EMPIRICAL RESEARCH

Socially Anxious Science Achievers: The Roles of Peer Social Support and Social Engagement in the Relation Between Adolescents' Social Anxiety and Science Achievement

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Abstract

Socially anxious youth are at an increased risk for academic underachievement, withdrawal from school, and negative peer relationships. Given that learning tasks in science classes rely heavily on peer collaboration and social skills, this study aimed to investigate the link between high-school adolescents' social anxiety and their science achievement while also determining whether and how peer social support and social engagement mediated the relation. Data was collected from 805 high-school students (48.7% female; 30.9% in 9th, 24.0% in 10th, 25.3% in 11th, 19.8% in 12th grade; 51.2% White, 29.8% Black, 11.4% Biracial, 7.6% Other). The results showed that socially anxious adolescents were more likely to report lower social engagement, which in turn predicted lower science performance. In addition, adolescents with social anxiety tended to experience less peer social support, which led to lower social engagement and subsequent lower science performance. These findings have important implications for guiding teaching practice and school-based interventions that support socially anxious adolescents in learning tasks.

Keywords Social anxiety · Social engagement · Peer support · Science achievement · Student engagement

Introduction

Social abilities, peer relationships, and school engagement are essential for adolescents' academic and psychological wellbeing (Wang et al. 2019; Wang and Hofkens 2019). During adolescence, the school context becomes a primary setting where youth continue to develop social competencies through daily interactions with peers and engagement in classes. A problem arises, though, when an adolescent lacks the necessary skills to successfully navigate social demands within the classroom environment. Not only do under-developed social skills interfere with an adolescent's ability to form and maintain close peer relationships (Tillfors et al. 2012), but they also contribute to academic disengagement, especially in subjects characterized by collaborative work (Osborne 2010). For example, science-related learning tasks often center around problem-solving, teamwork, and communication, thus simultaneously fostering science engagement and providing opportunities for social growth (Osborne 2010; Smith et al. 2009). Much like a youth's reading ability can affect their ability to solve word problems in math, a youth's social ability may preclude their science performance because of social competencies embedded within a given science-related task.

One of the primary contributors to adolescent social shortcomings is *social anxiety*, or intense fear or unease related to others' scrutiny in social situations (e.g., social interactions, being observed, performing in front of others (American Psychiatric Association (APA), 2013). According to de Lijster et al.'s (2018) systematic review, problems in academic and social functioning culminate during adolescence, thus contributing to the development of social anxiety. In fact, social anxiety disorder represents one of the most common and pervasive mental health challenges posed toward young adolescents, with the most recent data from the National Institute of Mental Health showing a 9.1% prevalence rate in US adolescents ages 13–18, with 1.3% experiencing severe impairment (Merikangas et al. 2010).

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Social anxiety interferes with the development of pro-social skills and acquisition of close peer relationships during adolescence, thereby placing these youth at risk for procuring poor social skills, experiencing low-quality friendships, and disengaging from academic work. Indeed, researchers have found that socially anxious youth have social skill deficits and poor interpersonal relationships with others (Motoca et al. 2012; Tillfors et al. 2012), and although findings regarding the relation between social anxiety and achievement have been mixed, socially anxious youth do report feeling that anxiety impairs their ability to function optimally within the school setting (de Lijster et al. 2018). In fact, very little is known about the mechanisms by which social anxiety influences science achievement. As such, the current study examines whether social anxiety predicts science achievement during adolescence and to what extent peer support and social engagement mediate the link between social anxiety and science achievement.

Theoretical and Empirical Framework

Self-system theory contends that human motivation is a function of three universal, innate basic psychological needs (Skinner and Pitzer 2012): the need for competence (i.e., the feeling that one is capable), the need for relatedness (i.e., the feeling of being connected to others), and the need for autonomy (i.e., the feeling of independence). Studies have shown that when these psychological needs are met, youth are more likely to internalize their motivation, engage in their studies, and value academic tasks (Niemiec and Ryan 2009; Skinner et al. 2008).

The need for relatedness carries particular weight for those studying adolescents' science engagement and achievement, as relatedness affects many aspects of an adolescent's academic and social experiences (Skinner and Pitzer 2012). Scholars have found that students' feelings of relatedness predict their academic achievement and correlate with their expectations for success, interest in academic material, perception of competence, and both emotional and behavioral engagement (Juvonen et al. 2012; Skinner and Pitzer 2012). Relatedness also serves as a protective factor against negative emotions (e.g., boredom, anxiety, frustration, and stress), and engaged, higher performing students tend to elicit more support from teachers, parents, and peers, which then increases future feelings of relatedness (Furrer and Skinner 2003). Conversely, students who feel as though they do not belong or have difficulty relating to those around them are more likely to have fewer experiences with competence and lower academic achievement than their more socially regulated peers (Wang and Holcombe 2010). These socially disconnected youth have also reported difficulties becoming constructively involved in their coursework, hence causing further social alienation and a decreasing

readiness to learn (Rice et al. 2013). In sum, student relatedness and engagement exist together in a positive feedback cycle in which relatedness prompts engagement, which in turn prompts future feelings of relatedness.

