliefs that they, too, possess the capabilities to master comparable activities (Bandura, 1995). Role models are especially influential when they are perceived as similar to the observer, suggesting that interaction with female faculty members and advanced students in STEM would positively affect the self-efficacy of female STEM students. Conversely, observing others fail can lead students to believe that they lack the competence to succeed and dissuade them from attempting the task (Schunk & Pajares, 2002).

Thus, effective exchanges with social models are potent among teenagers, because models are similar in many ways and students at these developmental levels are unfamiliar with many tasks. Coping models, who display confidence and adaptation when confronting errors in learning are significantly more effective in sustaining students' perceptions of self-efficacy than are mastery models who perform anything without errors. Model similarity is potent among children and adolescents because models are similar in many ways and students at these developmental levels are unfamiliar with many tasks. Coping models, who display confidence and adaptation when confronting errors in learning are significantly more effective in sustaining students' perceptions of self-efficacy than are mastery models who perform without errors (Schunk & Pajares, 2002).

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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 collective efficacy of the family (Pajares, 2006) (e.g. implicate parents/relatives in STEAM activities with participants). Families too have a climate and “feel” generated from the collective action of their individual members. Fostering the collective efficacy of a family pays dividends both for parents and for children

Parents and caregivers provide experiences that differentially influence children’s self-efficacy. Parents who provide an environment that stimulates youngsters’ curiosity and allows for mastery experiences help to build children’s self-efficacy (Schunk & Pajares, 2002). Moreover, parents' beliefs that they can affect the course of their children's lives is a more influential contributor to beneficial guidance under disadvantaged conditions than under advantaged conditions, where resources, social supports, and neighbourhood controls are more plentiful (Bandura, 1995). However, many times parents do not feel capable of providing such experiences, having lower parental self-efficacy.

Nurture parents/relatives own self-efficacy in STEAM (e.g. conducting STEAM workshops addressed to parents) (Pajares, 2006). Influence between parents and teenagers is bidirectional: teenagers who display more curiosity and exploratory activities promote parental responsiveness and willingness to engage in such activities (Schunk & Pajares, 2002).

having parents who value the pursuit of STEM is important, and the beliefs held by the parents need to be understood by the student (Kim et al., 2018)

Develop confidence of teachers in their own capacities to influence students

Nurture own teachers’ self- The confidence that teachers have in their capability to affect their students’ learning affects their instructional activities and their orientation toward the educational process (Pajares, 2006).

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