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Two Randomized Controlled Trials to Help Teachers Develop Physical Education Students' Course-Specific Grit-Perseverance and Mental Toughness

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Abstract

Adopting both a self-determination theory perspective and a proactive, asset-oriented approach to coping with stressors, we propose a hypothesized model to explain physical education students' year-long development of course-specific grit- perseverance (Study 1) and mental toughness (Study 2). In both studies, we used a randomized controlled trial research design with longitudinally assessed dependent measures (four waves) to test a hypothesized model in which teacher participation in an autonomy-supportive teaching workshop (experimental condition) would increase students' T2 perceived autonomy-supportive teaching and T2 perceived autonomy-supportive classmates, both of which would increase T3 need satisfaction, which would then explain longitudinal gains in students' T4 grit-perseverance (Study 1) and mental toughness (Study 2). In both Study 1 (57 teachers, 3,147 students) and Study 2 (38 teachers, 2,057 students), a multilevel structural equation modeling analysis showed that the hypothesized model fit the data very well. We conclude that the developmental roots of grit-perseverance and mental toughness can emerge proactively out of the asset-oriented experiences of interpersonal support and psychological need satisfaction that are central to self-determination theory.

Keywords: autonomy support; self-determination theory; need satisfaction; motivated cognition; peer support.

Educational Impact and Implications Statement

The prevailing wisdom is that grit and mental toughness emerge as students learn how to successfully negotiate adversity-based hardships ("no pain, no gain"). Contrariwise, we showed that students develop these engagement-generating resources by being in highly supportive environments. In two studies, we showed that grit and mental toughness develop in classrooms that offer students high levels of interpersonal support and motivational satisfaction.

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When facing challenges and setbacks, mental toughness and grit-perseverance represent two ways of thinking that can mobilize the behavior-based antecedents of effective and resilience coping, such as effort, persistence, deliberate practice, strategic planning, engagement, re-engagement, and nonprocrastination (e.g., Martin et al., 2013; Skinner et al., 2020; Wolters & Hussain, 2015). For instance, grit predicts both staying in school (vs. dropping out; Bowman et al., 2015; Eskreis-Winkler et al., 2014) and eventual achievement gains (controlling for prior achievement; Wolters & Hussain, 2015). Recognizing that these ways of thinking during challenges and setbacks support people's stick-to-itiveness, the purpose of the present investigation was to understand and explain the conditions under which grit-perseverance and mental toughness might grow and develop during the year-long physical education (PE) course.

Mental toughness is the personal capacity to persist, cope effectively, and produce high levels of performance when facing challenges and adversities (Gucciardi, 2017; Gucciardi et al., 2015). Mental toughness is a unidimensional construct that predicts persistence, goal progress, performance, and thriving under conditions of adversity (Gucciardi et al., 2015). In the search for the developmental roots of mental toughness, researchers have taken many different approaches (see Lin et al., 2017), including a focus on genetic factors (Horsburgh et al., 2009; Veselka et al., 2009), individual differences (Gucciardi & Jones, 2012; Nicholls et al., 2008; Sabouri et al., 2016), and environmental factors (Mahoney et al., 2014; St. Clair-Thompson et al., 2015). Almost without exception, these investigations have relied on correlational research methods to first find individuals who are already mentally tough and then figure out how they got to be that way (Collins & MacNamara, 2012; Powell & Myers, 2017). The post hoc working model is that mental

toughness begins to develop as people are exposed to demanding situations, such as stress, challenge, failure, adversity, and trauma. It develops in accordance to the extent that people learn (or are taught) how to change their way of thinking to overcome, rather than to be overwhelmed by, those demanding situations. These relatively constructive ways of thinking during adversity include learning cognitive reappraisal, positive or optimistic self-talk, goal setting, forgetting past information to better focus on current information, and problem-focused coping (Crust & Clough, 2011; Dewhurst et al., 2012; Kaiseler et al., 2009; Nicholls et al., 2008). Overall, mental toughness seems to emerge as a posttraumatic growth experience (Powell & Myers, 2017). In other words, by changing one's way of thinking, posttraumatic stress can be transformed into posttraumatic growth (Carmichael, 2018). If so, this line of research suggests an intervention approach in which individuals are first placed into very challenging situations (i.e., "trial by fire") and then taught how to think and cope to persist and perform well in the face of adversity (e.g., "Stress can be a good thing if you know how to use it; Crum & Crum, 2018, p. 71).

Grit is a similar personal capacity to help people persist, cope effectively, and produce high levels of performance when facing challenges and adversities. Grit is passion and perseverance in the pursuit of long-term goals (i.e., "Never give up"; Duckworth, 2016, p. 7). It is the personal capacity that energizes persistence in the pursuit of long-term goals. It predicts various manifestations of retention and sticking to it (e.g., stamina, graduating, re-engagement, and completing a task; Duckworth et al., 2007; Eskreis-Winkler et al., 2014; Tang et al., 2019). Grit consists of two moderately positively correlated constructs (i.e., perseverance of effort and consistency of interests; $r = .43$ in a meta-analysis of 39 studies; Guo et al., 2019). In the present study, however, we focused only on *course-specific grit-perseverance* because (a) grit's two-dimensional conceptualization has been rather successfully challenged (Clark & Malecki, 2019; Credé, 2018; Credé et al., 2017; Morell

et al., 2021); (b) grit-perseverance's track record of predicting persistence, retention, and achievement is fairly good, whereas grit consistency of interest's track record is fairly poor (Bowman et al., 2015; Credé et al., 2017; Lam & Zhou, 2022; Wolters & Hussain, 2015); and (c) course-specific (domain-specific) grit-perseverance tends to predict school persistence and success better than does trait (domain-general) grit-perseverance (Clark & Malecki, 2019). Grit-perseverance tends to develop to the extent to which individuals find a sense of purpose that boosts their goal commitment to such a high level that the resulting persistence, deliberate practice, and a "nose to the grindstone" delay of gratification determination can overcome practically any forthcoming challenge or setback (Duckworth et al., 2011; Tang et al., 2019). If so, this line of research suggests an intervention approach in which individuals learn (or are taught) how to internalize a strong enough goal commitment (e.g., "I won't quit!" "I'll show you!") to fuel and refuel their stamina, persistence, deliberate practice, and re-engagement even amid strong and persistent challenges.

The two possible approaches to intervention introduced earlier suggest that educators help students learn reactive and defensively oriented strategies rather than proactive and asset-oriented strategies (Martin & Marsh, 2009). A defensive orientation emphasizes the person's capacity to offset and overcome (i.e., defend against) setbacks and adversities. It reflects a medical model in which one receives a dose of adversity (a vaccination) to stimulate disease-resisting defenses (antibodies) that lead to health and resilience (Brunwasser et al., 2009). In contrast, a proactive, asset-based approach emphasizes the development of strengths so that the student can "stay on top of things" even during stress and setbacks (Martin & Marsh, 2009, p. 358). Through exposure to supportive relationships and experiences of psychological need satisfaction (Mahoney et al., 2014), students can develop empowering assets that derisk everyday adversities (e.g., stress and poor performance). For example, Collie et al. (2024) showed that teacher autonomy support

predicted Australian secondary students' reports of greater socioemotional competence (SEC), assessed as higher perceived competence for assertiveness, tolerance, social regulation, emotion regulation, and awareness. Discussing these cross-sectional findings, they suggested that "autonomy-supportive teaching practices may help develop students' global perceived-SEC—though longitudinal/experiment research is needed to confirm this" (Collie et al., 2024, p. 9).

A Self-Determination Theory Perspective

Adopting both a self-determination theory perspective (SDT; Ryan & Deci, 2017) and a proactive, asset-oriented approach to coping with stressors (Martin & Marsh, 2009), we propose a hypothesized model in which exposure to autonomy-supportive interpersonal relationships allows students taking the PE course to experience greater psychological need satisfaction, and these in-course experiences of need satisfaction would, over time, cultivate greater grit-perseverance (Study 1) and mental toughness (Study 2). To test this model, we conducted a pair of randomized controlled trials so that we could experimentally manipulate autonomy-supportive teaching (AST) to a high level. Our assumption was that course-specific grit-perseverance was malleable and could develop in a highly autonomy-supportive classroom environment, including autonomy support from one's teacher and from one's classmates. According to an SDT conceptualization of autonomy support (Patall et al., 2018; Reeve & Cheon, 2021, 2024), the "support" within autonomy support is threefold: (a) perspective taking—listening to, understanding, and taking the students' perspective to welcome and accept their input and suggestions; (b) interest support—supporting intrinsic motivation by providing instruction and classroom activities in need-satisfying ways; and (c) value support—supporting volitional internalizations by acknowledging negative feelings and providing explanatory rationales for each classroom challenge and teacher request.

When teachers participate in a workshop to learn AST, they become significantly more able to produce two important effects. First, intervention-enabled gains in AST lead students to perceive their teachers as autonomy-supportive toward them, which leads to in-class experiences of psychological need satisfaction, compared with students of teachers who do not participate in such a workshop (Reeve & Cheon, 2021; Reeve et al., 2022). Second, intervention-enabled gains in AST tend to foster peer-to-peer autonomy-supportive interactions and relationships (Assor et al., 2018; Kaplan & Assor, 2012; Tilga et al., 2020; Vollet et al., 2017). That is, the more teachers support students' autonomy, the more likely it becomes that those students will support the autonomy of their classmates (Cheon, Reeve, Marsh, & Jang, 2023). These two types of support—teacher autonomy support and classmates' autonomy support—have been found to be additive and complementary sources of students' greater in-class psychological need satisfaction (Cox et al., 2009; Tilga et al., 2020).

Need satisfaction facilitates a wide range of important student benefits (Jang, 2008; Ryan & Deci, 2017; Vansteenkiste & Ryan, 2013), including persistence- and engagement-enhancing ways of thinking, such as goal setting, self-endorsed values, academic resilience, self-regulated learning, and a positive self-concept (Ryan & Deci, 2017; Skinner et al., 2020). Given the facilitating effect of need satisfaction on persistence-generating ways of thinking, we expected that gains in psychological need satisfaction during the PE course would facilitate subsequent gains in both grit-perseverance and mental toughness.

