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RESEARCH

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Persisting in tough times across Hong Kong, mainland China, and the Philippines: grit, achievement goal orientation, and science engagement

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Abstract

Background Past studies of grit's educational benefits, such as science engagement, showed mixed results across cultures. So, we elaborated the prior model of grit (perseverance of effort, consistency of interest) with *adaptability to situations* (forming a *triarchic model of grit* TMG), and tested TMG's relation to subsequent science engagement.

Methods In this study, 1,972 high school students in Hong Kong, mainland China, and the Philippines completed surveys twice (about 6 months apart). We analysed these data with *multilevel structural equation modelling.*

Results Results showed that country income (GDP per capita) negatively predicted science engagement, while schools with the highest ability students had higher science engagement. Conscientiousness and overall grit positively predicted science engagement at both time periods. Consistency of interest negatively predicted science engagement.

Conclusions This research demonstrates the potential academic benefits of grit in non-Western societies. Promoting grit may serve as a pathway towards greater students' engagement in science.

Keywords Academic engagement, Achievement goal orientation, Triarchic model of grit

Introduction

Cultivating students' engagement in science, technology, engineering, and mathematics (STEM) is a critical pathway for producing skilled professionals (scientists, doctors, professors, etc.) who will innovatively solve many scientific and societal problems across the globe (Moore & Burrus, 2019; Wang et al., 2016). However, students' inclinations to engage in STEM-based professions have plummeted among adolescents, especially ethnic minority adolescents (Morgan et al., 2016; Whitcomb & Singh, 2021; Young et al., 2018). Indeed, as high school students age, their engagement in science often declines (e.g., in the United States; Bae & DeBusk-Lane, 2019; Muenks et al., 2018). Although past studies showed that external factors such as quality of peer relationships (Hilts et al., 2023; Scanlon et al., 2020) and school racial climate

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(Cerda-Smith et al., 2023) are positively linked to science engagement, past studies have not systematically determined the psychological factors that predict science engagement. As student engagement affects academic outcomes (Artura & Pérez-Bitrián, 2019; Botnaru et al., 2021; Wong et al., 2023), identifying psychological factors (e.g., grit) that can boost students' science engagement is critical.

In this study, we explore whether grit is linked to subsequent science engagement among high school students in Hong Kong, mainland China, and the Philippines. We also test whether achievement goal orientation mediates this link.

Conceptualization and measurement of Grit

Grit is one's tendency to show persistence despite setbacks (*perseverance of effort*) and steady aspirations or interests (*consistency of interests*) when working on temporally distant goals (Duckworth & Quinn, 2009; Duckworth et al., 2007). Students with more grit show better academic performance in spelling (Duckworth et al., 2007, 2011), mathematics, and sciences (Flanagan & Einarson, 2017; Jiang et al., 2019; Yu et al., 2021). Students with more grit than other students show greater science engagement, especially when succeeding in difficult science assessment tasks yielded more pride and joy (Bellocchi & Ritchie, 2015).

However, few studies examined how students' grit affected their science engagement and learning processes. Some showed that only *perseverance* relates to achievement (Bowman et al., 2015; Steinmayr et al., 2018). *Perseverance* can increase academic engagement to boost effective learning outcomes, but *consistency* did not (Datu et al., 2016). Furthermore, quantitative (Credé et al., 2017) and qualitative syntheses of grit studies (Datu, 2021) identified flaws in the original grit framework: (a) failure to replicate the original hierarchical two-factor model of grit across contexts (Credé et al., 2017; Datu et al., 2016; Muenks et al., 2017), (b) alternative models of grit (e.g., adding *adaptability to situations* to form a *triarchic model* of *grit* [TMG]; Datu et al., 2017b, 2018a), and (c) poor reliability estimates of the *consistency of interests* subscale in non-Western and collectivist societies (Datu et al., 2017a; Disabato et al., 2019).

Adaptability is one's capacity to flexibly calibrate or adjust goal-related pathways based on situational or contextual factors (Datu et al., 2017b, 2018a). People in collectivist cultures value a highly relational and context-sensitive self that incentivizes actions to fulfill the need to belong in social settings and communities (Markus & Kitayama, 1991; Suh, 2007), so *adaptability* might be a culturally sensitive dimension of grit in collectivist settings. Past studies showed that TMG was valid and reliable among students in the Philippines, Japan, and mainland China (Datu et al., 2017b, 2021a, 2021b). Hence, we examine grit's structure.

Research question 1: What are the factor structures of grit in Hong Kong, mainland China, and the Philippines?

Theoretical perspective

Past studies of grit's and its dimensions' (i.e., *perseverance* and *consistency*) links with learning outcomes show mixed results. Students with higher *perseverance* and *adaptability* often have higher intrinsic academic motivation (Datu et al., 2018b) and positive academic emotions (Zhang et al., 2021), and hence, possibly higher academic engagement. *Perseverance* and *adaptability* positively predicted academic engagement and other psychological outcomes, but *consistency* negatively predicted them or was not significant (Datu et al., 2017b, 2018b, 2021b). Grit explained little additional variance in self-reported academic engagement after controlling for other explanatory variables (e.g., self-regulation, Muenks et al., 2017; conscientiousness, Mayer & Skimmyhorn, 2017; Rimfield et al., 2016; motivation, Steinmayr et al., 2018; self-efficacy, Usher et al., 2019). The inconclusive evidence on the role of grit on educational outcomes (e.g., academic engagement) raises doubts about the academic benefits of grit (Credé et al., 2017; Hagen & Solem, 2021). The extent to which grit tracks students' engagement in math and science might depend on: (a) whether grit facilitates achievement goal orientation; (b) whether achievement goal orientation promotes academic engagement; and (c) the applicability of grit across cultural contexts. Also, few studies examined whether each TMG dimension was linked to subsequent domain-specific academic outcomes (e.g., science engagement; e.g., Datu et al., 2023), especially across cultural contexts.

As prior studies focused on behavioral, cognitive, and emotional dimensions (Wang et al., 2011), they neglected the interpersonal aspects that characterize students' dedicated involvement in academic activities. Past studies showed the salience of socially oriented achievement motives in interdependent contexts, so capturing the social aspect of students' engagement is critical, especially in collectivist societies (Bernardo, 2008, 2019). Hence, the four-factor model of engagement (behavioral, cognitive, emotional, and social; Wang et al., 2016) of students' involvement in math and science might more fully capture how students proactively engage in school-related tasks. Further, whereas *perseverance* relates to higher behavioral and cognitive engagement in math, *adaptability* is linked to greater cognitive and social engagement in science, controlling for conscientiousness and achievement goal orientations among primary school students in Hong Kong and Macau (Datu et al., 2023).