The Role of Social Anxiety in the Science Classroom

Social anxiety and academic achievement

One of the most significant barriers to fulfilling the need for relatedness is social anxiety. Researchers have found that social anxiety interferes with a person's ability to relate to others (Biggs et al. 2012; Tillfors et al. 2012). With social interactions representing a major hallmark of adolescent development, social anxiety not only forms a barrier to youth's social development, but it also undermines their ability to engage academically, especially in courses reliant on peer interaction and cooperation (de Lijster et al. 2018).

While researchers have looked at a general state of anxiety and schooling-specific anxiety (e.g., school phobia), few studies have focused on the relation between *social* anxiety and academic achievement. It can, however, be extrapolated from existing literature that a direct or indirect negative relation may exist between generalized anxiety (i.e., non-specific types of anxiety) and academic achievement, as anxiety has been associated with poor educational attainment and dropping out (de Lijster et al. 2018). In fact, one study found that 24% of students who had dropped out of high school cited anxiety as their primary reason for doing so (Van Ameringen et al. 2003).

Given that it particularly affects students' interactions with peers, several plausible mechanisms may explain social anxiety's relation to academic achievement. For instance, some researchers have attributed the link between anxiety and academic achievement to difficulties with attention and perceived risk (see de Lijster et al. 2018). Moreover, socially anxious students may be more prone to underachievement due to their unwillingness to solicit help from classmates or teachers (Erath et al. 2007). It remains unclear, though, whether this same explanation holds true for middle- or high-school students, and unfortunately, little extant research has explored how social anxiety may affect adolescents' academic achievement. Research has shown that students learn best when material is taught in an active style that promotes peer collaboration and small group work (Smith et al. 2009); yet, there is a pressing need to understand the processes by which social anxiety affects academic engagement and achievement, especially in subject domains where peer collaboration and group work set the stage for academic success.

The science classroom, then, becomes an environment laden with social consequences for the budding adolescent. Science learning involves generating analogies, metaphors,

problems, and models that build meaningful connections between new and old information, and peer interactions and group discussions have long been instructional tools that capitalize on the cooperative, collaborative nature of science as a discipline (Osborne 2010). By participating in these activities, students learn high-level cognitive concepts and have opportunities to engage in questioning, explaining, and elaborating (Smith et al. 2011); however, these techniques require students to have a certain aptitude for prosocial interactions. As such, those without the skills to form questions, entertain others' ideas, or feel comfortable enough to speak up in a group may fall behind in their problem-solving abilities and overall science achievement (Smith et al. 2009, 2011).

Because of the deleterious effects associated with generalized anxiety and generalized academic achievement, it is reasonable to postulate that social anxiety may interfere with success in science classrooms where achievement is predicated on a students' prosocial abilities. For example, one study found that the rate of participation during in-group discussion was central to students' scientific learning during collaborations (Osborne 2010). In other words, the more a student took part in peer discussion, the more that student consequentially learned. While many factors influence students' science participation (e.g., SES, gender, personality), students who are introverted, experience anxiety, or feel uncomfortable in a given classroom situation are less likely to fully participate in group discussions or collaborative activities (Oliveira and Sadler 2008). As such, social anxiety nefariously festers within the socially saturated science classroom, thereby posing a threat to participation, productivity, and overall science learning.

Social anxiety, peer social support, and academic achievement

Social support from others is a central element of the developmental trajectory traversing middle childhood and adolescence. Coinciding with advances in cognitive and emotional development that allow for increased perspective taking and heightened emotional intelligence (Byrnes 2006; Rosenblum and Lewis 2006), middle- and high-school youth begin the processes of developing stable friendships (Brown and Klute 2006), exploring the challenging world of romantic relationships (Bouchey and Furman 2006), and constructing their own sense of identity (Nakkula and Toshalis 2013). Likewise, adolescence marks a period during which social competencies carry increasing importance, thus affecting adolescents' abilities to form and maintain peer relationships (Wentzel 2012). In turn, these peer relationships aid in the development of further prosocial behaviors, school engagement, and academic achievement (Li et al. 2011; Wang et al. 2018).

Researchers have indicated that social anxiety interferes with the development and maintenance of healthy peer relationships in adolescence, finding that social anxiety is related to difficulties with prosocial interactions that lead to fewer positive peer interactions and subsequent barriers to social development (Motoca et al. 2012). Indeed, socially anxious adolescents report having few friendships, low levels of peer support, and high levels of peer victimization (de Lijster et al. 2018), three factors that in tandem contribute to negative social experiences. For example, an adolescent's socially anxious behaviors—such as the inability to maintain eye contact or withdrawal from social contexts—may be perceived as irritating or uncomely, therefore contributing to decreased peer acceptance and increased peer victimization (Tillfors et al. 2012). When the socially anxious adolescent encounters negative affect in response to their attempts to be prosocial, they are discouraged from future attempts at prosocial interactions (Biggs et al. 2012). As such, youth with social anxiety often sink deeper into social withdrawal with each rebuffed attempt at being prosocial, as the demonstration of awkward or uncouth social behavior decreases the quality and quantity of peer relations (Greco and Morris 2005).