Study 1: Development of Grit-Perseverance

We expected that the students of teachers who participated in the AST workshop (experimental condition) would develop greater course-specific grit-perseverance by the end of the academic year compared with students of teachers who did not participate in the workshop (control condition). This was hypothesis 1 (H1). Our hypothesized model to

explain why students in the experimental group would develop relatively greater year-end grit-perseverance appears in Figure 1. We hypothesized that students in the classrooms of highly autonomy-supportive teachers (i.e., "Experimental Condition" in Figure 1) would experience gains in both T2 AST (H2a) and T2 autonomy-supportive classmates (H2b), controlling for the T1 autoregressive effects and the three statistical controls of gender, grade level, and class size. We further hypothesized that both of these intervention-enabled sources of relationship support would increase students' psychological need satisfaction. Specifically, we hypothesized that greater T2 AST (H3a) and greater T2 autonomy-supportive classmates (H3b) would predict longitudinally greater T3 need satisfaction, controlling for autoregressive effects, experimental condition, and the three statistical controls. Finally, we hypothesized that it would be these T3 gains in need satisfaction that would then explain students' full-year longitudinal gains in T4 grit-perseverance (H4).

Methods

Participants

Teachers were 57 experienced, certified, full-time, ethnic Korean PE teachers (34 men, 23 women) who taught in one of 57 different schools (30 middle schools, 27 high schools) throughout the Seoul, South Korea, geographical area. This multisite intervention trial with only one teacher from each school was an important part of the research design because it allowed us to randomly assign teachers to experimental condition without a risk of intraschool cross-condition contamination. Teachers were, on average, 34.7 years old (*SD* = 5.8; *range* = 27–48) with 7.8 years (*SD* = 5.0; *range* = 2–19) of teaching experience. To increase our L2 sample size, we collected data from two classrooms for each teacher (i.e., our L2 unit of analysis was 114 classrooms rather than 57 teachers). In these 114 classrooms were 3,147 ethnic Korean students, including 1,666 (52.9%) girls and 1,481 (47.1%) boys, 1,777 (56.5%) middle and 1,370 (43.5%) high schoolers.

As to a priori statistical power, conducting a power analysis to determine the sample size needed to test a multilevel model with multiple hypothesized paths is a complex task (Thoemmes et al., 2010), so we used Morin et al.'s (2021) guidelines to estimate what constitutes adequate statistical power for this type of analysis. These guidelines recommended at least 50 L2 units with 10–15 participants per L1 unit (per classroom; Morin et al., 2021). Our sample of 114 classrooms (L2 unit) with an average class size of 27.6 students per class (L1 unit) exceeded these recommended guidelines.

Procedure, Research Design, and Teacher Workshop

The first author's university research ethics committee approved the research protocol. Our research design was an experimental, intervention-based randomized controlled trial with longitudinally assessed dependent measures. As shown in the Consolidated Standards of Reporting Trials (CONSORT) flowchart for a randomized controlled trial (see Figure S1 in Supplementary Materials [available online]), we randomly assigned each teacher into either the experimental (intervention; $n = 29$ teachers, 58 classrooms) or no intervention control ($n = 28$ teachers, 56 classrooms) condition. We collected four waves of data in which students completed the same 3-page questionnaire at the beginning (T1; Week 1), middle (T2; Week 10), and end (T3; Week 18) of the spring (first) semester and, again, at the end of the fall (second) semester (T4, Week 44). We included four waves of data collection in our research design so that we could evaluate each hypothesized path within the overall hypothesized model (see Figure 1) that posited effects from T1 to T2 (H2a, H2b), from T2 to T3 (H3a, H3b), and from T3 to T4 (H4). Across the four waves of data collection, missing cases (27.8%) and missing data (<0.1%) were reasonable. For the data collection, the questionnaire began with a consent form, and it asked students specifically about that particular class. As for the teacher workshop, the delivery of the three-part, 8-hr AST workshop followed the contents, activities, and procedures of previously published AST

workshops (e.g.,Cheon, Reeve, Marsh, & Jang, 2023; Reeve et al., 2022, and the Open Science Framework, 2023, project site).

Measures

All questionnaires were in the Korean language, as we had available a Korean-translated version of each English-language questionnaire (Jang et al., 2016), except for the grit-perseverance scale. Prior to the data collection, we professionally translated and back translated the grit-perseverance scale using Brislin's (1980) step-by-step guidelines. Each measure used the same 7-point bipolar response scale (1 = *strongly disagree*, 7 = *strongly agree*).

AST and Autonomy-Supportive Classmates. To assess perceived autonomy support, we used three 3-item scales (i.e., perspective taking, choice, and relevance) from the widely used and strongly validated Student Evaluation of Educational Quality survey (SEEQ; Marsh et al., 2019; Reeve & Cheon, 2024). In our data collection, we used two versions of these scales—a teacher version and a classmates version. The only difference between the two was that we used "My PE teacher . . . " as the item referent in the teacher version, whereas we used "My PE classmates . . . " as the item referent in the classmates version.

For perspective taking, students' scores on both versions of the SEEQ's Perspective Taking scale were internally consistent and showed a reasonable intraclass consensus: teacher perspective taking (e.g., "My PE teacher wants to know what we are feeling during class."; αs at T1, T2, T3, and T4 = .88, .86, .91, and .93; intraclass correlation coefficient (ICCs) = .07, .12, .13, and .15); and classmates perspective taking (e.g., "My PE classmates listen to how I would like to do things."; αs = .86, .93, .92, and .92; ICCs = .06, .08, .08, and .10). Scores on the teacher perspective taking scale have been shown to correlate very highly with

scores on the Learning Climate Questionnaire, which is the most often used instrument to assess perceived AST: $r = .85$ (Cheon, Reeve, Marsh, & Jang, 2023).

For interest support, students' scores on both versions of the SEEQ's Choice scale were internally consistent and showed reasonable intraclass consensus: teacher interest support (e.g., "My PE teacher gives us lot of choices about how to do our schoolwork."; αs = .83, .85, .88, and .90; ICCs = .09, .13, .12, and .14) and classmates interest support (e.g., "My PE classmates allow me to pursue my own interests."; αs = .85, .88, .89, and .89; ICCs = .09, .06, .08, and .10). Scores on the teacher choice scale correlated very highly with scores on the Learning Climate Questionnaire: $r = .86$ (Cheon, Reeve, Marsh, & Jang, 2023). For value support, students' scores on both versions of the SEEQ's Relevance scale were internally consistent and showed a reasonable intraclass consensus: teacher value support (e.g., "My PE teacher talks to us about how we can use the things we learn in this class."; αs = .84, .90, .88, and .89; ICCs = .06, .06, .09, and .11) and classmates value support (e.g., "My PE classmates explain why what I do in this class is important."; αs = .90, .93, .94, and .95; ICCs = .05, .06, .07, and .10). Scores on the teacher relevance scale have been shown to correlate very highly with scores on the Learning Climate Questionnaire: $r = .79$ (Cheon, Reeve, Marsh, & Jang, 2023).

Need Satisfaction. We used three scales to assess need satisfaction. For autonomy satisfaction, we used the five-item Perceived Autonomy scale (Standage et al., 2006; e.g., "In this PE class, I can decide which activities I want to do"; αs = .87, .92, .91, and .92; ICCs = .07, .10, .10, and .12). For competence satisfaction, we used the four-item Perceived Competence scale from the Intrinsic Motivation Inventory (Ryan et al., 1983; e.g., "In this PE class, I feel pretty competent."; αs = .87, .89, .90, and .89; ICCs = .03, .04, .06, and .07). For relatedness satisfaction, we used the five-item Relatedness Need Satisfaction Scale (Ng et al.,

2011; e.g., "In this PE class, I feel close to my teacher."; αs = .84, .86, .87, and .87; ICCs = .11, .08, .09, and .12).

Grit-Perseverance. For grit-perseverance, we used the six-item Grit-Perseverance scale (e.g., "I am a hard worker"; Duckworth et al., 2007). In the present study, we started each item with "In this PE class . . . " (αs = .75, .82, .83, and .83; ICCs = .02, .03, .04, and .06).

Social Validity Check. At the conclusion of the study, we asked all 29 teachers in the experimental condition to complete a seven-item questionnaire to serve as a social validity check on the teachers' intervention experience, using Cheon and Reeve's (2013) questionnaire. Items 1–6 asked teachers to use a 1–7 unipolar scale (*not at all—extremely*) to rate how useful and effective they found the workshop to be (see all six items in Table 1). Item 7 asked, "Compared to the quality of your teaching last year (before you participated in the workshop), would you say that your current classroom teaching effectiveness is now more effective, less effective, or about the same?" (Check one). A final open-ended question asked this follow-up question: "What reason or reasons explain why you checked the option you checked in question #7?"

Transparency and Openness

Neither Study 1 nor Study 2 was preregistered. However, both data sets and the Mplus syntax used to analyze the hypothesized model are available on the Open Science Framework (OSF) project site: https://osf.io/jhfg5/?view_only=50085d9cdbe34b58b4b0ea7425871d18. On the OSF project site, we also provide the study questionnaires, the CONSORT 2010 Checklist for a cluster randomized controlled trial for both studies, and the step-by-step procedures used in the AST workshop.

Data Analyses

We conducted three sets of analyses. The first analysis was a social validity check. Its purpose was to determine the extent to which teachers responded positively to the AST intervention experience (e.g., found it useful). The second analysis tested for the intervention effect on grit-perseverance's growth trajectory for students in the experimental (relative to the control) condition. Its purpose was to evaluate H1. The third analysis tested the hypothesized model. Its purpose was to evaluate H2a, H2b, H3a, H3b, and H4.