Thus, this investigation addresses the following research question:

Research question 2: Which of TMG's dimensions predict subsequent science engagement?

Based on the above theoretical assumptions and empirical evidence, we test the following hypotheses on the link of grit and its dimensions to science engagement:

Hypothesis 1: Time 1 *Grit*, especially *perseverance* or *adaptability*, positively predicts Time 2 science engagement.

Hypothesis 2: Time 1 *Consistency* negatively predicts Time 2 science engagement.

Although past studies suggest that TMG and its dimensions are related science engagement, no published study has shown grit's link to goal-related processes and their links to science engagement. In this study, we conjecture that achievement goal orientation—student's preferred goals in achievement-related contexts (Elliot & Murayama, 2008; Elliot & Thrash, 2001)—might serve as a mechanism by which grit increases science engagement. The 2×2 model of achievement goal orientation ([mastery or performance] x [approach or avoidance]) comprises: (a) mastery-approach goals to master specific skills or competencies; (b) mastery-avoidance goals to prevent mistakes or failure at mastering skills; (c) performance-approach goals to achieve better performance than other peers; and d) performance-avoidance goals to prevent peers' superior performance (Elliot & Murayama, 2008).

The achievement goals of students with more grit likely differ from those of other students. First, gritty students are persistent and focus on long-term ambitions regardless of external feedback or rewards (Duckworth et al., 2007), so they may prioritize the intrinsic value of academic activities and hence, mastery goals (Chen et al., 2018). Second, gritty students are driven to learn to master specific competencies (or mastery-approach goals) and show greater involvement in specific domains (e.g., science; Miksza et al., 2016).

Each dimension of grit (*perseverance, consistency,* or *adaptability*) might predict specific achievement goal orientations. As students who persist despite challenges often satisfy their basic psychological needs for competence (Jin et al., 2017), they often espouse mastery-approach goals. Indeed, students with high *perseverance* espoused all four types of achievement goals (i.e., mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance goals) in Chen et al. (2018). Meanwhile, other studies showed that students with higher *perseverance* than other students espoused higher mastery-approach goals and higher performance-approach goals, but *lower* work-avoidance goals (Alhadabi & Karpinski, 2020; Karlen et al., 2019).

Studies of *consistency of interests* and performance-approach goals showed mixed results; some show negative correlations (Karlen et al., 2019) while others showed non-significant associations (Alhadabi & Karpinski, 2020; Chen et al., 2018). Students with higher *consistency of interests* than others often adopted lower performance-avoidance goals in mainland China and the United States (Chen et al., 2018), but greater persistence in problem-solving tasks in specific subject areas (Miele et al., 2022). *Consistency* also had negative correlations with academic engagement (Datu et al., 2018b; Teuber et al., 2021).

In socially-oriented, collectivist cultures (e.g., China, Hong Kong, and the Philippines), students with greater flexibility of goal-related pathways and interests (or *adaptability*) than other students (Datu et al., 2017b, 2018a, 2018b) might show greater performance-approach or performance-avoidance goals. Students who successfully adapted to new learning activities often perceived greater control and enjoyed positive emotions (Stockinger et al., 2021; Zhang et al., 2021), which in turn, yielded greater engagement. As no published study has determined whether TMG's dimensions are linked to achievement goal orientation, we address this research question.

Research question no. 3: Does TMG and its dimensions predict subsequent achievement goal orientation?

Further, we test the following hypothesis:

Hypothesis 3: Time 1 *Grit*, especially *perseverance* or *adaptability*, positively predicts Time 2 achievement goal orientation: mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance goals.

Further, we hypothesize that grit predicts achievement goal orientation, which in turn predicts science engagement. According to achievement goal orientation theory (Elliot, 1999; Elliot & Murayama, 2008), mastery-approach goals are most adaptive for learning contexts. Students who have higher mastery-approach goals are more likely than others to use surface and deep learning strategies (Guo & Leung, 2020), espouse higher confidence in tasks related to science (Bae & DeBusk-Lane, 2019), and believe that academic achievement is a product of diligence (Arens & Watermann, 2021)—all of which are linked to higher engagement in science (Bae & DeBusk-Lane, 2019; Ben-Eliyahu et al., 2018; Lee et al., 2016).

By contrast, studies of performance-oriented goals (e.g., performance-approach) on academic engagement show mixed results (negative: Lau & Nie, 2008; positive: Datu & Park, 2019; non-significant; Duchesne et al., 2019). Cultural differences across societies might alter these links (Clalyton & Zusho, 2016; Zusho & Clayton, 2011). For example, given the salience of interdependent self-views in collectivist societies (Markus & Kitayama, 1991), students driven to outperform their peers (performance-approach goals) often adopted deep learning strategies (King et al., 2012), which might promote academic engagement. Together, these findings indicate the importance of determining whether achievement goal orientations are linked to academic outcomes, especially in collectivist cultures.

Students focused on context-related or social reasons for studying often had performance-approach or performance-avoidance goals, along with extrinsic forms of motivation (e.g., controlled motivation), which in turn were linked to higher engagement in a collectivist setting (Bernardo, 2008, 2019; Datu et al., 2018a, 2018b). When students espouse extrinsic motivation, they have higher likelihoods of fulfilling the expectations of others (e.g., parents and teachers), a salient feature of motivational process in collectivist societies (Markus & Kitayama, 1991; Zusho & Clayton, 2011). Given the inconclusive findings on links between achievement goal orientations and academic engagement, this study addresses the following question:

Research question no. 4: Do achievement goal orientations predict subsequent science engagement?

Further, we tested the following hypothesis:

Hypothesis 4: Time 1 Mastery-approach and performance-approach goals positively predict Time 2 science engagement.

Beyond exploring how TMG and its dimensions track achievement goal orientations and science engagement, we examine how cognitive and motivational processes undergird the complex links of grit to science engagement. Prior studies showed that grit operated via psychological mechanisms to yield educational benefits. For example, students with higher *perseverance* have greater drive to understand academic content (mastery goal orientation), which promotes intrinsic motivation and yields better academic performance (Karlen et al., 2019). Furthermore, students with greater *perseverance* and *consistency* showed greater self-efficacy and achievement goal orientation (i.e., mastery goals, performance-approach, and performance-avoidance goals), which were linked to greater academic achievement (Alhadabi & Karpinski, 2020). Students who are gritty tend to focus on intrinsic reasons for involvement in school-based activities (Eskreis-Winkler et al., 2014), show greater science engagement (Datu et al., 2023), and have greater overall academic engagement (Datu et al., 2018b). However, no published study to date has determined whether achievement goal orientation mediates the links of TMG's facets to engagement. Hence, we address the following research question:

Research question 5: Do achievement goal orientations mediate the links of TMG and its dimensions to concurrent or subsequent science engagement?