As can be seen, behaviors associated with social anxiety can influence peer social support or interpersonal relationships with peers (Tillfors et al. 2012). In addition, peer social support may serve as a mediator between social anxiety and academic achievement, as students who experience support and acceptance from their peers are more likely than their lesser-supported classmates to experience gains in both academic effort and achievement (Wang and Eccles 2012, 2013; Li and Lerner 2013). Because individuals with social anxiety harbor deficits in social development, socially anxious adolescents may experience poor peer social support, which in turn may lead to suboptimal academic achievement. When considering the science classroom (i.e., a context in which success often hinges on students' ability to interact in a prosocial manner), peer social support may influence the likelihood of current and future engagement and achievement in science-related tasks and professions (Wang et al. 2019). Hence, it is paramount for researchers to poise peer social support as a mediating variable between student social anxiety and science achievement.

Social anxiety, social engagement, and academic achievement

Relatedness serves as a primary psychological need fulfilled by meaningful relationships, and for adolescents especially, needs for relatedness are often met in the school context through their social engagement (Wang and Hofkens 2019; Wentzel 2012). *Social engagement* refers to the extent to

which adolescents are motivated to interact with others and value their interpersonal relationships (Wang and Hofkens 2019). It involves adolescents' willingness to invest in the interaction, formation, and maintenance of relationships with teachers and peers at school. To be clear, social engagement differs from peer social support in that it refers to the act of being socially involved in the classroom, while peer social support refers to the feelings of being accepted and supported by one's peers (Wang and Hofkens 2019). While researchers have found associations between these constructs (i.e. students who feel accepted by peers are more likely to engage; Li et al. 2011; Ryan and Shin 2011), it is possible that a student can feel that they have elevated levels of peer social support without being socially engaged in the classroom. For example, a student may feel supported by their peers, but remain uninterested in the content of the class, which leads the student to disengage from the material.

Researchers have revealed that social engagement is tightly linked to adolescents' academic and socio-emotional wellbeing, as adolescents who are socially engaged tend to have more advanced social competencies, such as conflict-resolution skills and knowledge of what constitutes appropriate social interactions (Kiefer and Ryan 2011). For example, Furrer and Skinner (2003) examined relatedness between students and peers, parents, and teachers, finding that engagement in these social relationships correlated with better academic performance and increased psychological coping mechanisms. Additionally, social engagement benefits a student's socio-emotional well-being by providing outlets to deal with stressors and increasing feelings of connectedness and belongingness to the school setting itself (Juvonen et al. 2012).

While the research on social anxiety and social engagement is limited, some scholars have suggested that the symptoms of social anxiety may affect a student's social engagement. For example, students with social anxiety often report having difficulty talking in front of the class or feeling anxious while in class (Van Ameringen et al. 2003). Since social anxiety includes both difficulties in peer interactions and fears of being evaluated negatively, students with social anxiety often present low levels of social engagement (Christenson et al. 2012). In particular, students with social anxiety may exhibit withdrawal behavior in the classroom by avoiding certain types of social engagement (Biggs et al. 2012), such as participating in small group discussions or asking peers and teachers questions.

Social engagement may also mediate the relation between social anxiety and academic achievement such that symptoms of social anxiety cause students to become less socially engaged in the classroom. Lack of social engagement, then, would lead to lower academic achievement. Although social engagement has not yet been tested in this

particular mediation role, researchers have looked at the role of anxiety and stress in relation to engagement: There is a link between psychological distress, engagement, and achievement such that distress is negatively associated with school engagement, thus contributing to poor academic achievement (Roeser et al. 2002). Moreover, recent literature has touted the importance of social engagement within the school context, presenting the concept as a niche component of academic engagement with direct implications for overall student academic achievement (Wang and Hofkens 2019). In doing so, the previously uncelebrated role of social engagement shows promise as a viable intervention target to help students struggling to meet relatedness needs, which in turn may help students bolster peer support networks as well as their ability to achieve academically.

The Current Study

While many studies have explored the relations between school engagement and achievement, this study proposed a more nuanced view of engagement by examining the roles of peer social support, social engagement, and social anxiety in science classrooms. Of particular note is the dearth of research examining the role of social anxiety in the science classroom, especially considering the consequences posed to socially anxious youth when confronted with primarily social academic tasks (e.g., lab work with partners). While some researchers have examined the role of social anxiety in college classrooms (e.g., Brook and Willoughby 2015), few have examined science classrooms in middle or high schools. As such, it is imperative that the influence of social anxiety on academic achievement, peer social support, and social engagement be studied in adolescents due to the risk of social anxiety increasing at the same time relatedness becomes central to positive youth development. Given the role of social engagement and peer social support in promoting academic performance in classroom settings (Wang and Hofkens 2019), examining both constructs as mediators between social anxiety and academic achievement would present a pathway for intervention that bolsters both engagement and achievement in socially anxious youth.

