Teacher characteristics as predictors of mathematics attitude and perceptions of engaged teaching among 12th grade advanced mathematics students in the U.S

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ABSTRACT
The present study examined the 2015 Trends in International Mathematics and Science Study “Advanced” data to examine how the educational credentials of maths teachers and other teacher characteristics were related to attitude towards advanced mathematics and perceptions of engaged teaching among 12th-grade students enrolled in advanced mathematics courses in the U.S. As attitudinal outcomes in this study, two measures of attitude towards mathematics were employed – the Students Like Learning Advanced Mathematics scale and the Students Value Advanced Mathematics scale, and one measure of student perception of engaged teaching – the Students’ Views on Engaging Teaching in Advanced Mathematics Lessons. A set of multilevel regression analyses were conducted predicting each of these aforementioned outcomes. No statistically significant effects on the attitudinal outcomes were observed for teacher variables. Positive effects were noted for parental education on students’ valuing of advanced mathematics. A prominent finding was that higher levels of parental education were associated with higher student levels of valuing mathematics, which likely reflects a family/home culture that implicitly or explicitly places high value on science and mathematics. Identifying factors that might facilitate positive attitude is important to increase the likelihood that students will choose, and be retained in, mathematics and STEM education and careers.

Developing and enhancing student attitudes towards mathematics remains an important goal in mathematics education. Although some evidence linking attitude towards mathematics and mathematics achievement exists – Buxton (1981), for example, reported that a negative attitude towards maths may, in fact, interfere with cognitive processes and even prompt children to refuse to attempt maths – a direct relationship between attitudes towards mathematics and mathematics achievement has not
definitely been established (see meta-analysis by Ma & Kishor, 1997). However, a more recent meta-analysis by Çiftçi and Yıldız (2019) examined 336 independent studies that used 2003 to 2015 TIMSS data and found a moderate, positive effect of an attitudinal construct – student self-confidence in mathematics – on mathematics achievement. This effect did not vary between primary and secondary school students, but the effect of self-confidence was stronger in studies examining more recent TIMSS data. Additionally, Kalaycioglu (2015) and Karakolidis, Pitsia, and Emvalotis (2016) observed that mathematics self-efficacy was related to maths achievement, while Dickhauser, Dinger, Janke, Spinath, and Steinmayr (2016) and Yurt (2015) found that intrinsic motivation significantly predicted mathematics achievement. A larger issue, however, may be the consistently observed low enrolment rates and high attrition rates in STEM fields (Sithole et al., 2017). That is, enhancing constructs such as interest, confidence, and valuation of mathematics, regardless of whether these attitudes directly relate to achievement, can help to attract and retain high-ability students into these fields. Additionally, fostering positive attitudes might hold particular potential benefit for women. Ellis, Fosdick, and Rasmussen (2016), for example, using data from a large national survey that they conducted, found that women were 1.5 times more likely to abandon STEM studies after enrolling in college-level calculus than were men, and the authors attribute this attrition to lack of mathematics confidence among women.

Teacher characteristics also can be considered when considering predictors of students’ attitudes towards mathematics. Walberg’s (1981, 1992) Classroom Practices Educational Productivity Model, for example, identified instructional factors as one of the three essential factors that can influence students’ affective development (the other factors being environmental and personal factors). Most extant research, however, has focused on teacher characteristics as they relate to student achievement outcomes. As reported in Clotfelter, Ladd, and Vigdor (2006), a number of studies (e.g. Aaronson, Barrow, & Sanders, 2003; Ballou, Sanders, & Wright, 2004; Hanushek, Kain, O’Brien, & Rivkin, 2005; Nye, Konstantopoulos, & Hedges, 2004; Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004) examining teacher characteristics (e.g. teacher credentials, continuing education, teacher experience) and how these characteristics relate to student achievement have found that, beyond teaching experience (e.g. number of years teaching) no teacher characteristics regularly or reliably predict student achievement. Also, with teaching experience, prior research (Clotfelter et al., 2006; Hanushek et al., 2005) suggested that the effects of this characteristic on student achievement are not consistent across time, and that experience in a teacher’s early years of teaching are more impactful on student achievement than later experience.