So, we tested this hypothesis:

Hypothesis 5: Time 2 Mastery-approach goals and performance-approach goals mediate the links of Time 1 TMG's dimensions to Time 2 science engagement.

As past studies have shown that the following variables are linked to academic outcomes, we include them in our statistical model to reduce *omitted variable bias* (Kennedy, 2008): gender (Ellis et al., 2008), country (Chiu & Xihua, 2008), past achievement of students in a school (*ability banding*, Chiu et al., 2017), cultural values (e.g., collectivism, power distance; Bonneville-Roussy et al., 2019), and society-level economic indicators (i.e., national income [GDP per capita] and national household inequality [Gini coefficient]; Chiu, 2015). (Studies of socioeconomic status's links with psychological traits and outcomes show mixed results; positive: Conger et al., 2010; Conger et al., 2021; negative: *strength-based model of poverty*, Frankenhuis & Nettle, 2020.) As past studies strongly linked grit to conscientiousness (Duckworth et al., 2007; Rimfield et al., 2016), we included conscientiousness in our statistical model. Figure 1 illustrates the links among explanatory variables and outcome variables in this study.

Methods

To address the methodological weaknesses of prior studies of grit and student engagement—such as cross-sectional designs (Datu et al., 2018b, 2023)—this research collected data at two time points separated by about 6 months. Students across schools in Hong, Kong, mainland China, and the Philippines participated in this study. Hence, these data might provide evidence of: (a) temporal precedence (Maxwell & Cole, 2007) among grit, achievement goal orientation, and engagement in science, (b) mediating effects of achievement goal orientation (Geiser, 2013), and (c) differences across schools and countries. Specifically, this research explored the associations of Time 1 grit and its dimensions with Time 2 achievement goal orientations and Time 2 science engagement, controlling for Time 1 conscientiousness and other demographic factors (e.g., country-level GDP per capita, school ability band, and gender). We use a multilevel structural equation model (ML-SEM; Goldstein, 2011) to (a) account for these nested data of students within schools within countries and (b) accurately test our mediation model.

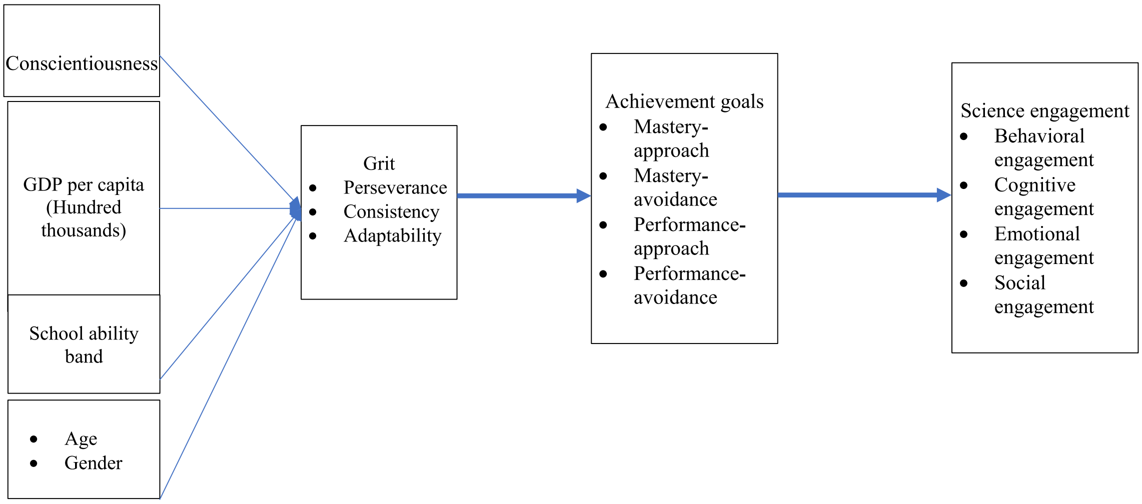

Fig. 1 Conceptual framework of the study

Participants and procedures

Statistical power differs across levels. For α = 0.05 and an expected effect size of 0.17, statistical power for 1,972 students exceeds 0.99 (Konstantopoulos, 2008). For the 16 classes in this study, low statistical power raises the likelihood of a false negative, but we retain our usual confidence in our significant results (Cohen et al., 2003). This sample size also exceeds the minimum requirement of 440 for a structural equation model that accounts for 16% of the variance (Wolf, et al., 2013). Participants include 1,972 high school students from 3 schools in Hong Kong (n = 613), 2 schools in mainland China (n = 804), and 9 schools in the Philippines (n = 555). Their mean age was 13.72 (SD = 1.05). There were 968 girls, 951 boys, and 53 students with other gender orientations. Regarding grade level, there were 301 secondary one, 953 secondary two, 408 secondary three, 302 secondary four, and 1 secondary six students; 7 students did not report their year level. In Hong Kong and mainland China, secondary one to secondary three constitute junior high school while secondary four to six constitute senior high school. In the Philippines however, secondary one to four constitute junior high school while secondary five and six constitute senior high school. Among students in Hong Kong and China, 540 attended band 1 schools, 245 attended Band 2 schools, and 630 attended Band 3 schools. In Hong Kong, and mainland China, band 1 schools cater to students with strong past achievement while band 3 schools admit students with poor past achievement. Two students failed to report their school information. The Philippines does not have school banding.

Before contacting participating schools in Hong Kong, mainland China, and the Philippines, the first author secured an ethical review clearance from the Human Research Ethics Committee at the Education University of Hong Kong. Then, we emailed invitation letters explaining this study to 14 schools in these three regions. Next, classroom teachers distributed consent forms for parents and their children to participate in this study. About 6 months apart, participants received a link to an online Qualtrics survey, each of which required approximately 15 min to complete. Due to COVID-19 outbreaks, Time 1 and Time 2 surveys were administered during September 2020 and March 2021 in one school in Hong Kong and all schools in the Philippines and mainland China. In the remaining two secondary schools in Hong Kong, the surveys were sent in January 2021 and June 2021. This data was part of a longitudinal project that explores predictors of academic engagement in selected Asian contexts.

Measures

Students in the Philippines responded to the English versions of all surveys below, and students in Hong Kong and mainland China responded to the Chinese versions.