This study examined the link between adolescents' social anxiety and science achievement and whether the link was mediated by adolescents' peer social support and social engagement. Three specific hypotheses were proposed in this study. The first hypothesis was that social anxiety would be negatively associated with science achievement either directly or indirectly. The second hypothesis positioned social engagement as a mediator between social anxiety and science achievement in consideration of evidence showing that social anxiety was associated with poor social skills and fear of interacting

with peers (Biggs et al. 2012; Erath et al. 2007). The third hypothesis illustrated peer social support as a mediating variable, given that social anxiety was related to lower levels of peer social support. In other words, it was predicted that students experiencing higher levels of social anxiety would be more likely to experience low peer social support, which would then lead to lower science grades.

Methods

Participants

Participants were high-school students enrolled in a large-scale longitudinal research project examining the role of contextual and motivational factors on student engagement. The sample included 805 ninth- (30.9%), tenth- (24.0%), eleventh- (25.3%), and twelfth-grade students (19.8%; 48.7% female; 51.2% White, 29.8% Black, 11.4% Biracial, 7.6% Other; 59.2% qualified for free/reduced price lunch; ages ranging from 14–18 years old) from three public high schools in the Mid-Atlantic region of the United States.

Procedure

All participants were invited to take part in the study using school-based recruitment. At each school, the researchers discussed the study with science teachers and received their consent accordingly. These science teachers distributed consent forms informing students and parents about the study's purpose and procedures. More than 98% of eligible participants consented to the study, with participant rates being equal across grades. Participating students completed computer-based surveys that took approximately 45 minutes to complete. To accommodate for potential literacy issues, all survey questions were audio-recorded, and headphones were made available to students. Research staff were present and available during the survey administration to address any student questions about the survey's purpose or content. In appreciation of their time and participation, research staff provided students with a small gift after completing the survey.

Measures

Social anxiety

Students' social anxiety was assessed using the widely used and well-validated Social Phobia subscale of the *Screen for Child Anxiety-Related Disorders* (SCARED; Birmaher et al. 1997, 1999). This six-item, self-report subscale measured the degree to which students experience social anxiety on a five-point Likert agreement scale (1 = *not true at all*; 5 = *very true*; α = 0.91), with example items such as "I feel

nervous with people I don't know well," and "I feel nervous when I am with other children or adults and I have to do something while they watch me".

Peer social support

Peer social support was measured using the Peer Social Support subscale from the *Classroom Life Measure* (Johnson et al. 1983). The subscale has received adequate reliability and validity in prior studies (Rowe et al. 2010). This five-item, self-report subscale measured the degree to which students experience social anxiety on a five-point Likert agreement scale (1 = *not true at all*; 5 = *very true*; α = 0.87), with example items such as "In science class, other students care about my feelings," and "I can count on other students for help when I need it in science class".

Social engagement

Social engagement was measured using the four-item *Science Social Engagement Subscale* (see Wang et al. 2019). This scale was developed and validated using a sequential mixed-methods design. The authors conducted open-ended interviews with secondary-school science teachers and student focus groups to learn how they conceptualized social engagement. From the qualitative data, the authors developed survey items and the final items of social engagement were refined based on the measurement model. This scale specifically measured students' engagement with their peers and teachers in the classroom context using a five-point Likert agreement scale (1 = *not true at all*; 5 = *very true*; α = 0.73), with items such as "When working with others, I don't share my ideas," and "I don't ask for help even if I need it".

Science achievement

Students' cumulative science course grade and science standardized test scores were collected from the school records to represent indicators of science achievement. The test scores were recalibrated to a scale of 0–100, with a mean of 50 and a standard deviation of 10, and the scores across years are directly comparable.

Covariates

Student demographic characteristics were obtained from school records (e.g., adolescents' race, gender, and free or reduced-price lunch status). Missing race and gender information were supplemented by adolescents' self-reports. All models included adolescents' gender (1 = *boy*; 0 = *girl*), race (1 = *White*; 0 = *racial minority*), grade level, prior science achievement, free or reduced-price lunch

status (1 = free/reduced price lunch; 0 = paid lunch), and science class.

Analytic Plan

Path analysis was used to examine whether the association between social anxiety and science performance was mediated by social engagement and peer social support in the science classrooms (i.e., whether the effect of social anxiety in the fall on the science course grade at the end of the school year was mediated by social engagement and peer social support in the spring). The distribution-of-the-product approach was used as a valid, robust approach to test indirect effects (MacKinnon et al. 2002, 2004). Specifically, RMediation developed by Tofighi and MacKinnon (2011) was used to implement the approach which produces the confidence interval for an indirect effect based on the point and standard error estimates of the coefficients that constitute the indirect effect. If the confidence interval did not include zero, then the indirect effect was significant.

