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Positive aspects of sport for fostering strong STEM identities

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Introduction

With the growing demand for Science, Technology, Engineering and Math (STEM) careers it is important to increase female participation in STEM. Females entering the STEM workforce will enhance ingenuity in STEM fields as they will bring new and diverse perspectives to spaces that have been historically male-dominated. On average, females and males have displayed similar scores in studies on math achievement (Else-Quest et al., 2010), however, females are still a minority within many STEM academic degrees and careers (Frank, 2019; Government of Canada, 2021).

A study on individual and gender differences in choice of STEM careers identified that more females were in the high-math/high-verbal ability category compared to males, and that females with high math ability were likely to also have high verbal ability (Wang et al., 2013). This is an important identification because it highlights the potential for high achieving females in STEM to have choice and considerations of occupations in the field (Wang et al., 2013). Even if an individual has greater choice when considering career options, their belief that they will be successful in a particular career is important during their decision making (Eccles, 2009). Therefore, women who could succeed in STEM careers may gravitate away from them given the prevailing gender stereotypes associated with these fields.

Other fields where gender diversity is already more prevalent, such as some sport programs, could be explored to offer alternative frameworks that position positive experiential approaches for increasing female participation and retention in other traditionally male-dominated fields, such as STEM. Parallels between sport and STEM exist. Sport and STEM programs exist on a continuum scale where negative and/or positive qualities influence youth. You may ask yourself, what within the realm of sport allows females to flourish? And, how can the positive factors that have increased female participation in sport be utilized within STEM teaching? Previous research has analyzed ways to increase a student's motivation for STEM fields, but none to-date have explored how positive aspects of sport can be utilized in STEM. For example, a sport-based Positive Youth Development (PYD) model offers an example to counter the current deficit-oriented approaches to increasing diversity in STEM (McCullough, 2011; Ilumoka, 2012; Saucerman and Vasquez, 2014; Cronin et al., 2022; Mossman et al., 2022). Models such as Social Cognitive Career Theory (SCCT) (Betz and Hackett, 1997) are based on interest and choice and "encompass a variety of constructs such as self-efficacy in a particular domain, outcome expectations, and interests as well as contextual factors that influence career choices" (Fouad and Santana, 2017). This includes positive math performance activities (Navarro et al., 2007) and positive role models in STEM careers (Ericksen and Schultheiss, 2009).

Our position is that PYD sports model has specific skill building steps that work to increase self-efficacy and provide positive contextual factors. It does not replace theories such as SCCT or how STEM is integrated into curriculum (Moore et al., 2020), it sets up positive skill building opportunities for females. The PYD model focuses on strengths and assets for developmental growth rather than focusing on problems (e.g., Holt et al., 2007, 2012). A sports-based PYD model is multifactorial and involves appropriate role models, programs promoting life skills and positive peer and parent influence. PYD programs provide opportunities for youth to flourish in the future by instilling positive qualities (Gould and Carson, 2008). With this approach, PYD components in STEM could offer opportunities for increasing the number of females that pursue STEM careers.

Increasing diversity in STEM: sport as a model

Performance anxiety and exposure

A contributing factor currently affecting female students' feeling of control with STEM learning is math anxiety since it is directly related to math performance (Stoet et al., 2016) and this anxiety needs to be addressed when looking to increase the number of students in STEM (Foley et al., 2017). It has been validated that in multiple countries females have greater math anxiety than males (Haynes et al., 2004; Stoet et al., 2016). Increased math anxiety could account for math avoiding behaviors and lack of intent to enter a STEM field (Wang, 2013; Stoet et al., 2016). STEM exams are analogous to sport performances because each requires applying skills to unique situations under pressure. For example, in a math exam students need to use "algorithmic reasoning" as opposed to "memorized reasoning" (Bergqvist, 2007). There is a need to recognize and apply the correct algorithms to a problem the student has not seen before. In physics students use mechanistic reasoning to explain how the parts make up the properties of the whole (Hung and Jonassen, 2006) and in chemistry use multiple molecular representations (Avargil and Piorko, 2022). Similarly, an athlete will have to respond to competition situations using algorithmic and mechanistic reasoning. What can keep an athlete grounded in their conviction to succeed is previous experience and positive practice scenarios. Duncan et al. (2017) recommend reducing anxiety by simulating a competition during practice time. It has been shown that math anxiety can be lowered by tutoring lessens (Supekar et al., 2015), supplementary exercises that enhance math strategies (Passolunghi et al., 2020), or an intensive digital training (Ng et al., 2022).