Social Validity Check. We asked teachers in the experimental condition to complete a seven-item poststudy questionnaire to evaluate their workshop experience (i.e., social validity check). Questions 1–6 asked teachers how clear and understandable they found the workshop to be, how much they agreed with and responded positively to its recommended teaching practices, how useful to their teaching they found the workshop to be, how satisfied they were with the recommendations, how much the recommended practices enhanced their teaching effectiveness, and how much they would recommend the workshop to other teachers. We analyzed these data using simple descriptive statistics as we interpreted mean scores of 6.0 or greater (on a 1–7 scale) as reflecting a positive workshop experience. Question 7 was a three-option multiple-choice question that asked, "Compared to the quality of your teaching at the beginning of the year (before you participated in the workshop), would you say that your *classroom teaching effectiveness* is now more effective, less effective, or about the same (check one): (a) more effective, (b) less effective, or (c) about the same." A final open-ended question asked teachers to explain why they checked their selected option from Question 7, which was analyzed qualitatively.

Intervention Effect on Growth in Grit-Perseverance. We tested whether students of teachers in the experimental condition experienced greater growth in grit-perseverance over the course of the academic year than did students of teachers in the control group. To conduct this growth analysis, we used a structural equation modeling analysis in which

teacher participation in the intervention was the independent variable and students' grit-perseverance scores at T1, T2, T3, and T4 served as the repeated measures dependent variable (slope: T1 = 0, T2 = 1, T3 = 2, T4 = 3). We used the six items from the Grit-Perseverance scale to serve as indicators of the latent variable at T1, T2, T3, and T4. We entered gender, grade level, and class size as statistical controls. The focus of the analysis was to test for a Condition × Time interaction (i.e., scores increased more for students in the experimental condition than they did for students in the control condition).

Test of the Hypothesized Model. The data had a two-level longitudinal structure with repeated measures (four waves) nested within students (Level 1, $N = 3{,}147$) nested within classrooms (Level 2, $k = 114$) and nested further within teachers (a cross-classified Level 2, $k = 57$). Given this data structure, we used a multilevel structural equation modeling analysis to test the measurement and hypothesized models. We used Mplus (version 8.7; Muthén & Muthén, 2019), the "model = complex" command to handle the nested structure of the data, the maximum likelihood robust estimator, and the full information maximum likelihood estimation procedure for handling missing data. To evaluate model fit, we used standard goodness-of-fit statistics: root mean square error of approximation, standardized root mean square residual, comparative fit index, and Tucker--Lewis index. We first tested for the fit of the 30-item, eight-latent variables measurement model. We second tested the hypothesized model by adding experimental condition as an uncentered predictor (control = 0, experimental = 1), the hypothesized paths in Figure 1, and gender (male = 0, female = 1), grade level (middle = 0, high = 1), and class size ($M = 27.6$ students/class) as grand mean-centered covariates. The hypothesized model proposed a mediation effect, so we used the "model indirect" command in Mplus to perform a follow-up mediation analysis.

Results

Social Validity Check

Twenty-five of the 29 (86%) teachers in the experimental condition returned the poststudy social validity questionnaire. As shown in Table 1, teachers reported universally high scores on Questions 1–6 ($Ms \geq 6.2$). On Item 7, all 25 teachers (100%) selected "more effective." Thirteen of the 25 teachers provided a brief essay to explain their "more effective" response, and we have provided these essays on the OSF project site. Generally speaking, to explain their "more effective" selection, teachers tended to emphasize (a) the student benefits they observed and (b) an improved quality in the teacher–student relationship.

Test for Longitudinal Growth in Grit-Perseverance

The SEM model with T1, T2, T3, and T4 grit-perseverance, experimental condition, and the three covariates fit the data well, $\chi^2(316) = 623.50$, $p < .001$, $RMSEA = .018$, $SRMR = .022$, $CFI = .985$, and $TLI = .982$. As illustrated in Figure 2, the Condition × Time interaction was significant, $B = 0.06$, $SE = 0.02$, $t = 3.84$, $p < .001$ (T1–T4 $M\,\Delta$: $+0.46_{Exp}$vs. $+0.14_{Con}$). Grit-perseverance scores increased more in the experimental condition (4.63 increased + 0.46 to 5.09 from T1 to T4) than they did in the control condition (4.65 increased + 0.14 to 4.79). This finding confirmed H1.

Test of the Hypothesized Model

Table 2 shows the descriptive statistics with unstandardized and standardized beta weights for the 30 indicators in the measurement model. The measurement model fit the data reasonably well, $\chi^2(362) = 1{,}850.00$, $p < .001$, $RMSEA = .036$, $SRMR = .033$, $CFI = .958$, and $TLI = .950$. Table 3 shows the correlation matrix for the variables included in the hypothesized model. The hypothesized model fit the data reasonably well, $\chi^2(473) = 2{,}311.56$, $p < .001$, $RMSEA = .035$, $SRMR = .046$, $CFI = .948$, and $TLI = .940$. Figure 3 shows the unstandardized beta weights (with *SEs*) for the hypothesized paths. In a supplemental analysis, we repeated the test of the hypothesized model after removing the three statistical controls. This hypothesized model without the statistical controls fit the data

very similarly as did the hypothesized model with the statistical controls, $\chi^2(395) = 2{,}062.24$, $p < .001$, $RMSEA = .037$, $SRMR = .048$, $CFI = .953$, and $TLI = .945$, and the effect sizes (B) and p-values associated with each path depicted in Figure 3 remained virtually unchanged.

Consistent with H2a, experimental condition increased T2 AST ($B = 0.29$, $SE = 0.05$, $t = 5.55$, $p < .001$), controlling for T1 AST ($B = 0.51$, $p < .001$), gender ($B = -0.04$, $p = .348$), grade level ($B = -0.03$, $p = .002$), and class size ($B = 0.04$, $p = .167$). Consistent with H2b, experimental condition increased T2 autonomy-supportive classmates ($B = 0.17$, $SE = 0.05$, $t = 3.66$, $p < .001$), controlling for T1 autonomy-supportive classmates ($B = 0.53$, $p < .001$), gender ($B = -0.04$, $p = .261$), grade level ($B = -0.02$, $p = .001$), and class size ($B = 0.04$, $p = .247$).

Consistent with H3a and H3b, in the prediction of T3 need satisfaction, both T2 AST ($B = 0.20$, $SE = 0.04$, $t = 5.43$, $p < .001$) and T2 autonomy-supportive classmates ($B = 0.36$, $SE = 0.03$, $t = 10.88$, $p < .001$) were individually significant predictors, controlling for T1 need satisfaction ($B = 0.42$, $p < .001$), T1 AST ($B = -0.06$, $p = .107$), T1 autonomy-supportive classmates ($B = -0.11$, $p = .004$), experimental condition ($B = 0.08$, $p = .056$), gender ($B = -0.01$, $p = .871$), grade level ($B = -0.01$, $p = .015$), and class size ($B = 0.00$, $p = .886$).

Consistent with H4, in the prediction of T4 grit-perseverance, T3 need satisfaction was an individually significant predictor ($B = 0.42$, $SE = 0.04$, $t = 9.37$, $p < .001$), controlling for T1 grit-perseverance ($B = 0.48$, $p < .001$), T1 need satisfaction ($B = -0.09$, $p = .072$), AST at T1 ($B = 0.03$, $p = .535$) and T2 ($B = -0.01$, $p = .750$), autonomy-supportive classmates at T1 ($B = -0.09$, $p = .038$) and T2 ($B = 0.10$, $p = .022$), experimental condition ($B = 0.08$, $p = .052$), gender ($B = 0.06$, $p = .034$), grade level ($B = -0.01$, $p = .563$), and class size ($B = 0.06$, $p = .008$). In the test for mediation, the total (omnibus) indirect effect including all

three mediators (T2 AST, T2 autonomy-supportive classmates, and T3 need satisfaction) rather strongly mediated the direct effect of experimental condition on T4 grit-perseverance: total indirect effect = 0.09, $SE = 0.02$, $t = 3.84$, $p < .001$.

Discussion

The twofold purpose of Study 1 was to evaluate the extent to which (a) students of teachers in the experimental condition developed greater year-end course-specific grit-perseverance than did students of teachers in the control group and (b) the hypothesized model depicted in Figure 1 could explain why this was so. Findings confirmed the direct effect of experimental condition on a year-end rise in T4 grit-perseverance (H1; see Figure 2). Findings further supported the overall hypothesized model (see Figure 3), including all five individual hypotheses embedded within it. Manipulated AST increased perceived AST (H2a) and perceived autonomy-supportive classmates (H2b), both of which increased midyear psychological need satisfaction (H3a, H3b), which then explained students' year-end gains in grit-perseverance (H4). The one unexpected finding to emerge was that the path from T2 autonomy-supportive classmates to T4 grit-perseverance was also significant. We conclude that the Study 1 findings strongly support our SDT-based, asset-oriented hypothesized model. However, we further recognize that although midyear gains in need satisfaction mostly explained year-end gains in grit-perseverance (H4), a second, supplemental enhancement effect to year-end gains in grit-perseverance also occurred, which was classmates' perceived autonomy support. Given these positive results, we conducted a second randomized controlled trial to expand our focus to include a second persistence-facilitating way of coping with setbacks—namely, mental toughness.

Study 2: Development of Mental Toughness

Similar to grit-perseverance, mental toughness is a personal capacity that allows students to generate persistence and high performance in the face of challenge and adversity

(Gucciardi et al., 2015). In Study 2, we sought to apply the Study 1 hypothesized model that successfully explained the development of grit-perseverance to the development of mental toughness. In conducting Study 2, although we retained the Study 1 hypothesized model, we made three changes to the Study 2 research methodology. First, we changed the outcome measure to mental toughness. Second, we included a new hypothesized path from T2 peer support to T4 mental toughness (i.e., H4b) because of the Study 1 finding that the path from T2 peer support to T4 grit-perseverance was significant. Third, we changed the measure of peer support from "autonomy-supportive classmates" to "relatedness-supportive classmates." We made this change because the research literature on peer relationships in the PE setting has focused much more on peer-to-peer relatedness support than it has on peer-to-peer autonomy support (Cox et al., 2009; Cheon, Reeve, Marsh, & Jang, 2023; Leo et al., 2023; Ntoumanis & Vazou, 2005; Shen et al., 2012; Sparks et al., 2017; White et al., 2021), and we wanted to determine whether our positive findings for autonomy-supportive classmates in Study 1 would show similar positive findings for relatedness-supportive classmates in Study 2. Relatedness support occurs as students (a) show caring for their classmates' welfare, (b) create a friendly, prosocial classroom atmosphere, and (c) generate a sense of group unity and shared social responsibility (Ntoumanis & Vazou, 2005; Wentzel et al, 2018). Based on previous studies, we expected (a) that perceived relatedness support from one's classmates and perceived autonomy support from one's teacher would both enhance students' midyear psychological need satisfaction (Slemp et al., 2024) and (b) that teachers who participated in an AST workshop would be able to facilitate perceived relatedness-supportive classmates (Cheon, Reeve, & Marsh, 2023; Cheon, Reeve, Marsh, & Jang, 2023).