Grit

Responding to the Triarchic Model of Grit Scale (TMGS) survey (English: Datu et al., 2017b; Chinese: Datu et al., 2021b), students reported their *perseverance of effort* (i.e., 3 items), *consistency of interests* (3 items), and *adaptability to situations* (4 items). The English version yielded acceptable reliability estimates for *perseverance* (α = 0.75–0.84) and *adaptability* (α = 0.85–0.88), but the reliability of the *consistency* subscale varied across different undergraduate student samples (α = 0.60–0.84; Datu et al., 2017a). The Chinese version had acceptable reliability for all TMG dimensions ($\alpha_{perseverance} = 0.77$;

$\alpha_{consistency} = 0.75$; $\alpha_{adaptability} = 0.82$; Datu et al., 2021b). Items were rated on a 5-point scale with endpoints “Not like me at all” (1) and “Very much like me” (5). Sample items include: “I am a hard worker” (*perseverance*), “New ideas and projects distract me from previous ones” (reverse scored to capture *consistency*), and “Changing plans or strategies is important to achieve my long-term goals in life” (*adaptability*).

Academic engagement in science

This study used a short version of the science engagement scale (Wang et al., 2016) with 17 items measuring the participants’ behavioral (5 items), cognitive (4 items), emotional (4 items), and social engagement (4 items). The English ($\alpha = 0.93$) and Chinese ($\alpha = 0.93$) versions of these subscales showed high reliability coefficients (Datu et al., 2021a). Items were rated on a 5-point scale with endpoints “Strongly disagree” (1) and “Strongly agree” (5). Sample items include: “I go through the work for science class and make sure that it’s right.” (cognitive engagement in science), “I stay focused in science.” (behavioral engagement in science), “I enjoy learning new things about science.” (emotional engagement in science), and “I build on others’ ideas in science.” (social engagement in science).

Achievement goal orientation

This study used the 12-item Achievement Goal Questionnaire-Revised (Elliot & Murayama, 2008) to assess mastery-approach goals (3 items), mastery-avoidance goals (3 items), performance-approach goals (3 items), and performance-avoidance goals (3 items). Studies showed that all dimensions of the Chinese version of this scale had acceptable reliability coefficients ($\alpha_{mastery\text{-}approach} = 0.86$; $\alpha_{mastery\text{-}avoidance} = 0.95$; $\alpha_{performance\text{-}approach} = 0.81$; $\alpha_{performance\text{-}avoidance} = 0.87$) in mainland China (Chen et al., 2018). Its English version had acceptable reliability estimates ($\alpha_{mastery\text{-}approach} = 0.74$; $\alpha_{performance\text{-}approach} = 0.76$; $\alpha_{performance\text{-}avoidance} = 0.76$) except for the mastery-avoidance goals subscale ($\alpha_{mastery\text{-}avoidance} = 0.60$) in the Philippines (Datu & Park, 2019). Items were rated using a 5-point scale with endpoints “Absolutely disagree” (1) and “Absolutely agree” (5). Sample items include: “My aim is to completely master the material presented in this class” (mastery-approach goals), “I am striving to do well compared to other students” (performance-approach goals), “My aim is to avoid learning less than I possibly could” (mastery-avoidance goals), and “My goal is to avoid performing poorly compared to others” (performance-avoidance goals).

Conscientiousness

This study used the 5-item conscientiousness subscale of the Big Five Inventory (John et al., 1991). Both Chinese ($\alpha = 0.92$) and English ($\alpha = 0.85$) versions of this scale had acceptable reliability estimates (Datu et al., 2021a). Items were rated on a 5-point scale with endpoints “Disagree strongly” (1) and “Agree strongly” (5). One sample item is: “I see myself as someone who does a thorough job”.

Apart from the abovementioned questionnaires, we used Hofstede’s Insights (2021) for measures of cultural dimensions (i.e., individualism, power distance, masculinity, uncertainty avoidance, indulgence, long-term orientation) across participant countries. We also used measures of each country’s 2021 economic indicators: gross domestic product (GDP) per capita and *Gini coefficient* (a measure of income inequality; World Population Review, 2021).

Analytic issues and statistical strategies

Accurate analyses of these data must address issues involving data, outcomes, and explanatory variables (see Table 1). Data issues include missing data and survey measurement error. As missing data (29% in these data) can bias results, reduce estimation efficiency or complicate data analyses, we estimate the missing data with *Markov Chain Monte Carlo multiple imputation*, which outperforms *listwise deletion, pairwise deletion*, *mean substitution*, and *simple imputation* according to computer simulations (Peugh & Enders, 2004; via *LISREL 10.1* with single-chain, EM Posterior mode initial estimates, Jeffreys priors, 500 imputations, 200 burn-in iterations, and 100 iterations (Joreskog & Sorbom, 2018). To reduce survey measurement errors, we use multiple questions for each construct to create a precise index. We analyze whether sets of questions reflect one or more underlying constructs (e.g., perseverance) via *multilevel confirmatory factor analyses* (ML-CFA, Joreskog & Sorbom, 2018). As past studies showed mixed results regarding the best measurement model of grit across contexts, we tested four possible factor structures of grit to find the optimal one (i.e., single-factor, correlated multiple factors, hierarchical factors, and bifactor; Datu et al., 2016; Credé et al., 2017; Disabato et al., 2019).

Outcome issues include school differences and multiple outcomes. As students in the same school at the same time likely resemble one another more than those in different schools at different times (*nested data*), an ordinary least squares regression underestimates the *standard errors*, so we use a *multilevel analysis* (Hox et al., 2017). Multiple outcomes can have correlated residuals that underestimate standard errors, so we use *multivariate outcome multilevel analysis* (Hox et al.,

Table 1 Statistics strategies to address each analytic difficulty

Analytic difficulty	Statistics strategy
Data set	
• Missing data (01??10011)	• Markov chain monte carlo multiple imputation (Peugh & Enders, 2004)
• Survey measurement errors	• Multilevel confirmatory factor analysis (Joreskog & Sorbom, 2018)
Outcome variables	
• Nested data (students within schools)	• Multilevel analysis (aka Hierarchical linear modeling, Hox et al., 2017)
• Multiple outcomes (Y_1, $\mathbf{Y_2}$, ...)	• Multivariate outcome multilevel analysis (Hox et al., 2017) • Multilevel structural equation model (Joreskog & Sorbom, 2018)
Explanatory variables	
• Indirect, multi-level mediation effects ($X \rightarrow \mathbf{M} \rightarrow Y$)	• Multilevel *M-test* (MacKinnon et al., 2004) • Multilevel structural equation model (Joreskog & Sorbom, 2018)
• Interaction sequence differences across dyads	• Statistical discourse analysis (Chiu & Lehmann-Willenbrock, 2016) • Multilevel analysis (Hox et al., 2017)
• Cross-level interactions (Student x school)	• Random effects model (Hox et al., 2017)
• Interaction in structural equation model	• Residual centering (Little et al., 2012)
• Many hypotheses' false positives	• Two-stage linear step-up procedure (Benjamini et al., 2006)
• Compare effect sizes ($\beta_1 > \beta_2$?)	• Lagrange multiplier tests (Bertsekas, 2014)
• Consistency of results across data sets (Robustness)	• Separate multilevel, single outcome models • Analyses of subsets of the data (Kennedy, 2008) • Original (not estimated) data

2017) and a *multilevel structural equation model* (ML-SEM, Joreskog & Sorbom, 2018).