Positive role models and identity

Positive role models have been identified as an important factor in increasing and/or maintaining physical activity in adolescence (Young et al., 2015). Lack of positive roles models in sport for adolescent females has been recognized in a number of countries, including Canada, as a barrier to sport participation (e.g., Casey et al., 2009; Bélanger et al., 2011). A positive role model in sport for an adolescent female is most likely associated to the gender the student identifies with Young et al. (2015) and who models a sport-based PYD model. From this validated link between role models and sport participation (Young et al., 2015) and the current research within STEM fields that indicates there are too few positive role models for adolescent females (Steinke et al., 2008; Cheryan et al., 2011, 2015) we can assume that increasing role models will be key to engagement of females in STEM.

Both environment and role models influence students' identity. In sport, feeling that you belong in the environment and seeing other girls and women participate in the sport contribute to perceptions that girls play sports. This visible connection is not overt in school classrooms. Although researchers have found that general academic achievement influences identity (Matthews et al., 2014), and that individual identity can by precluded by the identity expected by their social groups at school (Islam, 2014). Kim et al. (2018) argues that a STEM identity is "socially based identity grounded in the extent to which individuals see themselves and are accepted as a member of a STEM discipline or field" (Kim et al., 2018). The classroom environment does not consistently promote positive STEM identity and many classroom environments lack diversity, role modeling and teacher preparedness which are needed for building STEM identity. In team sport, a collective identity can emerge and these identities can "influence expectations for success" (Eccles, 2009) and these collective identities are especially important to underrepresented groups (Malorni et al., 2023). Similarly, research shows female students find that a personal connection to what they perceive as a STEM "community" helps them develop the perception "they belong" in STEM (Saville et al., 2023) and this belonging leads to positive affect (Alivernini et al., 2023). Young women who have a strong STEM identity attribute their positive STEM beliefs from having connections with instructors and finding a culture where they feel they belong (Saville et al., 2023). Peer groups who are supportive of STEM positively influence STEM career interest (Robnett and Leaper, 2013) and the personal interactions [with instructors] has a greater effect on STEM self-efficacy than actual performance levels (Skipper and Leman, 2017).

Motivation and mastery

It was identified that adolescent females with low self-esteem might identify easier with female coaches and more readily internalize their positive talk compared to male coaches (Coatsworth and Conroy, 2006). This identification is important since girls normally show lower ratings of self-esteem and self-concept than boys in middle and high school (Mahaffy, 2004). A study on motivational climate found that gender of a coach was a predictor of an athlete's perception of motivational climate, where female coaches were more greatly associated with mastery of motivational climate compared with male coaches (Vazou, 2010). This study also noted that female athletes tend to perceive more mastery involving cues compared to males possibly due to difference in measures of competence and socialization found between genders (Vazou, 2010). Mastery goals are those that focus

on skill development. The student's aim is to improve their skill rather than the outcome of an exam. Performance goals lead to better achievement of simple tasks, whereas mastery goals facilitate attainment on challenging tasks (Senko, 2019). This is important for STEM because of the algorithmic reasoning needed to successfully work through STEM exam problems. A mastery-oriented classroom is created by the nature of the tasks (mastery focus), involving students in decision making, types of evaluation, and classroom climate" (Furner and Gonzalez-DeHass, 2011). A mastery climate creates higher levels of engagement (Curran et al., 2015) which is necessary for girls to be interested in STEM and can have "a buffering effect on stereotype threat" (Deemer, 2004).