As in Study 1, we expected that students of teachers who participated in the AST workshop (experimental condition) would develop greater year-end course-specific mental

toughness than would students of teachers who did not participate in the workshop (control condition). This was hypothesis 1 (H1). Also, as in Study 1, we applied a similar hypothesized model to explain why students in the experimental group might develop relatively greater year-end mental toughness than students in the control group. That is, largely consistent with Study 1, we hypothesized that (a) students in the classrooms of teachers in the experimental condition would experience gains in both T2 AST (H2a) and T2 relatedness-supportive classmates (H2b), (b) greater T2 AST (H3a) and greater T2 relatedness-supportive classmates (H3b) would both predict longitudinally greater T3 need satisfaction, and (c) greater T3 need satisfaction (H4a) and greater T2 relatedness-supportive classmates (H4b) would both explain longitudinal gains in T4 course-specific mental toughness.

Methods

Participants

Teachers were 38 experienced, certified, full-time, ethnic Korean PE teachers (28 men, 10 women) who taught in one of 38 different schools (22 middle schools, 16 high schools) throughout Seoul, South Korea. To increase our L2 sample size, we, again, collected data from two classrooms for each teacher (i.e., our L2 unit of analysis was 76 classrooms rather than 38 teachers). Teachers were, on average, 36.3 years old (*SD* = 5.2; *range* = 25–44) with 8.6 years (*SD* = 4.0; *range* = 1–14) of teaching experience. In these 78 classrooms were 2,057 ethnic Korean students: 1,009 (49.1%) girls and 1,048 (50.9%) boys, 1,169 (56.8%) middle and 888 (43.2%) high schoolers. As to statistical power, our sample of 78 classrooms (L2 units) with an average class size of 27.1 students per class exceeded the statistical power guidelines for multilevel analyses (i.e., 50 L2 units with at least 10–15 L1 participants per class; Morin et al., 2021).

Procedure, Research Design, and Teacher Workshop

The first author's university research ethics committee approved the research protocol. Our research design was an experimental, intervention-based randomized controlled trial with longitudinally assessed dependent measures. As shown in our CONSORT flowchart for a randomized controlled trial (see Figure S2 in Supplementary Materials [available online]), we randomly assigned each teacher into either the experimental (intervention; $n = 18$ teachers, 36 classrooms) or control (no intervention; $n = 20$ teachers, 40 classrooms) condition. Students completed the same 3-page questionnaire at the beginning (T1; Week 1), middle (T2; Week 10), and end (T3; Week 18) of the spring (first) semester and, again, at the end of the fall (second) semester (T4, Week 44). Across the four waves of data collection, missing cases (5.3%) and missing data (<0.1%) were low. The questionnaire began with a consent form, and it asked students specifically about that particular class. As for the teacher workshop, the delivery of the three-part, 8-hr AST workshop followed the contents, activities, and procedures of both Study 1 and previously published AST workshops (see the OSF project site).

Measures

All questionnaires were in the Korean language as we had available a Korean-translated version of each English-language questionnaire, except for the Mental Toughness Index (MTI) measure. Prior to the pilot study, we professionally translated and back translated the MTI using Brislin's (1980) step-by-step guidelines. Each measure used the same 7-point bipolar response scale (1 = *strongly disagree*, 7 = *strongly agree*).

For AST, we used the 6-item Learning Climate Questionnaire (Black & Deci, 2000; e.g., "My PE teacher listens to how I would like to do things."). Students' scores showed high internal consistency (αs at T1, T2, T3, and T4 were .91, .92, .94 and .94, respectively) with a high class consensus (ICCs = .15, .11, .12, and .19).

For relatedness-supportive classmates, we used the three-item Peer Relatedness Support scale from the Peer Motivational Climate in Youth Sport questionnaire (Ntoumanis & Vazou, 2005; e.g., "During this PE class, most of my peers make their classmates feel valued."; αs = .81, .85, .87, and .88; ICCs = .14, .09, .11, and .18).

For psychological need satisfaction, we used three scales. For autonomy satisfaction, we, again, used the five-item Perceived Autonomy scale (Standage et al., 2006; αs = .89, .91, .88, and .93; ICCs = .13, .06, .09, and .15). For competence satisfaction, we, again, used the four-item Perceived Competence scale from the Intrinsic Motivation Inventory (αs = .90, .90, .91, and .91; ICCs = .11, .06, .00, and .15). For relatedness satisfaction, we used the two-item Perceived Relatedness scale (Furrer & Skinner, 2003; e.g., "When I am interacting with my PE teacher, I feel accepted."; αs = .82, .86, .88, and .91; ICCs = .14, .08, .10, and .17).

Mental toughness was assessed with the eight-item MTI, though we added the stem "During this PE course, . . . " to each item (e.g., "During this PE course, I consistently overcome adversity."; Gucciardi et al., 2015; αs = .93, .95, .96, and .94; ICCs = .14, .08, .10, and .17).

Data Analyses

We conducted two sets of analyses. The first analysis tested for the intervention effect on mental toughness' growth trajectory for students in the experimental (relative to the control) condition. Its purpose was to evaluate H1. The second analysis tested the hypothesized model. Its purpose was to evaluate H2a, H2b, H3a, H3b, H4a, and H4b.

Intervention Effect on Growth in Mental Toughness

Similar to Study 1, we conducted a growth analysis for mental toughness scores over the course of the academic year. We, again, used a structural equation modeling analysis in which the independent variable was experimental condition, and the repeated measure was students' mental toughness at T1, T2, T3, and T4 (slope: T1 = 0, T2 = 1, T3 = 2, T4 = 3). We

used the eight items from the MTI to create the mental toughness latent variable at T1, T2, T3, and T4. We entered gender, grade level, and class size as statistical controls.

Test of the Hypothesized Model

The data had a two-level longitudinal structure with repeated measures (four waves) nested within students (Level 1, $N = 2{,}057$) nested within classrooms (Level 2, $k = 78$) and nested further within teachers (a cross-classified Level 2, $k = 38$). Given this data structure, we, again, used a multilevel structural equation modeling analysis to test the measurement and hypothesized models. As in Study 1, we used Mplus (version 8.7; Muthén & Muthén, 2019) and the maximum likelihood robust estimator, full information maximum likelihood estimation procedures for handling missing data, and standard goodness-of-fit statistics (*RMSEA*, *SRMR*, *CFI*, and *TLI*). First, we tested for the fit of the 40-item, eight-latent variables measurement model. Second, we tested the hypothesized model by adding experimental condition as an uncentered predictor (control = 0, experimental = 1), the hypothesized and control paths, and gender, grade level, and class size as grand mean-centered covariates. The hypothesized model proposed a mediation effect, so we, again, used the "model indirect" command in Mplus to perform a follow-up mediation analysis.

Results

Test for Longitudinal Growth in Mental Toughness

The SEM model with T1, T2, T3, and T4 mental toughness, experimental condition, and the three covariates fit the data reasonably well, $\chi^2(554) = 1{,}671.99$, $p < .001$, $RMSEA = .031$, $SRMR = .021$, $CFI = .972$, and $TLI = .968$. As illustrated in Figure 4, the Condition × Time interaction was significant, $B = 0.20$, $SE = 0.04$, $t = 5.58$, $p < .001$ (T1–T4 $M\,\Delta$: $+0.85_{Exp}$ vs. $+0.11_{Con}$). That is, mental toughness increased more for students in the experimental condition (4.79 increased + 0.85 to 5.64 from T1 to T4) than it did for students in the control condition (5.03 increased + 0.11 to 5.14). This finding confirms H1.

Test of the Hypothesized Model

Table 4 shows the descriptive statistics with unstandardized and standardized beta weights for the 40 indicators in the measurement model. The measurement model fit the data reasonably well, $\chi^2(692) = 3{,}005.38$, $p < .001$, $RMSEA = .040$, $SRMR = .031$, $CFI = .952$, and TLI = .946. Table 5 shows the correlation matrix for the 12 variables included in the hypothesized model. The hypothesized model fit the data reasonably well, $\chi^2(843) = 3{,}436.99$, $p < .001$, $RMSEA = .039$, $SRMR = .046$, $CFI = .945$, and $TLI = .939$. Figure 5 shows the unstandardized beta weights (with *SEs*) for the hypothesized paths. In a supplemental analysis, we repeated the test of the hypothesized model after removing the three statistical controls. This hypothesized model without the statistical controls fit the data very similarly as did the hypothesized model with the statistical controls, $\chi^2(735) = 3{,}168.76$, $p < .001$, $RMSEA = .040$, $SRMR = .046$, $CFI = .948$, and $TLI = .942$, and the effect sizes (B) and p-values associated with each path depicted in Figure 5 remained virtually unchanged.

Consistent with H2a, experimental condition increased T2 AST ($B = 0.36$, $SE = 0.08$, $t = 4.27$, $p < .001$), controlling for T1 AST ($B = 0.44$, $p < .001$), gender ($B = 0.02$, $p = .678$), grade level ($B = -0.05$, $p = .528$), and class size ($B = -0.01$, $p = .534$). Consistent with H2b, experimental condition increased T2 relatedness-supportive classmates ($B = 0.30$, $SE = 0.08$, $t = 3.94$, $p < .001$), controlling for T1 relatedness-supportive classmates ($B = 0.47$, $p < .001$), gender ($B = -0.06$, $p = .265$), grade level ($B = 0.00$, $p = .965$), and class size ($B = -0.01$, $p = .024$).