All analyses were conducted in *Mplus 8.3* (Muthén and Muthén 1998–2019). Because of the clustering nature of the data (e.g., students nested within science classrooms) and the study's focus on student-level effects, the authors used "Type = complex" command in *Mplus* along with robust maximum likelihood estimation method (MLR). This method corrects the standard errors of the model parameters for the clustering effects. In addition, MLR is a full information maximum likelihood method which accommodates missing at random data by incorporating missing data patterns in the model estimation process without deleting any incomplete cases (Yuan and Bentler 2000).

Results

The descriptive statistics for the continuous variables and the correlations among the key variables and covariates are shown in Table 1.

Main Effect

According to Fig. 1, adolescents' social anxiety did not predict science course grades ($b = 0.03$, $SE = 0.04$, $p = ns$) or science standardized test scores directly ($b = 0.02$, $SE = 0.04$, $p = ns$).

Mediation Effect

Social engagement as the mediator

As shown in Fig. 2, adolescents' social anxiety was associated with lower social engagement (model with science

Table 1 Descriptive statistics and zero-order bivariate correlations among key study variables

		1	2	3	4	5	6	7	8	9	10
1	Race	1									
2	Gender	0.04	1								
3	SES	−0.47**	−0.01	1							
4	Grade Level	−0.04	0.03	0.10**	1						
5	Science Grade (one-year prior)	0.45**	−0.18**	−0.41**	−0.18**	1					
6	Social Anxiety	−0.04	−0.09**	0.07*	−0.04	−0.03	1				
7	Social Engagement in Science	0.23**	0.02	−0.23**	0.04	0.28**	−0.13**	1			
8	Social Support in Science	0.28**	−0.02	−0.24**	0.01	0.29**	−0.12**	0.34**	1		
9	Science Course Grade	0.39**	−0.19**	−0.33**	−0.01	0.62**	0.03	0.29**	0.29**	1	
10	Science Test Score	0.40**	−0.05	−0.46**	−0.36**	0.60**	0.01	0.28**	0.29**	0.61**	1
	Means (SD)	0.55 (0.50)	0.51 (0.50)	0.59 (0.49)	10.34 (1.11)	80.09 (13.33)	2.65 (1.08)	3.33 (0.97)	3.22 (1.00)	75.60 (13.75)	1482.87 (60.39)

*$p < 0.05$; **$p < 0.01$

course grades: $b = -0.16$, $SE = 0.05$, $p < 0.01$; model with science standardized test scores: $b = -0.16$, $SE = 0.05$, $p < 0.01$). In addition, greater social engagement was associated with higher science course grades ($b = 0.20$, $SE = 0.05$, $p < 0.001$) and higher science standardized test scores ($b = 0.21$, $SE = 0.05$, $p < 0.001$). As a result, there was a significant indirect effect of social anxiety on science performance through social engagement (model with science course grades: $b = -0.03$, $SE = 0.01$, $p < 0.05$, 95% CI [−0.06, −0.01]; model with science standardized test scores: $b = -0.03$, $SE = 0.01$, $p < 0.01$, 95% CI [−0.06, −0.01]). Specifically, social anxiety was linked to lower social engagement, which in turn was linked to poorer science performance.

Peer social support as the mediator

Models fit the data perfectly. As shown in Fig. 2, adolescents with higher social anxiety tended to receive lower peer social support (model with science course grades:
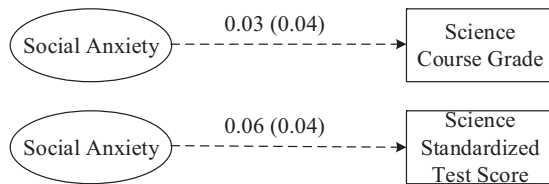
Fig. 1 The direct link between social anxiety and science performance

$b = -0.14$, $SE = 0.05$, $p < 0.01$; model with science standardized test scores: $b = -0.14$, $SE = 0.05$, $p < 0.01$). Peer social support was not associated with science performance (model with science course grades: $b = 0.10$, $SE = 0.07$, $p = ns$; model with science standardized test scores: $b = 0.09$, $SE = 0.05$, $p < 0.10$). As a result, peer support did not mediate the association between social anxiety and science performance.

Peer social support and social engagement as sequential mediators

Although peer social support was not found to mediate the association between social anxiety and science performance, there was a significant indirect effect of social anxiety on science performance through peer social support and then social engagement (model with science course grades: $b = -0.01$, $SE = 0.00$, $p < 0.05$, 95% CI [−0.02, −0.002]; model with science standardized test scores: $b = -0.01$, $SE = 0.00$, $p < 0.01$, 95% CI [−0.02, −0.003]). In other words, social anxiety was linked to lower peer social support and then to lower social engagement, which in turn was linked to lower science performance (see Fig. 3).