Explanatory variable issues include indirect effects, cross-level interactions, many hypotheses' false positives, effect size comparisons, and robustness. Separate, single-level tests of indirect mediation effects on nested data can bias results, so we test for simultaneous multi-level mediation effects with a *multilevel M-test* (MacKinnon et al., 2004) and a ML-SEM.

With nested data, incorrectly modeling interaction effects across levels (e.g., student X school) can bias the results, so we use a *random effects* model (Hox et al., 2017). If an explanatory variable's regression coefficient (e.g., $\beta_{yvj} = \beta_{yv0} + g_{yvj}$) differs across levels ($g_{yvj} \neq 0$?), then we model the possible cross-level moderation with structural variables (e.g., gender). Often correlated with their component variables, interaction terms can cause unstable results, so we use *residual centering* to remove such correlations (Little et al., 2012).

As testing many hypotheses can cause *false positives*, we reduce their likelihood via the *two-stage linear step-up procedure*; it outperformed 13 other methods in computer simulations (Benjamini et al., 2006). When testing whether effect sizes differ, *Wald* and *likelihood ratio* tests do not apply at boundary points, so we use *Lagrange multiplier tests*, which also have more statistical power for small deviations from the null hypothesis (Bertsekas, 2014).

Lastly, we test whether the results remain stable (*robust*) despite small data or analytic differences (Kennedy, 2008). As any mis-specified equation in a multiple outcome model can introduce errors into otherwise correct equations, we also model each outcome variable separately. Then, we separately run subsets of the data. Next, we run these analyses on the original data.

Multilevel confirmatory factor analyses

We tested each construct's survey items for internal validity (e.g., perseverance of effort) and minimized their measurement errors with an ML-CFA. Bartlett factor scores yield unbiased estimates of factor score parameters (Joreskog & Sorbom, 2018). To assess the fit of the CFA to single, multiple, hierarchical, and bifactor models, we used the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error approximation (RMSEA), and standardized root mean square residual (SRMR), which minimize Type I and Type II errors under many simulation conditions (Hu & Bentler, 1999). We used two fit thresholds: good (CFI & TLI > 0.95; RMSEA < 0.06; SRMR < 0.08) and moderate (0.90 < CFI & TLI < 0.95; 0.06 < RMSEA < 0.10;

0.08 < SRMR < 0.10). As school level variance was not significant in the 2-level confirmatory factor analyses (CFA) of science engagement, conscientiousness, grit and achievement goal orientations, we ran single-level analyses.

Explanatory model

We modeled student engagement with a *multivariate outcome, multilevel analysis*, starting with a *variance components* model to test for significant differences at each level: student and school (Hox et al., 2017).

$$\mathbf{Engagement\_Time\_2}_{yij} = b_y + e_{yij} + f_{yj} \quad (1)$$

In the vector of $\mathbf{Engagement\_Time\_2}_{yij}$, outcome y (cognitive engagement in science, behavioral engagement in science, emotional engagement in science, social engagement in science, overall engagement in science) of student i in school j had a grand mean intercept β_y, with unexplained components (*residuals*) at the student- and school-levels (e_{yij}, f_{yj}).

We entered explanatory variables one at a time (organized into sets for reader convenience) to estimate the variance explained by each variable and to test for mediation effects (Kennedy, 2008). A *nested hypothesis test* (Δ^2LL) determined the significance of each explanatory variable (Kennedy, 2008). To raise precision and reduce *multicollinearity*, we omitted *non-significant* variables (which did not cause *omitted variable bias*, Kennedy, 2008).

$$\begin{aligned}\mathbf{Engagement\_Time\_2}_{yij} = {} & b_y + e_{yij} + f_{yj} \\ & + b_{ys}\mathbf{Region}_{yj} + b_{ytj}\mathbf{Demographics}_{yij} \\ & + b_{yu}\mathbf{School}_{yj} + b_{yvj}\mathbf{Grit\_Time\_1}_{yij} \\ & + b_{ywj}\mathbf{Engagement\_Time\_1}_{yij} \\ & + b_{yxj}\mathbf{Goal\_Time\_2}_{yij} \\ & + b_{yzj}\mathbf{Interactions}_{yij}\end{aligned} \quad (2)$$

Structural variables (region, demographics, school) could influence malleable process variables (grit, engagement, goal), so the former preceded the latter. First, we entered **Region** variables one at a time: GDP_per_capita, Gini, long-term orientation, power distance, individualism, masculinity, uncertainty avoidance, indulgence, Hong Kong, and Philippines (baseline = mainland China). Next, we entered **Demographics**: Girl, Secondary 2, Secondary 3, Secondary 4, Secondary 5, Secondary 6 (baseline = Secondary 1), and conscientious. Then, we entered **School** variables: Band 1, Band 2 (baseline = Band 3). To address hypothesis 1, 2, 3, and 4, we entered **Grit_Time_1**: perseverance, lasting interest, adaptability, and overall grit. Next, we entered **Engagement_Time_1**, which are the same variables as **Engagement_Time_2** but 6 months earlier. Then, we added **Goal_Time_2** variables: mastery-approach goals, mastery-avoidance goals, performance-approach goals, performance-avoidance goals, and overall achievement goal orientation. Lastly, we tested for interactions among these variables.

To test hypothesis 5, we used *multi-level mediation tests* to create a *multi-level path analysis* (Hox et al., 2017) for the ML-SEM (Joreskog & Sorbom, 2018). We removed non-significant variables to yield the final model. The *total effect* (TE) of an explanatory variable on the outcome was the sum of its *direct effects* (DE) and all of its *indirect effects* (IE). (IE of explanatory variable X on outcome Y via mediator M [X → M → Y] was the product of the standardized parameter linking X to M multiplied by the total effect of M on Y [(X → M) * (M → Y)].) We also analyzed residuals for influential outliers.