Consistent with H3a and H3b, in the prediction of T3 need satisfaction, both T2 AST ($B = 0.21$, $SE = 0.04$, $t = 4.85$, $p < .001$) and T2 relatedness-supportive classmates ($B = 0.31$, $SE = 0.04$, $t = 7.58$, $p < .001$) were individually significant predictors, controlling for T1 need satisfaction ($B = 0.37$, $p < .001$), T1 AST ($B = 0.05$, $p = .277$), T1 relatedness-

supportive classmates ($B = –0.16$, $p = .012$), experimental condition ($B = 0.22$, $p = .001$), gender ($B = 0.09$, $p = .037$), grade level ($B = 0.10$, $p = .123$), and class size ($B = 0.00$, $p = .799$).

Consistent with H4a and H4b, in the prediction of T4 mental toughness, both T3 need satisfaction ($B = 0.47$, $SE = 0.04$, $t = 12.94$, $p < .001$) and T2 relatedness-supportive classmates ($B = 0.11$, $SE = 0.05$, $t = 2.13$, $p = .033$) were individually significant predictors, controlling for T1 mental toughness ($B = 0.18$, $p = .040$), T1 need satisfaction ($B = −0.07$, $p = .355$), T1 ($B = 0.00$, $p = .999$) and T2 ($B = 0.06$, $p = .142$) AST, T1 relatedness-supportive classmates ($B = −0.02$, $p = .757$), experimental condition ($B = 0.24$, $p < .001$), gender ($B = 0.08$, $p = .063$), grade level ($B = 0.09$, $p = .141$), and class size ($B = −0.01$, $p = .474$). In the test for mediation, the total (omnibus) indirect effect including all three mediators (T2 AST, T2 relatedness-supportive classmates, and T3 need satisfaction) rather strongly mediated the direct effect of experimental condition on T4 mental toughness: total indirect effect = 0.24, $SE = 0.05$, $t = 5.34$, $p < .001$.

Discussion

Similar to Study 1, the twofold purpose of Study 2 was to evaluate the extent to which (a) students of teachers in the experimental condition developed greater year-end course-specific mental toughness compared with students of teachers in the control group and (b) the hypothesized model could explain why this was so. Findings supported both the direct effect of experimental condition on a year-end rise in T4 mental toughness (H1; see Figure 4) as well as the overall hypothesized model and each of its six embedded hypotheses (H2a–H4b; see Figure 5). The primary reason why students experienced this year-end rise in mental toughness was because they first experienced greater midyear psychological need satisfaction, though relatedness support from one's classmates explained additional year-end gains in mental toughness.

General Discussion

In two longitudinal studies, each conducted over the course of one academic year, we found that educational environments can support students' development of course-specific grit-perseverance and mental toughness. However, under normal classroom conditions (i.e., the control group), secondary grade-level students only modestly converted their PE course experience into greater grit-perseverance or mental toughness. Study 1 control group students reported stable (not statistically significantly greater) T1 to T4 grit-perseverance scores of 4.65 and 4.76 ($d = 0.12$; see Figure 2), and Study 2 control group students reported stable and not statistically significantly greater T1 to T4 mental toughness scores of 5.10 and 5.15 ($d = 0.10$; see Figure 4). In contrast, Study 1 experimental group students reported rising and statistically significantly greater T1 to T4 grit-perseverance scores (4.64 rose to 5.12, $d = 0.39$; see Figure 2). Similarly, Study 2 experimental group students reported rising and statistically significantly greater T1 to T4 mental toughness scores (4.79 rose to 5.62, $d = 0.78$; see Figure 4). Given these between-group differences, the key question becomes: How did they do it? How did these middle and high school students develop their grit-perseverance and mental toughness?

The Developmental Path From AST

According to both an SDT perspective and the present findings, the path to developmental gains in grit-perseverance and mental toughness begins with the teacher. This pathway starts with the teacher's professional training in how to provide classroom instruction in a highly autonomy-supportive way. In our investigation, we provided teachers in the experimental group with a professional development experience in the week before classes started. Once class started, these teachers were able to provide autonomy-supportive teacher–student relationships and to establish a "we value and support each other" prevailing peer-to-peer classroom climate that heightened students' perceptions that their classmates

were both highly autonomy supportive (Study 1) and relatedness supportive (Study 2). Together, students' experiences of autonomy-supportive teaching and autonomy-supportive and relatedness-supportive classmates created the classroom conditions in which students were significantly more likely to experience psychological need satisfaction during their PE course.

The most proximal antecedent of students' year-end gains in grit-perseverance and mental toughness was greater psychological need satisfaction. In past research, these experiences of need satisfaction have been shown to enhance students' academic resilience (Bostwick et al., 2022), agency (Reeve et al., 2022), and volitional internalizations (e.g., "This is important to me." "I want to improve and get better at this."; Vansteenkiste et al., 2018). These experiences of interpersonal support and need satisfaction are important facilitators of persistence-empowering ways of thinking because the PE course typically introduces numerous challenges and stressors to adapt to, such as feared activities (e.g., swimming), physical challenges, threats of being injured, social comparison pressure, threats of being socially embarrassed (e.g., afraid of being photographed in the locker room), feeling inadequate or overwhelmed, grade pressure, threats of social exclusion and body shaming, competitive stress, performance anxiety, and bullying episodes (Åsebø et al., 2020). The primary reason why students developed greater grit-perseverance and mental toughness was because they experienced high levels of in-class psychological need satisfaction (as per H3a). A secondary or supplemental reason these students developed greater grit-perseverance and mental toughness was because they experienced high levels of peer-to-peer support during class (as per H4b; Ryan et al., 2005).

Overall, we suggest that the developmental path from AST to grit-perseverance and mental toughness (a) starts with having a highly autonomy-supportive teacher, (b) progresses as students are surrounded by highly supportive relationships, (c) takes root with frequent and

recurring experiences of need satisfaction and volitional internalizations, and (d) grows to fruition as students apply these assets (i.e., need satisfaction and peer support) to the management of the challenges and setbacks that come their way.

Support or Adversity?

The current study advances the knowledge base of SDT. Specifically, SDT has recently been challenged for focusing on supports rather than on adversity as a basis for personal growth (see Bauer et al., 2019; Koole et al. 2019). Responding to this challenge, Ryan et al. (2019) argued that SDT assumes that developmental challenges are optimally met with positive coping and resilience. The important question within this "support or adversity?" debate is how people develop inner resources such as grit-perseverance, mental toughness, and related personal resources, such as resilience. In speaking to this debate, Ryan et al. (2019) argued:

> *We need not introduce or expose individuals to damaging conditions to help them grow; adding toxins to the waters of childhood is not sufficient to create "resilience." Instead, resilience concerns how individuals respond to these threats and deprivations. SDT research suggests that resilience is facilitated by support for autonomy, scaffolding of competencies, and a sense of acceptance and connection. Children, adolescents, and young adults will come upon "hard knocks" on their own, and when they do, those with a backdrop of love and support will, SDT predicts, handle them better.* (p. 120)

Nonetheless, a paucity of studies within the SDT framework have focused on the development of engagement-facilitating personal resources, such as resilience, grit-perseverance, and mental toughness. And the studies that do exist have used only cross-sectional research designs. The findings from the present investigation, thus, provide important evidence regarding the SDT position that having a developmental history or current

context that is need supportive facilitates the development of such inner resources. The current findings suggest that providing a supportive developmental context (experimental group) better fosters grit and mental toughness than does allowing students to "sink or swim" (control group).

This line of reasoning is supported by qualitative data collected from people with amazing levels of mental toughness (successful Paralympic athletes) who cite "supportive relationships" and "good teammates" as critical facilitators of both their mental toughness and exceptional performances (Raabe et al., 2021). It is further supported by cross-lagged panel model analyses showing that grit and well-being are reciprocally positively related, suggesting a virtuous upward cycle between subjective well-being and grit in early adolescence (Zhang et al., 2023). Therefore, the take-home message suggested by these findings (see Figures 3and 5) on how educators can help students develop their mental toughness is this: Offer students a highly autonomy-supportive teacher.

It is possible for students to triumph over adversity without an autonomy-supportive teacher, without supportive classmates, and without in-class need satisfaction. However, in the absence of interpersonal support and need satisfaction experiences, demanding situations can potentially overwhelm or even motivationally crush the student. Facing adversity, students are somewhat "at risk" of suffering "dark side" motivations and experiences, such as psychological need frustration and helplessness. Rather than expect students to develop grit-perseverance and mental toughness in the face of failure and adversity, we suspect that these environmental conditions (failure, adversity) would be more likely to "backfire" and put students at risk of developing personal vulnerabilities, such as need frustration and helplessness (Bartholomew et al. 2011).

Limitations

Three methodological decisions limit the conclusions that can be reached and the generalizations that can be made. First, all the data collected to test the hypothesized model included students' self-reports. A more methodologically rigorous investigation would include data from other informants, such as teacher ratings, raters' classroom observational scores, behavioral markers of persistence, or psychophysiological markers of students' grit-perseverance and mental toughness.

Second, as to generalizability, it is not clear whether the present findings with Korean secondary grade students taking a PE course apply to other cultural settings, to primary grade-level students, and to different domains (e.g., sports). Our data set did include variations in grade level (middle school vs. high school), but grade level did not predict either grit-perseverance or mental toughness, which suggests that our findings may generalize across the middle to high school grade levels, at least in the present data sets.

Third, our intervention focused only on AST. Future research might similarly train teachers on how to offer both autonomy-supportive and structured teaching (Cheon et al., 2019, 2020; Meng & Wang, 2016). Teacher-provided structure (e.g., clarify expectations, set goals, and provide role models) may offer students something important to volitionally internalize (e.g., a standard of excellence). Hence, a future intervention might offer teachers training in how to provide classroom structure in a highly autonomy-supportive way.

Conclusions

Grit-perseverance and mental toughness can be developed over time by providing PE students with a highly autonomy-supportive teacher—a teacher who can create classroom conditions of high interpersonal support and empowering psychological need satisfaction. We conclude that the developmental roots of grit-perseverance, mental toughness, and perhaps other engagement-generating ways of thinking can be constructively developed via in-class experiences of interpersonal support and psychological need satisfaction.