Fit indices and post-hoc analyses

The indices for model examining science course grades as the outcome indicate that the model fit the data well:
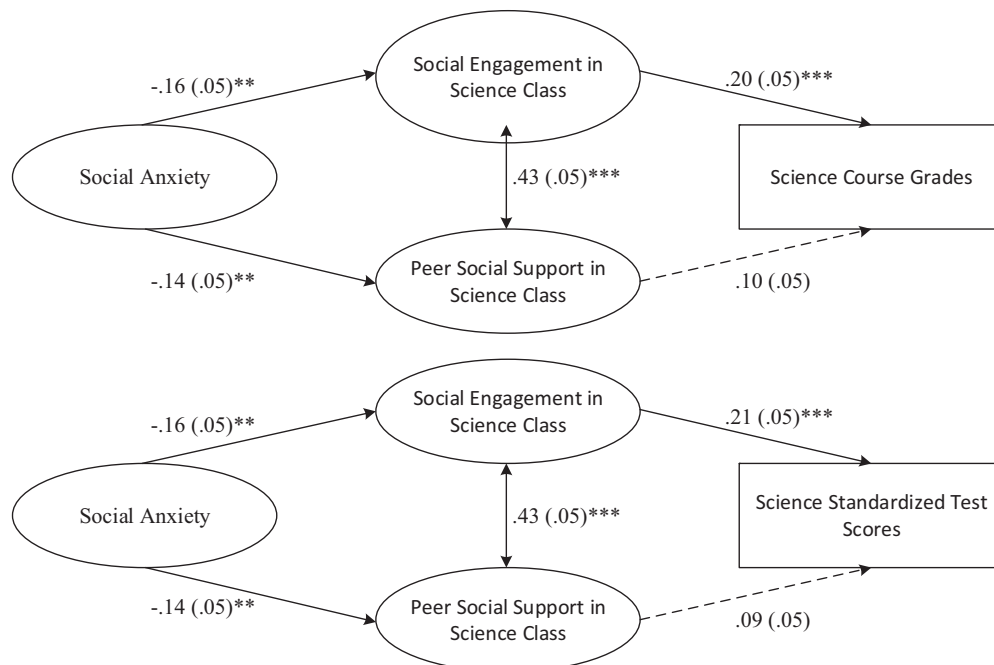
Fig. 2 The mediation model with social engagement and peer social support as co-occurring mediators. Specific indirect effect via social engagement: $b = -0.03$, $SE = 0.01$, $p < 0.05$, 95% CI [−0.06, −0.01]; specific indirect effect via social engagement: $b = -0.03$, $SE = 0.01$, $p < 0.01$, 95% CI [−0.06, −0.01]. **$p < 0.01$, ***$p < 0.001$
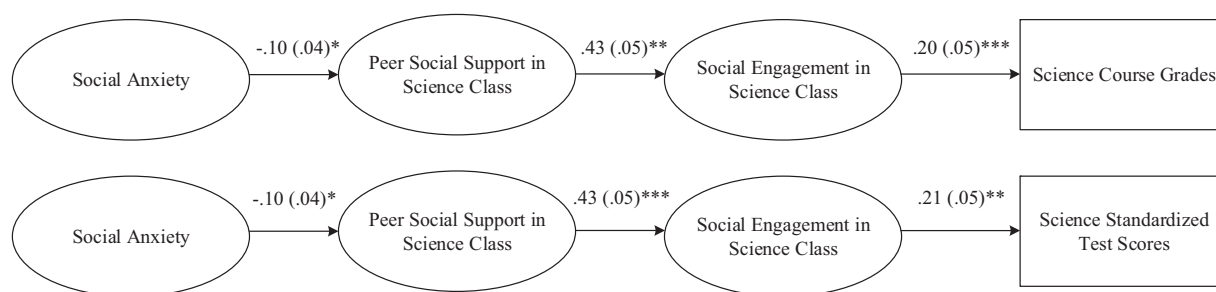
Fig. 3 The mediation model with peer social support and social engagement as sequential mediators. Specific indirect effect via peer social support and social engagement: $b = -0.01$, $SE = 0.00$, $p < 0.05$, 95% CI [-0.02, -0.002]; specific indirect effect via peer social support and social engagement: $b = -0.01$, $SE = 0.00$, $p < 0.01$, 95% CI [-0.02, -0.003]. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

χ^2 (155) = 573.67, $p < 0.001$, RMSEA 0.06 90% CI [0.05, 0.06] CFI 0.92 TLI 0.91 SRMR 0.08. Multi-group analyses examining whether gender and grade level moderated the observed pathways did not result in a significant improvement in model fit [gender: $\Delta\chi^2$ (3) = 2.18, $p = ns$; grade level: $\Delta\chi^2$ (9) = 11.37, $p = ns$), suggesting that neither demographic category emerged as a significant moderator.

The indices for model examining science standardized test scores as the outcome indicate that the model fit the data well, χ^2 (155) = 583.12, $p < 0.001$, RMSEA 0.06 90% CI [0.05, 0.06] CFI 0.92 TLI 0.91 SRMR 0.09. Multi-group analyses examining whether gender and grade level moderated the observed pathways did not result in a significant improvement in model fit [gender: $\Delta\chi^2$ (3) = 2.01, $p = ns$; grade level: $\Delta\chi^2$ (6) = 7.77, $p = ns$), suggesting that neither demographic category emerged as a significant moderator.