Results

Factor analyses and measurement invariance tests

While a single factor fit the data best for conscientiousness and for science engagement, four separate factors (mastery approach, mastery avoidance, performance approach, performance avoidance) best fit the data regarding goals (see Table 2 and Additional file 1: Tables

Table 2 Goodness-of-fit measures for each construct (best fitting factor structure)

Fit measure	Science engagement (single)	Conscientiousness (single)	Grit (nested)	Achievement goal orientations (separate)
SRMR	0.096	0.063	0.033	0.075
CFI	0.979	0.996	0.987	0.968
IFI	0.979	0.996	0.987	0.968
TLI	0.974	0.991	0.977	0.956
RMSEA	0.033	0.041	0.035	0.044
χ^2	601	38	148	410
df	111	5	25	47
p	0	0	0	0
AGFI	0.991	0.996	0.993	0.988
RFI	0.968	0.990	0.972	0.950

SRMR standardized root mean square residual, *CFI* comparative fit index, *IFI* incremental fit index, *TLI* Tucker–Lewis index, *RMSEA* root mean square error approximation, *df* degrees of freedom, *AGFI* adjusted goodness of fit index, *RFI* relative fit index

S1, S2, and S3). To address our first research question, a *nested* (or *bifactor*, Rodriguez et al., 2016) model of a general grit factor and 3 specific factors (perseverance, consistent interest, and adaptability) best fit the grit-related responses (see Table 2 and Additional file 1: Table S4). The bifactor model shows that TMG's components (e.g., consistency of interests) both (a) highly relate to the underlying latent grit construct and (b) are distinct. Hence, these components can show separate relations with other explanatory and outcome variables. The measurement models of conscientiousness, grit, achievement goal orientation, and science engagement were invariant across regions (Hong Kong, mainland China, and the Philippines; see Additional file 1: Table S5). (Intermediate results are available upon request).

Descriptive statistics

Table 3 reports the descriptive statistics of all the demographic, explanatory, and outcome variables. A review of the Omega coefficients indicates that all subscales had acceptable internal consistency coefficients in this study.

Explanatory model

To address research questions 2, 3, and 4, we tested a structural equation model of demographic factors, TMG, and other psychological attributes (e.g., conscientiousness and science engagement) at Time 1 on achievement goal orientations and science engagement at time 2. Most of the variance in science engagement at time 2 occurred at the student level (85%) rather than the school level (15%). As school level variance was not significant, we ran a single-level SEM, which showed a good fit (SRMR = 0.056; CFI = 0.976; TLI = 0.975; RMSEA = 0.070; $\chi^2[1{,}363] = 6.948$; $p < 0.001$; IFI = 0.976; RFI = 0.969; see Fig. 1).

National income, school banding, psychological attributes at time 1, and goals at time 2 were linked to science engagement at time 2 (see Table 4 and Fig. 1). Students in countries with higher GDP per capita showed less engagement in science at time 2 (TE = -0 .073 = −0.090 + −0.017 + −0.030; see Fig. 2, left, top); all indirect effects were mediated via conscientiousness at time 1 (IE = −0.090 = −0.383 * 0.235; Fig. 2, second from left, middle), consistency of interests at time 1 (IE = −0.017 = −0.211 * −0.082; Fig. 2, third from left, top), or grit at time 1 (IE = −0.030 = −0.171 * 0.178;

Table 4 Direct, indirect, and total effects of each significant explanatory variable on science engagement at time 2

Variable	Engage in science (Time 2)		
	Direct effect	Indirect effect	Total effect
GDP per capita		−0.073	−0.073
Band 1	0.062		0.062
Time 1			
Conscientious		0.235	0.235
Consistency of interests	−0.053	−0.029	−0.082
Grit		0.352	0.352
Engagement in science	0.329	0.320	0.649
Time 2			
Mastery approach	0.557		0.557

Table 3 Descriptive statistics and internal consistency coefficients of the explanatory and outcome variables (N = 1,120)

Variable	Mean	SD	Min	Median	Max	Omega
GDP per capita	21,927	18,592	8,452	17,192	59,520	
Age	13.817	1.067	11	14	18	
Girl	0.446	0.497	0	0	1	
Band 1	0.485	0.500	0	0	1	
Band 2	0.208	0.406	0	0	1	
Consistency of interest at time 1	3.096	0.880	1	3	5	0.715
Consistency of interest at time 2	3.249	0.941	1	3.186	5	0.715
Grit at time 1	3.568	0.710	1	3.632	5.112	0.815
Grit at time 2	3.743	0.803	1	3.821	6.431	0.815
Mastery-approach goals at time 1	4.088	0.698	1	4.048	5	0.850
Mastery-approach goals at time 2	4.075	0.737	1	4	5	0.850
Conscientious at time 1	4.067	0.957	1	4	7	0.900
Conscientious at time 2	4.016	0.810	1	4.021	5.095	0.900
Science engagement at time 1	3.958	0.657	1	4	5.013	0.962
Science engagement at time 2	3.954	0.721	1	4	5.013	0.962

Omega measures reliability

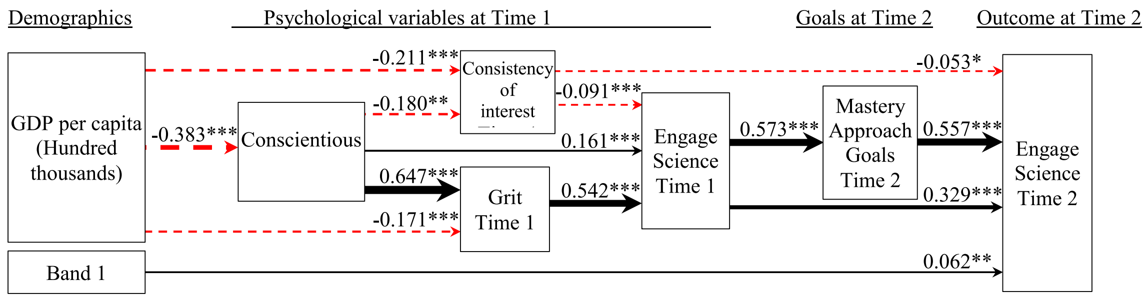

Fig. 2 Structural equation model of science engagement at time 2 with solid black arrows indicating positive effects, red dashed arrows indicating negative effects, and thicker arrows indicating larger effect sizes

Fig. 2, third from left, bottom). Meanwhile, students in school band 1 had more engagement in science at time 2 (DE = TE = −0.062; Fig. 2, bottom).