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Table 1

Descriptive Statistics on the Fidelity Check Questionnaire Items for Teachers in the Experimental Condition (Study 1)

Fidelity Check Questionnaire Item		*M*	*SD*
1	The recommended teaching strategies were clear and easy to understand.	6.20	0.71
2	I agreed with and responded positively to the workshop's recommended teaching practices.	6.24	0.72
3	The workshop was useful to my teaching.	6.24	0.72
4	I was satisfied with the recommendations featured in the workshop.	6.20	0.64
5	My use of the recommended teaching strategies helped me produce a positive change in my teaching effectiveness.	6.28	0.74
6	I would recommend the workshop to other teachers at my school.	6.16	0.85
		Count	%
7	Compared to the quality of your teaching at the beginning of the year (before you participated in the workshop), would you say that your *classroom teaching effectiveness* is now more effective, less effective, or about the same (check one):		
	___ More effective	25	100%
	___ Less effective	0	0%
	___ About the same	0	0%

Note. *M* = Mean, *SD* = Standard Deviation, Count = Frequency count, % = Percentage of responses. Possible *Range* of scores, 1-7. *N* = 25 teachers.

Table 2

Descriptive Statistics with Unstandardized and Standardized Beta Weights for All 30 indicators within the Grit Measurement Model (Study 1)

Observed Variable	Time 1					Time 2					Time 3					Time 4				
	M	(*SD*)	*B*	*SE*	*β*	*M*	(*SD*)	*B*	*SE*	*β*	*M*	(*SD*)	*B*	*SE*	*β*	*M*	(*SD*)	*B*	*SE*	*β*
Autonomy-Supportive Teaching Indicators																				
1. Perspective taking	5.29	(1.09)	1.00	-	.89	5.53	(1.17)	1.00	-	.91										
2. Interest support	5.25	(1.10)	.98	.02	.87	5.46	(1.18)	.98	.01	.89										
3. Value support	5.15	(1.10)	.82	.02	.73	5.37	(1.20)	.87	.02	.80										
Autonomy-Supportive Classmates Indicators																				
1. Perspective taking	5.04	(1.16)	1.00	-	.90	5.38	(1.28)	1.00	-	.94										
2. Interest support	5.03	(1.17)	1.00	.02	.91	5.33	(1.24)	.98	.01	.92										
3. Value support	4.46	(1.42)	.76	.02	.69	4.68	(1.64)	.75	.02	.70										
Need Satisfaction Indicators																				
1. Autonomy satisfaction	4.99	(1.12)	1.00	-	.87						5.42	(1.19)	1.00	-	.87					
2. Competence satisfaction	4.70	(1.24)	.81	.02	.72						5.04	(1.32)	.86	.02	.76					
3. Relatedness satisfaction	4.90	(1.07)	.97	.02	.84						5.36	(1.10)	1.03	.02	.91					
Grit Indicators																				
During this PE course,																				
1. I finish whatever I begin.	4.87	(1.41)	.78	.03	.61											5.17	(1.45)	.84	.03	.69
2. Setbacks don't discourage me.	4.30	(1.61)	.55	.03	.43											4.73	(1.73)	.65	.03	.54
3. I am a hard worker.	4.92	(1.48)	.80	.02	.63											5.25	(1.51)	.80	.03	.66
4. I achieved a goal that took a lot of work.	4.35	(1.69)	.78	.03	.61											4.61	(1.80)	.77	.03	.64
5. I am diligent.	4.25	(1.54)	.92	.03	.65											4.63	(1.67)	.83	.03	.69
6. I have overcome setbacks to conquer an important challenge.	4.70	(1.84)	1.00	-	.78											5.04	(1.48)	1.00	-	.83

Note. Possible range for each observed variable was 1-7.

M = mean; (*SD*) = standard deviation; *B* = unstandardized beta weight; *SE* = standard error; *β* = standardized beta weight.

Table 3

Intercorrelations and Descriptive Statistics for Experimental Condition, Latent Variables, and Statistical Controls in the Grit Hypothesized Model (Study 1)

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Experimental Condition	-	-.02	-.06	-.04	-.01	.20	.13	.16	.15	.13	-.35	.05
Time 1 Baseline												
2. Autonomy-Supportive Teaching		-	.68	.76	.44	.51	.36	.44	.31	-.05	-.01	.02
3. Autonomy-Supportive Classmates			-	.81	.55	.35	.52	.48	.34	-.03	.01	-.01
4. Need Satisfaction				-	.65	.39	.43	.55	.41	.05	-.01	-.02
5. Grit					-	.23	.29	.35	.53	.04	-.01	-.03
Time 2												
6. Autonomy-Supportive Teaching						-	.68	.59	.38	.01	-.20	.09
7. Autonomy-Supportive Classmates							-	.64	.44	-.01	-.14	.06
Time 3												
8. Need Satisfaction								-	.59	.00	-.18	.07
Time 4												
9. Grit									-	.04	-.15	.12
Statistical Controls												
10. Gender										-	.04	-.03
11. Grade Level											-	-.28
12. Class Size												-
Descriptive Statistics												
Mean	0.48	5.23	4.84	4.86	4.62	5.45	5.13	5.27	4.94	0.47	0.44	27.6
Standard Deviation	0.50	0.97	1.11	1.01	1.13	1.08	1.25	1.09	1.21	0.50	0.50	5.8

N = 3,147 students. Any $r > .06$, $p < .05$; any $r > .08$, $p < .01$; and any $r > .10$, $p < .001$.

Table 4

Descriptive Statistics with Unstandardized and Standardized Beta Weights for All 40 Indicators within the Mental Toughness Measurement Model (Study 2)

Observed Variable	Time 1					Time 2					Time 3 (Need Satisfaction) or Time 4 (Mental Toughness)				
	M	(*SD*)	*B*	*SE*	*β*	*M*	(*SD*)	*B*	*SE*	*β*	*M*	(*SD*)	*B*	*SE*	*β*
Autonomy-Supportive Teaching Indicators															
1. I feel my teacher provides me with choices and options.	5.02	(1.18)	.76	.03	.67	5.34	(1.32)	.83	.03	.72					
2. I feel understood by my teacher.	5.12	(1.14)	.84	.03	.73	5.34	(1.34)	.90	.02	.78					
3. My teacher conveys confidence in my ability…in this course.	5.02	(1.11)	.91	.03	.79	5.38	(1.26)	.96	.02	.83					
4. My teacher encourages me to ask questions.	5.06	(1.15)	1.00	-	.87	5.34	(1.29)	1.00	-	.87					
5. My teacher listens to how I would like to do things.	4.94	(1.15)	.94	.03	.82	5.23	(1.28)	.94	.03	.82					
6. My teacher tried to understand how I see things before suggesting a new way to do things.	5.06	(1.10)	.97	.03	.85	5.37	(1.22)	.98	.02	.86					
Relatedness-Supportive Classmates Indicators															
During this PE class, most of my peers…															
7. Make their classmates feel valued.	5.11	(1.16)	1.00	-	.87	5.40	(1.26)	1.00	-	.90					
8. Care about everyone's opinions.	4.72	(1.31)	.71	.03	.62	5.10	(1.41)	.76	.03	.68					
9. Make their classmates feel accepted.	4.97	(1.13)	.95	.03	.83	5.34	(1.25)	.95	.02	.85					
Need Satisfaction Indicators															
10. Autonomy satisfaction	4.81	(1.04)	1.00	-	.92						5.33	(1.18)	1.00	-	.95
11. Competence satisfaction	4.38	(1.21)	.85	.02	.78						4.96	(1.29)	.88	.02	.83
12. Relatedness satisfaction	5.49	(0.93)	.69	.03	.64						5.75	(1.03)	.76	.03	.73
Mental Toughness Indicators															
During this PE course,															
13. I believe in my ability to achieve my goals.	4.89	(1.18)	1.00	.03	.82						5.32	(1.26)	.99	.02	.88
14. I am able to regulate my focus when performing tasks.	5.00	(1.15)	.99	.02	.83						5.42	(1.22)	.99	.02	.88
15. I am able to use my emotions to perform the way I want to.	4.78	(1.24)	.97	.02	.75						5.29	(1.30)	.91	.02	.81
16. I strive for continued success.	5.10	(1.17)	1.00	-	.82						5.47	(1.24)	1.00	-	.89
17. I…execute my knowledge of…required to achieve my goals.	4.80	(1.21)	.94	.03	.77						5.29	(1.29)	.95	.02	.84
18. I consistently overcome adversity.	4.86	(1.18)	.97	.03	.80						5.32	(1.29)	.99	.02	.88
19. I…execute appropriate skills or knowledge when challenged.	5.04	(1.22)	.92	.03	.75						5.44	(1.24)	.94	.02	.85
20. I can find a positive in most situations.	4.91	(1.15)	.99	.03	.81						5.36	(1.27)	1.01	.02	.90

Note. Possible range for each observed variable was 1-7. *M* = mean; (*SD*) = standard deviation; *B* = unstandardized beta weight; *SE* = standard error; *β* = standardized beta weight.