Discussion

Social anxiety poses a significant threat to prosocial development during adolescence, and this threat has consequences for academic participation and performance (de Lijster et al. 2018), especially in science classrooms where cooperation, participation, and deliberation are inherent to the learning process (Osborne 2010). Not only does social anxiety jeopardize active participation in science classrooms, it also affects youth's overall social engagement in school as well as their likelihood of having a positive peer support network (Biggs et al. 2012; Motoca et al. 2012; Tillfors et al. 2012). To better understand how these variables affect science learning, this study examined the mediating roles of peer social support and social engagement in the relation between social anxiety and science achievement.

Although social anxiety did not have a direct effect on science performance, results indicated a negative association between adolescents' social anxiety and their social engagement and peer social support in science class (see Fig. 2). In addition, the link between social anxiety and science performance was mediated by social engagement:

Socially anxious adolescents were more likely to report lower social engagement, which was then linked to lower science performance. Finally, peer social support and social engagement performed as sequential mediators, meaning that adolescents with higher social anxiety tended to experience less peer social support, when then led to lower social engagement and subsequent lower science performance (see Fig. 3).

Social Anxiety and Science Achievement

Because of the harmful effects associated with generalized anxiety on generalized academic achievement (see de Lijster et al. 2018), it seemed reasonable that social anxiety would directly interfere with success in science classrooms, as achievement in these environments is often predicated on a students' prosocial abilities (Wang et al. 2019). Results indicated that social anxiety only indirectly predicted science performance through social elements of the science classroom, namely peer social support and social engagement during science-related tasks. Given that social interactions are a major hallmark of adolescent growth, it is developmentally apropos that social anxiety would serve as a barrier to developing a healthy, supportive peer group that later affects social engagement and academic achievement.

Social Anxiety, Social Engagement, and Science Achievement

While social anxiety negatively correlated with both social engagement and peer social support, only social engagement mediated the relation between social anxiety and science achievement. When a student's relatedness needs are met through prosocial peer interactions, they develop social skills necessary for school engagement, the formation of friendships, and academic achievement, thus naturally supporting their ability to develop competence and autonomy (Niemiec and Ryan 2009). Students with social anxiety, though, have difficulty socially engaging with others even in the most innocuous of settings, often feeling

pressure as if they were performing in front of or being critiqued by others (APA 2013). Moreover, adolescents with social anxiety have difficulty initiating conversations and seeking out social opportunities with peers because of general discomfort in social situations (Biggs et al. 2012). It is plausible to assume, then, that school-related tasks involving social interaction would provoke uneasy feelings from a youth suffering with social anxiety, resulting in a lower level of social engagement than their less socially anxious peers. In particular, science achievement requires participation in learning tasks that involve peer collaboration, questioning, and elaboration, lest the student jeopardize their full understanding of higher-level science concepts (Osborne 2010). Therefore, students with higher social anxiety experience lower levels of social engagement in science-related tasks, which in turn results in lower science achievement scores.

Social Anxiety, Peer Social Support, Social Engagement, and Science Achievement

The third prediction situated peer social support alongside social engagement as a concurrent mediator between social anxiety and science achievement. Findings did not support this hypothesis; rather, it was found that peer social support served as a sequential mediator in a chain that links social anxiety to peer support, peer support to social engagement, and social engagement to science achievement. In other words, adolescents with higher social anxiety experienced less support from peers, thus contributing to a reduction in social engagement, which then resulted in lower science achievement.

Adolescents higher in social anxiety reported feeling less peer social support, aligning with research showing that students with social anxiety have difficulty initiating and maintaining positive relationships with peers (Biggs et al. 2012). When a student feels important to key social partners, such as peers, they are more likely to exert effort, persistence, and participation in school activities (Furrer and Skinner 2003). Conversely, students with unmet relatedness needs are more likely to have fewer experiences with competence and lower academic achievement than their more socially regulated peers (Niemiec and Ryan 2009). These socially disconnected youth report difficulties becoming constructively involved in their coursework, resulting in further social alienation and a decreasing readiness to learn (Li and Lerner 2013; Li et al. 2011).

It makes sense, then, that peer social support and social engagement served as sequential mediators, as students who do not receive strong social support from their peers are less likely to socially engage in academic tasks (Juvonen et al. 2012). With the social nature of science classes, the need for prosocial skills and peer support amplifies, thereby placing

the socially anxious youth at a disadvantage in classrooms relying on social interaction as a means of learning. As science-related tasks frequently require prosocial interaction within the classroom, those contending with a lack of peer social support would have difficulty socially engaging in classroom activities or responding cooperatively to classroom tasks (Erath et al. 2007), thus resulting in a decreased ability to comprehend the material as reflected in their science course grade and science standardized test scores.