Psychological attributes at time 1 (i.e., conscientiousness, consistency of interests, overall grit, science engagement) were linked to science engagement at time 2. Students with greater conscientiousness showed greater science engagement at time 2 (TE = 0.235 = 0.015 + 0.115 + 0.105; Fig. 2, second from left), mediated via consistency of interests (IE = 0.015 = −0.180 * −0.082; Fig. 2, third from left, second from top), overall grit (IE = 0.115 = 0.647 * 0.178; Fig. 2, third from left, second from bottom), or science engagement at time 1 (IE = 0.105 = 0.161 * 0.649; Fig. 2, third from right, middle). Students with greater consistency of interest showed less science engagement at time 2 (TE = −0.082 = −0.053 + −0.059; Fig. 2, fourth from right, top), with a direct effect of -0.053 and an indirect effect mediated via science engagement at time 1 (IE = −0.059 = −0.091 * 0.649; Fig. 2, third from right, top). This result supports hypothesis 2 (Time 1 *Consistency* negatively predicts Time 2 science engagement). Students with more grit showed more science engagement at time 2 (TE = 0.352; fourth from right, bottom), mediated via science engagement at time 1 (IE = 0.352 = 0.542 * 0.649; Fig. 2, third from right, bottom). This result supports hypothesis 1 (Time 1 *Grit* positively predicts Time 2 science engagement). Students with more engagement in science at time 1 showed more science engagement at time 2 (TE = 0.649 = 0.329 + 0.320; Fig. 2, third from right, bottom), with a direct effect of 0.329 and an indirect effect via mastery approach goals at time 2 (IE = 0.320 = 0.573 * 0.557; Fig. 2, second from right, middle). Together, these results showed that students with more grit at Time 1 had more science engagement at Time 2, which in turn was linked to greater mastery goals at Time 2. This result partially supports hypothesis 3 (*Grit* positively predicts Time 2 achievement goal orientation).

Students with greater mastery approach goals at time 2 showed more science engagement at time 2 (DE = TE = 0.557; Fig. 2, second from right, middle). This result partially supports hypothesis 4 (Time 1 mastery-approach and performance-approach goals positively predict Time 2 science engagement). Together with the grit results, these results showed that students with more grit at Time 1 showed greater science engagement at Time 1, which was linked to greater mastery approach goals at Time 2, which in turn yielded greater science engagement at Time 2. These results partially support hypothesis 5 (Mastery-approach goals and performance-approach goals mediate the links of Time 1 TMG's dimensions to Time 2 science engagement.)

This model explained 0.638 of the variance (*squared multiple correlation*) in science engagement at time 2. All other explanatory variables and mediation effects were not significant. Ancillary regressions and statistical tests are available upon request. Analysis of residuals showed no substantial outliers. Robustness tests on data subsets, single outcomes, and on the original data showed similar results.

Discussion

As some studies of the original model of grit did not show strong links to achievement goal orientation and engagement in science in non-Western countries, this study examined an alternative triarchic model of grit (TMG) on these outcomes among high school students in Hong Kong, mainland China, and the Philippines during the pandemic. The highest ability school banding, time 1 measures (conscientiousness, grit, engagement in science) and mastery approach at time 2 all positively predicted engagement in science at time 2. By contrast, national income and consistency of interests at time 1 negatively predicted engagement in science at time 2.

Factor structure of grit

Prior studies showed mixed results regarding the factor structure of grit; some support two separate factors (Muenks et al., 2017; Tyumeneva et al., 2019), but others support a bifactor model of grit with *perseverance* and *consistency* as specific factors (Duckworth & Quinn, 2009; Duckworth et al., 2007; Li et al., 2018). This research provides evidence of a bifactor model of grit with *perseverance of effort, consistency of interests*, and *adaptability to situations* as first-order latent factors among high school students in Hong Kong, mainland China, and the Philippines, consistent with past studies showing a bifactor, triarchic model of grit in collectivist societies (Datu et al., 2017b, 2018a, 2021a).

These bifactor results help explain the mixed results of past studies, showing that the triarchic model of grit has both (a) a general grit factor in many cultural contexts (Disabato et al., 2019), and (b) distinct dimensions with observed and latent links to other constructs (Bowman et al., 2015; Datu et al., 2016). Specifically, these results show that along with the *overall grit construct*, its *consistency of interests* dimension has distinct links to concurrent learning processes and subsequent engagement. Unlike prior studies that conceptualize grit via a correlated three-factor model (Datu et al., 2017a, 2018b) or a hierarchical two-factor model (Duckworth & Quinn, 2009; Duckworth et al., 2007), the superior bifactor model captures the unique contributions of both the general grit factor's and consistency of interest component's links to observed indicators (Cucina & Byle, 2017; Molenaar, 2016). These results also show how a *bifactor model* approach overcomes the methodological drawbacks of *total score* or *individual score* approaches to operationalizing the grit construct (Chen et al., 2012). Future research can test whether culture or other socioecological attributes account for grit's factor structure differences across societies.

Socio-contextual predictors of engagement in science

This study showed that students from societies with higher national incomes had less conscientiousness, grit, and consistency of interests, and hence, less Time 2 academic engagement in science. These results are consistent with the *strength-based model of poverty* (Frankenhuis & Nettle, 2020), which showcases some benefits of exposure to financial adversity, such as fostering cognitive and non-cognitive abilities. Future research can further delineate the mechanisms of such benefits of living in low-income countries and contexts.

Further, in schools whose students have high academic abilities at Time 1, students had greater engagement in science over time. This result is consistent with *skill development* theory: prior achievement drives self-concept and engagement (Sewasew & Schroeders, 2019). Specifically, students with higher test scores, homework grades, and other achievement assessments (especially in science) provide the bases of their positive beliefs about their ability, which motivates them to further engage in similar activities and learning (in science).

Conscientiousness and engagement in science

This study showed that Time 1 conscientiousness positively predicted Time 2 science engagement. Specifically, students with greater conscientiousness at Time 1 showed greater grit at Time 1, and science engagement at both Time 1 and Time 2, supporting past studies showing conscientiousness' strong link with grit (Duckworth et al., 2007; Rimfield et al., 2016) or grit's link to engagement (Datu et al., 2018b; Yoon et al., 2020). As conscientious students are more inclined to show perseverance, consistency, and adaptability for long-term goals, they are likely to actively spend effort and time working on a wide range of academic tasks over time. Hence, this study pinpoints a precise psychological mechanism that undergirds how conscientiousness yields educational payoffs (Hill & Jakcson, 2016).

Conscientiousness at Time 1 showed a negative link to consistency of interest at Time 1 that eventually yielded tiny positive links to science engagement at both Time 1 and Time 2 (0.016 and 0.015, respectively). Although past cross-sectional studies showed that conscientious students showed higher *consistency of interests* than other students at one time (Abuhassàn & Bates, 2015; Ponnock et al., 2020), our study suggests that conscientious students' interests can differ across time as they adapt to changing guidelines and adopt flexible interests or goal pathways to attain distant future ambitions. These results suggest a slightly greater strategic dedication to the broader goal (science engagement) than to the same tactic (consistency of interest). Future studies can determine whether conscientious students have greater flexibility of goal-related pathways and interests en route to greater science engagement (and detail possible mechanisms).