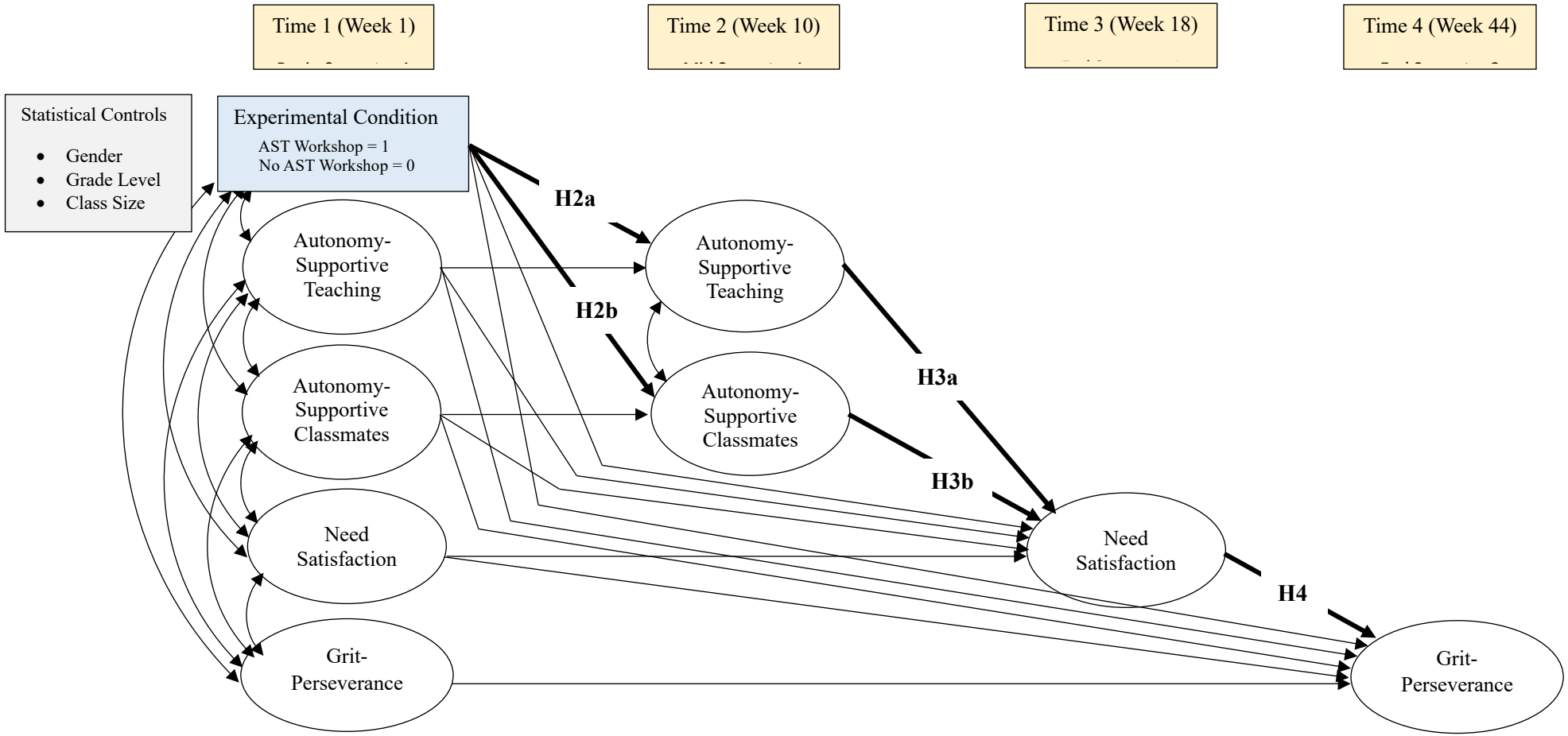
Table 5

Intercorrelations and Descriptive Statistics for Experimental Condition, Latent Variables, and Statistical Controls in the Mental Toughness Hypothesized Model (Study 2)

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Experimental Condition	-	-.09	-.11	-.09	-.09	.19	.16	.23	.30	.02	.49	.04
Time 1 Baseline												
2. Autonomy-Supportive Teaching		-	.74	.66	.60	.45	.35	.37	.28	-.04	-.03	-.08
3. Relatedness-Supportive Classmates			-	.75	.73	.33	.47	.36	.30	-.02	.04	-.07
4. Need Satisfaction				-	.89	.29	.35	.44	.34	.07	.00	-.11
5. Mental Toughness					-	.27	.34	.40	.34	.06	.02	-.10
Time 2												
6. Autonomy-Supportive Teaching						-	.69	.50	.43	.02	.07	-.01
7. Relatedness-Supportive Classmates							-	.53	.46	-.01	.09	-.07
Time 3												
8. Need Satisfaction								-	.65	.05	.15	-.04
Time 4												
9. Mental Toughness									-	.07	.20	-.05
Statistical Controls												
10. Gender										-	-.06	-.15
11. Grade Level											-	-.04
12. Class Size												-
Descriptive Statistics												
Mean	0.47	5.03	4.93	4.90	4.92	5.33	5.28	5.35	5.37	0.51	0.43	28.8
Standard Deviation	0.50	0.94	1.02	0.90	0.97	1.09	1.15	1.03	1.12	0.50	0.49	5.4

N = 2,057 students. Any $r > .06$, $p < .05$; any $r > .08$, $p < .01$; and any $r > .10$, $p < .001$.

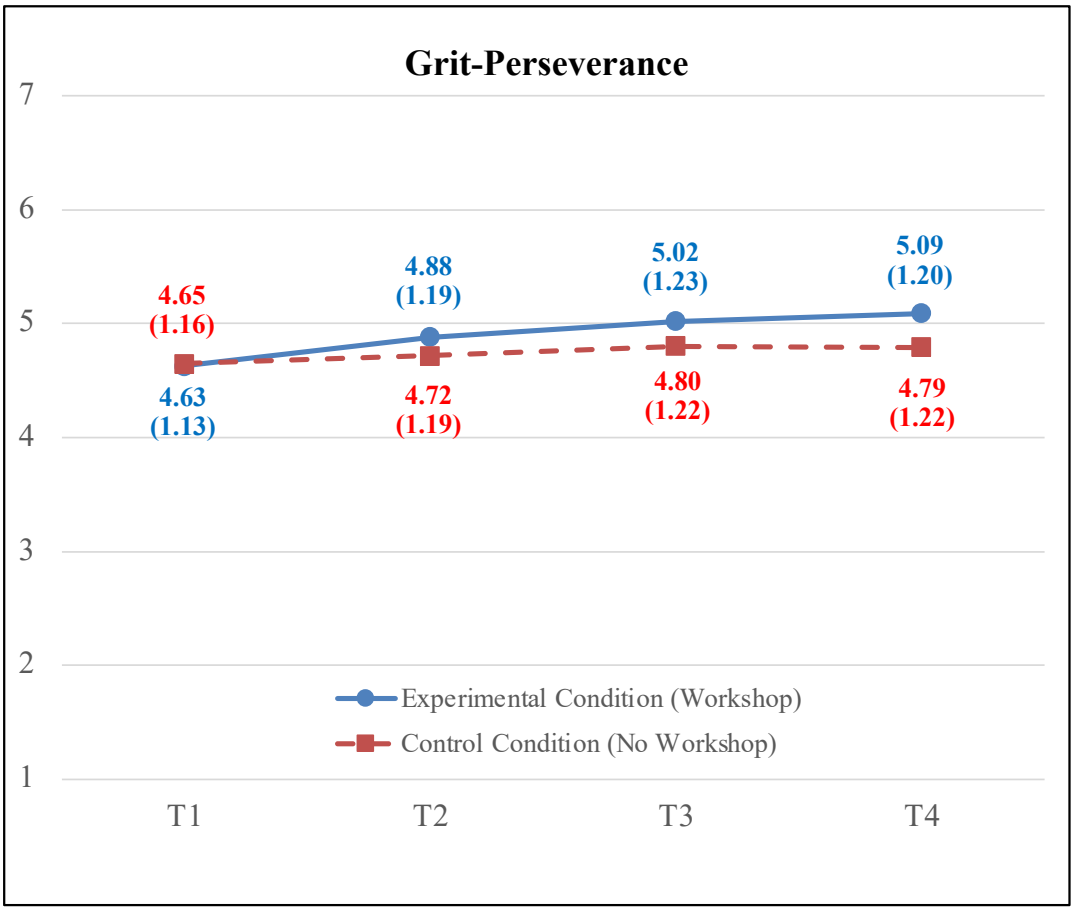
Figure 1
Hypothesized Model to Predict Greater Grit



Note. The three statistical controls of gender, grade level, and class size were included in the hypothesized model but are not shown in the figure.