Finally, it is worth mentioning that the mediation effects were stronger in the model examining course grades than in the one measuring standardized test scores. This difference may have been due to the nature of these particular science achievement measures: While standardized test scores reflect the individual's understanding of science-related material, science course grades may be based on an amalgamation of participation, effort, skill, and understanding in both individualized and/or group science-related tasks. In other words, science course grades may be a more inherently social measure of science achievement than science standardized test scores, thereby explaining the stronger mediation impact of social anxiety on science course grades than on science standardized tests.

Limitations and Future Research Directions

There are several limitations that should be taken into consideration when interpreting this study's results. First, this study examined social anxiety as a character trait rather than social anxiety as a psychiatric disorder. The sample for this study consisted of general high-school students who were asked to report on their social anxiety levels on a continuum. Results were not intended to be generalized to students with social anxiety *disorder*, which implies a more pervasive state than a character trait. Social anxiety, as measured in this study, likely fluctuates over time, posing the possibility of temporal variations in peer social support and social engagement that may differentially impact science achievement over time. To address this limitation, future research should consider longitudinal approaches to understanding the fluctuation of social anxiety over time as well as designs comparing students with trait-based and state-based social anxiety.

In addition, this study cannot infer causality between variables due to its correlational nature; however, this study suggests important links between social anxiety, peer social support, social engagement, and science achievement that should be considered in future research. Along with the correlational nature of the study, students self-reported on all major independent variables. Given that youth with social anxiety may have a negative bias surrounding their perceptions of their role in social relationships (Biggs et al. 2012; Erath et al. 2007), it may be the case that students

with higher social anxiety are not accurate reporters when answering questions regarding peer social support. In addition, the level and discipline of science classes and the schools in which these classes occur may have affected the nature and frequency of students' social interactions and science engagement. To improve upon this study's design, future research should consider longitudinal inquiries that assess social anxiety from multiple vantage points (i.e., peer, teacher, parent, observer) and across multiple schools and science disciplines.

Moreover, science achievement was measured using student grades and standardized tests scores, and it is debatable as to whether these measures truly represent a student's achievement in any given academic domain. Interestingly, though, researchers have found an association between certain personality traits, such as conscientiousness and openness, and domain-specific achievement in secondary education (Meyer et al. 2019). Therefore, future research should carefully consider the use of achievement tests alongside other indicators of science achievement, such as science interest, task value, and self-efficacy. Furthermore, moderators of the relation between social anxiety and science achievement measures should be explored to find potential group differences regarding gender, race/ethnicity, socioeconomic status, and personality type.

Despite these limitations, this study contributed to the social anxiety and learning literature. It marks the first exploration of the complicated link between social anxiety and science achievement. Given that social anxiety interferes with youth's social skills and the nature of social engagement, this study demonstrates a clear link between these constructs. Moreover, this study tested a mediation model that elucidates the roles of peer social support and social engagement as behavioral and psychological mechanisms between social anxiety and science achievement. Considering the social nature of science classes and the reliance on collaboration in understanding scientific concepts, it is imperative to understand the essentiality of getting students to socially engage in classes.

Implications for Practice

With social anxiety posing significant threats to science performance via a pathway through both peer social support and social engagement, it is critical that researchers, educators, and interventionists continue exploring this line of inquiry. Science educators, especially those working with adolescents prone to social anxiety, should be aware of the role that social anxiety plays in developing peer support networks and socially engagement in learning. As the science classroom is primarily social, science educators should be aware that the social nature of their classroom may differentially impact students based on their level of prosocial

abilities. As such, science educators must remain vigilant and committed to elements of differentiated instruction that may deter feelings of social anxiety in their students.

While science educators should be aware of the information presented by this study, interventionists may stand to gain the most. We now know that peer social support plays a particularly salient role in the science classroom, influencing whether students are socially engaged in science-related classrooms and their eventual ability to achieve in the sciences. Interventions may involve direct social skill instruction or classroom team-building exercises to help students feel more comfortable around their peers, particularly in classrooms where social engagement predicates learning and achievement.

Conclusion

Harkening back to the lessons embedded within self-system theory, social interactions in the school setting provide adolescents with a canvas ripe for strengthening their relatedness, exploring their competence, and exercising their autonomy (Wang and Hofkens 2019). However, the current study shows that youth struggling with social anxiety may experience deficits in their ability to form and maintain a positive peer support network, thus decreasing their social engagement in academics, which in turn decreases their ability to perform academically. Therefore, it is critical that we continue to highlight the role that social anxiety plays in a student's ability to form healthy, prosocial peer relationships so that they can fully engage and experience success in academic settings.

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Data Sharing and Declaration The datasets generated and/or analyzed during the current study are not publicly available, but they are available from the corresponding author on reasonable request.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical

standards. A review conducted by the Institutional Review Board approved the study to be consistent with the protection of the rights and welfare of human subjects and to meet the requirements of the Federal Guidelines.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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