Grit and engagement in science

Students with more grit (underpinned by *perseverance of effort, consistency of interests,* and *adaptability to situations*) at Time 1 showed greater science engagement at both Time 1 and Time 2, consistent with hypothesis 1 and past studies showing grit's positive links with school motivation (Eskreis-Winkler et al., 2014) and academic engagement (Datu et al., 2018b; Hodge et al., 2018), thereby countering doubts about the relevance of grit for educational outcomes (Rimfield et al., 2016; Steinmayr et al., 2018; Usher et al., 2019). These results suggest that gritty students immediately appreciate the importance of persistence and consistency of interests, so they show higher concurrent engagement in academic tasks. Their greater concurrent engagement can increase positive experiences and emotions that facilitate their future engagement on similar academic activities. Specifically, this result is consistent with the claim that compared to other students, gritty students have greater intrinsic motivation for learning, which in turn predicts greater overall academic engagement (Datu et al., 2018b).

In this study, *perseverance of effort* did not separately correlate with achievement goal orientation or science engagement in this study, consistent with Sudina and Plonsky's (2021) results. By contrast, other studies claimed that only perseverance of effort positively predicted academic engagement (Bowman et al., 2015; Credé et al., 2017; Muenks et al., 2017). Possibly, domain-specific (e.g., science) results differ from domain-general (academic) results; future studies can test this idea (Mosewich et al., 2021).

Meanwhile, *consistency* negatively predicted science engagement. Time 1 *consistency of interests* negatively predicted engagement in science at both Time 1 and Time 2, supporting hypothesis 2 and cohering with past studies (Datu et al., 2018b; Jiang et al., 2019; Teuber et al., 2021). As people in collectivist societies often perceive a context-sensitive self (Markus & Kitayama, 1991; Suh, 2007), they might adopt flexible interests or strategies to cope with environmental or social demands rather than pursue consistent interests over time. The effect sizes of grit and consistency of interests on academic engagement ranged from small to moderate (based on standard cut-off values; Gignac & Szodorai, 2016), which are comparable to the magnitude of effects detected between grit and academic achievement outcomes in past meta-analytic reviews (Credé et al., 2017; Lam & Zhou, 2022).

Achievement goal orientation and engagement in science

Mastery-approach goals at Time 2 (but not Time 1) positively predicted Time 2 science engagement. These results partially support hypothesis 4 and achievement goal orientation theory (Elliot, 1999; Elliot & Murayama, 2008). This result is also consistent with the claim that compared to other students, those with mastery-approach goals have higher science self-efficacy (Bae & DeBusk-Lane, 2019) and deep learning strategies (Guo & Leung, 2020; King et al., 2012), and hence proactively exert more effort in science-related activities. These findings also align with those of past studies showing that students with mastery-approach goals often show higher academic achievement in collectivist settings (An et al., 2021; Chen, 2016). Based on conventional guidelines for interpreting effect sizes (Gignac & Szodorai, 2016), the mastery-approach goals have moderate effects on subsequent academic engagement, which add to the evidence of such effects but varying in size–with research showing weak (Guo et al., 2023) and moderate to strong effects (Huang, 2016) of mastery-approach goals on academic outcomes.

Moreover, Time 2 performance-approach goals were not linked to Time 2 science engagement, contributing to the mixed results of such past studies (Chen, 2016; Lau & Nie, 2008; Linnenbrink-Garcia et al., 2008). Possibly, limited classroom interactions during the pandemic reduced exposure to classmates and reduced a student's motivation to outperform them. Future research can explore whether unpredictable COVID-19 pandemic teaching arrangements (e.g., suspension of face-to-face classes) account for some of the above non-significant effects.

Limitations and future research

This study's limitations include its (a) correlational and two-wave design, (b) convenience sampling, (c) 6-month interval, and (d) student's self-reported measures. Our correlational, longitudinal study precludes causal inferences, so future studies can use randomized, controlled experiments. As the COVID-19 pandemic hindered data collection, we used convenience sampling to recruit high school student participants; future studies can use stratified sampling to collect representative data to facilitate generalizability of results. As the COVID-19 pandemic has exacerbated high school students' academic worries and their motivation to focus on school-work (Lessard & Puhl, 2021), further studies of these issues in countries like the Philippines after the pandemic recedes can help determine the relative impact of the pandemic on our results.

In this study, the interval between the first and second phases of data collection was only 6 months, so future studies can use longer intervals. Our data only consisted of students' self-reported measures, which can increase the likelihood of common method variance (Podsakoff et al., 2003), so future studies can also include student behaviours, student brain measures, or teacher-report measures of student attributes.

Implications

This study suggests three possible implications for science teachers and psychologists. As students with more grit show higher science engagement, educational psychologists, teachers, and policy makers can test whether implementing grit-based educational interventions (Alan et al., 2019) might improve students' engagement in STEM-related subjects. Further, grit's links with higher concurrent and subsequent engagement in science suggest the importance of identifying other motivational processes that serve as mechanisms by which grit increases learning. For example, as studies have shown that grit might relate to better learning via its link to greater intrinsic motivation (Datu et al., 2018b; Eskreis-Winkler et al., 2014), future studies can test whether these findings generalize across science topics or other STEM-related learning outcomes among high school students. As conscientious students show more grit and science engagement than other students, teachers and their can consider creating and testing psychoeducational interventions to strengthen their students' achievement-orientation and academic engagement.

Conclusion

As past studies of grit and academic engagement showed mixed results, this study draws on the triarchic model of grit (Datu et al., 2017a, 2018a) and the achievement goal orientation framework (Elliot, 1999; Elliot & Murayama, 2008) to model science engagement. Our results show that students with more grit show greater mastery-approach goals and science engagement after 6 months. We hope that our research can contribute to on-going empirical debates about grit's longitudinal links to academic achievements and career accomplishments in STEM disciplines.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40594-024-00462-x.

Additional file 1: Table S1. Unstandardized factor loadings (their standard errors) and standardized factor loadings for single factor of science engagement. **Table S2.** Unstandardized factor loadings (their standard errors) and standardized factor loadings for single factor structure of conscientious. **Table S3.** Unstandardized factor loadings (their standard errors) and standardized factor loadings for nested structure of grit, perseverance, consistent interest, and adaptability. **Table S4.** Unstandardized factor loadings (their standard errors) and standardized factor loadings for separate factors of mastery-approach goals, mastery-avoidance goals, performance-approach goals, and performance-avoidance goals. **Table S5.** Results of measurement invariance tests

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Author contributions
JADD conceptualized and implemented the study and prepared this article's original and final drafts. CMM contributed to conceptualizing the study, analyzed the data, and improved the initial draft of this article. YL collected data in mainland China and provided inputs to improve this manuscript. NJM collected data in the Philippines and provided inputs in the initial draft of this article.

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Availability of data and materials
This study's data will be available upon request to the corresponding authors.

Declarations

Ethics approval and consent to participate
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.

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

Competing interests
There is no competing interests in this investigation.

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