Sport coaches can impact youth positively and negatively depending on their created motivational climate (Schaillée et al., 2017; Cronin et al., 2022). A sport coach who facilitates mastery motivational climate elicits PYD by encouraging factors such as effort and individual improvement (Schaillée et al., 2017). A sport coach who facilitates performance can elicit negative effects by encouraging factors such as social comparison (Schaillée et al., 2017). Parallels of positive and negative engagement were also observed in science classrooms. Shumow and Schmidt (2013) reported that in science classrooms where students had two types of goals, mastery goal orientation or performance approach goal orientation, these were largely determined by the teacher's goal orientation approach that they used with their students.

Peers and mastery climate

Peer motivational climate likely has a stronger influence on athletes' personal approach to development than coaches or parents due to the reduced power imbalance among peers compared to coaches and parents (Smith et al., 2010). It has been reported that peer performance motivational climate is associated with burnout in sport (Smith et al., 2010) and that peer mastery motivational climate is associated with positive character and support for teammates (Agans et al., 2018). Jõesaar et al. (2012) found that peer mastery motivational climate can be enhanced by having autonomy support from coaches whereby athletes perceive their coach understands their perspective and provides them choices in decision making. Therefore, coaches who promote peer mastery motivational climate with autonomy support increase motivation (Cronin et al., 2022). Applied to STEM, teachers who promote peer mastery climate with autonomy support may increase female students' intrinsic motivation for STEM as seen in sport (Jõesaar et al., 2012).

Students also learn mastery focus when they are able to use skills in applied situations. For example, Bressler et al. (2022) gave one group traditional instruction and a second group a game design task. The game design group focused more on learning goals and were mastery-oriented while the group receiving traditional instruction remained performance-oriented (Bressler et al., 2022). The cross application from sport is convincing (Meece et al., 2006; Curran et al., 2015), if STEM teachers promote mastery motivational climate, more female students may feel in control of their learning and thereby have increased confidence and determination.

Discussion

Implications for practitioners

To create a more positive climate in STEM environments, educators can adopt aspects from sports-based PYD programs by focusing on mastery and creating an opportunity for girls to participate in a community of learning. Applying positive aspects of sport to STEM classrooms will help foster strong STEM identities in young adolescent girls (Saville et al., 2023). We recommend the development of STEM curriculum and classroom conditions that integrate aspects of PYD that focus on mastery, reduce anxiety by exposure, role models and supportive peer environments.

A focus on mastery can be done by emphasizing effort as well as individual and team progress when assessing assignments and preparing for tests and examinations. Students might be more accepting of assessment outcomes when they conceptualize using maximum effort that identifies effort placed within and learning achieved on the students part, within realization of outcome marks relative to competencies or rubrics. This might contribute to utilization of skill development in learning to accept error as part of academic learning and advancement. The research strongly suggests that creating peer support by working in teams and providing role-models positively influences adolescent girls' STEM identity (Cheryan et al., 2011; Young et al., 2015). Which is why we recommend including more team-based assignments that require multiple iterations so that trial and error are expected. This will also reduce anxiety by exposure to STEM by practice and build test taking strategies. Utilizing exploratory and fun ways to practice STEM concepts in addition to traditional learning methods will also increase exposure to STEM by practice. Practice could include STEM video games such as an augmented reality of chemical structures (Tarng et al., 2022). Finally, fostering a welcoming and inclusive environment by creating spaces that reflect more of the girls' interests (Saville et al., 2023) will be important to create a sense of belonging in STEM.

Implications for future research

Future research on these aspects of a PYD sports model needs to focus on which practice for performance strategies are most effective and how best to structure group activities and projects to promote mastery. For example, the effectiveness of using video games to learn mastery can be tested against or simultaneously with traditional instruction. Future research can also assess how well role models can implement autonomous coaching strategy in STEM settings. Finally, researchers need to look at the efficacy of interventions to create a sense of belonging in STEM for girls/women and other under-represented persons in STEM and determine if changes to the STEM learning environment can increase a sense of positive STEM identity.

Author contributions

CC conceptualized and lead the writing process. JJ, HT-S, and SC conceptualized the sport and STEM interaction and

contributed to the writing process. All authors contributed to manuscript revision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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