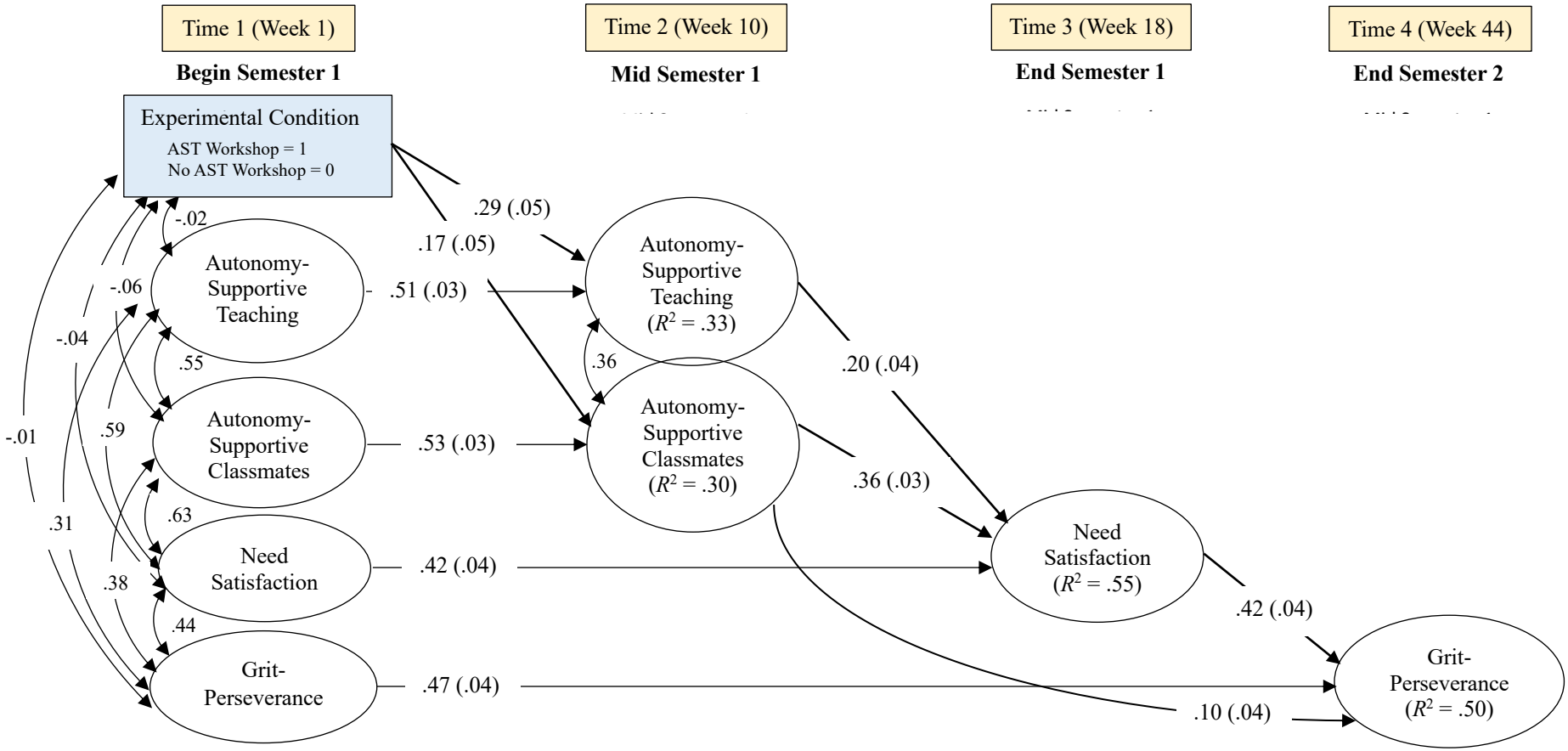
Figure 2

Students in the Experimental Condition Reported a Greater Increase in their Course-Specific Grit-Perseverance than Did Students in the Control Condition



Note. The numbers in the figure are group mean scores, while the numbers in parentheses are standard deviations. T1 = Time 1; T2 = Time 2; T3 = Time 3; T4 = Time 4.

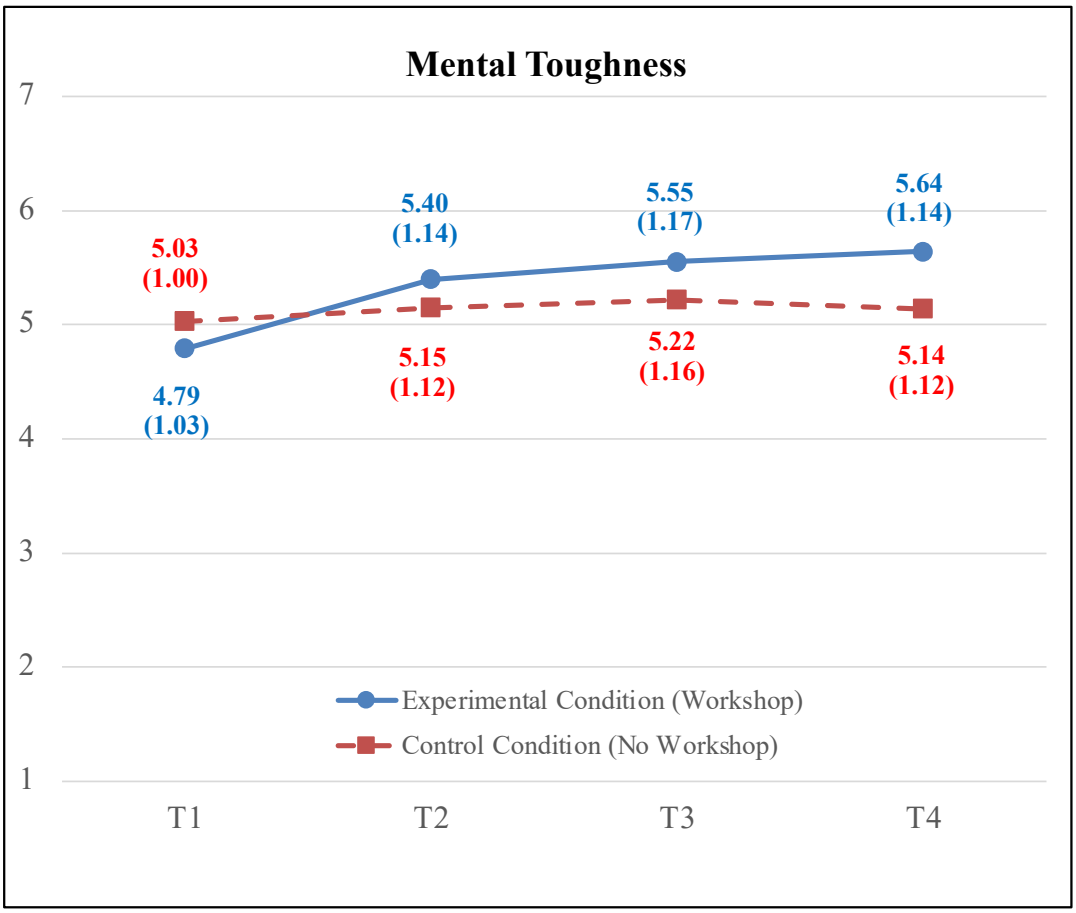
Figure 3
Test of Hypothesized Model to Predict Greater Grit-Perseverance



Note. Numbers represent unstandardized beta weights with standard errors in parentheses.
Solid lines represent significant paths, $p < .05$. All effects include the three statistical controls of gender, grade level, and class size.
Overall model fit: $X^2(473) = 2{,}311.56$, $p < .001$, *RMSEA* = .035, *SRMR* = .046, *CFI* = .948, and *TLI* = .940.

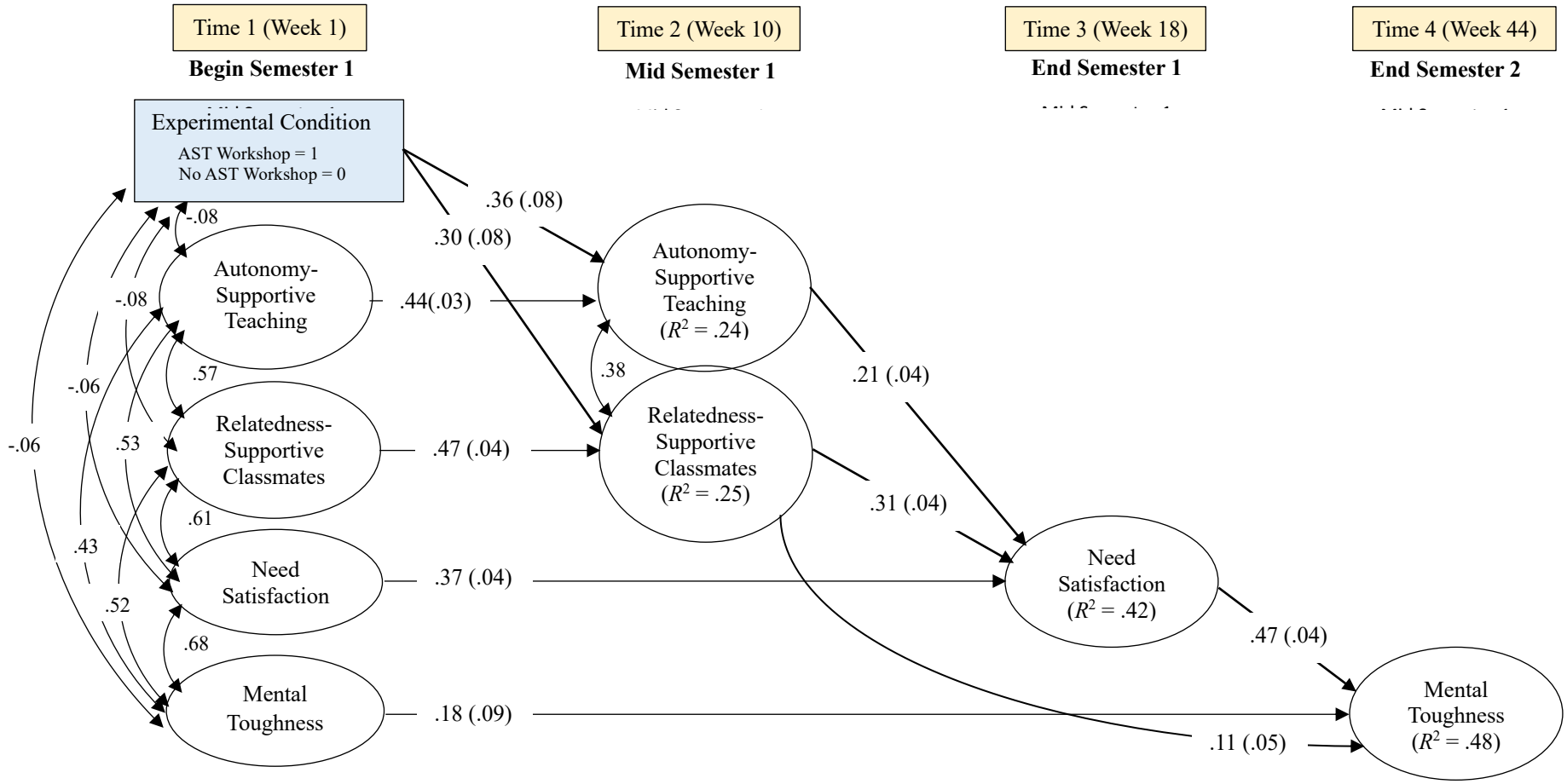
Figure 4

Students in the Experimental Condition Reported a Greater Increase in their Course-Specific Mental Toughness than Did Students in the Control Condition



Note. The numbers in the figure are group mean scores, while the numbers in parentheses are standard deviations. T1 = Time 1; T2 = Time 2; T3 = Time 3; T4 = Time 4.

Figure 5
Test of Hypothesized Model to Predict Greater Mental Toughness



Note. Numbers represent unstandardized beta weights with standard errors in parentheses.
Solid lines represent significant paths, $p < .05$. All effects include the three statistical controls of gender, grade level, and class size.
Overall model fit: $X^2(843) = 3{,}436.99$, $p < .001$, *RMSEA* = .039, *SRMR* = .046, *CFI* = .945, and *TLI* = .939.