Similarly, as noted by Burroughs et al. (2019), other studies examining effects of teacher advanced degrees, certification, or subject specialisation (e.g. Aaronson et al., 2003; Blomeke, Olsen, & Suhl, 2016; Hanushek & Luque, 2003; Harris & Sass, 2011; Luschei & Chudgar, 2011) have reported non-significant, weak, or inconsistent effects of these teacher attributes on student achievement. However, studies that examine data from multiple countries (e.g. Akiba, LeTendre, & Scribner, 2007; Gustafsson & Nilsen, 2016; Montt, 2011; Woessman, 2003) have found relationships between the attained degree of a teacher and student achievement outcomes in mathematics, science, and reading. Clotfelter, Ladd, and Vigdor (2007), analysing administrative data over a 10-year period from North Carolina, found that teacher licensure, test scores, and teacher experience each were positively related to 3rd-8th grade student performance, with larger
effects on mathematics achievement than reading achievement. Notably, however, they found that whether a teacher possessed a master’s degree had no statistically significant effect on student achievement. This was true regardless of when the teacher earned the degree and, in fact, teachers who earned their degree more than five years after entering the teaching profession were less effective in facilitating student achievement than those without a degree. Further, Clotfelter et al. (2007) found that possession of a doctoral degree was observed to have a large negative effect on student achievement, although the authors noted that this might have been an anomaly due to the small number of teachers in their sample with such a degree. In an early study, Clotfelter et al. (2006) also found that, among 5th grade students, the relationship between teacher characteristics and student achievement is biased because teachers with higher credentials tend to be matched with students who are more disadvantaged. When controlling for such matching, the authors found that teacher experience and licensure tests scores were positively associated with student achievement.

The Trends in International Mathematics and Science Study (Martin, Mullis, & Hooper, 2016) is a set of large-scale assessments focusing on science and mathematics knowledge among students in 4th grade, 8th grade, and in their final year of secondary education. Data also are collected on other, non-cognitive characteristics, including student attitudes. These attitudes, which can be characterised as the positive or negative feelings that a person holds towards an object or phenomenon (Rosenberg & Hovland, 1960), or “the evaluation of an object, concept, or behavior along a dimension of favor or disfavor, good or bad, like or dislike” (Ajzen, 2001, p. 3) have been operationalised by TIMSS as a set of scales that focus on “liking” and “valuing” mathematics. “Liking” mathematics encompasses intrinsic motivation to learn, while “valuing” mathematics includes extrinsic motivation to learn, utility, and value. They draw upon the self-determination theory of Deci and Ryan (1985), which holds that the motivation behind the choices made by people are self-motivated and self-determined and, further, are driven by the need for competence, autonomy, and social relations (Deci & Ryan, 1995). Various meta-analyses (e.g. Hattie, 2009; Lee & Stankov, 2018; Osborne, Simon, & Collins, 2003) have demonstrated that student motivation positively predicts performance. Compared to the effects of motivation, task value generally has been found to be less strongly related to student performance (Michaelides, Brown, Eklof, & Papanastasiou, 2019). However, studies using the TIMSS data have found a strong predictive effect of task value (Hooper et al., 2017; Mullis, Martin, Gonzales, & Chrostowski, 2004).

Although the prior studies have examined how teacher characteristics relate to student achievement, relatively little research has examined how teacher characteristics relate to student attitudes – specifically, students’ intrinsic motivation to learn advanced mathematic and student’s valuing of advanced mathematics, or how these characteristics relate to students’ perceptions of engaged teaching. An additional area of interest with little extant research concerns how these effects may manifest among the population of students in their final year of high school. This point of time is of particular interest because many of these students will be commencing post-secondary studies and soon making pivotal and critical choices regarding enrolment in college-level science, technology, engineering, and maths (STEM) courses, as well as choosing major fields of study. For many students and particularly women students and students from diverse backgrounds, these choices could have lifelong consequences in terms of careers,
income, and social advancement. Thus, any potential teacher effects at this stage are of particular interest and importance.

The purpose of the present study was to use a large, nationally representative data set – the 2015 TIMSS “Advanced” data set (Martin et al., 2016) – to examine how the educational credentials of maths teachers (specifically, highest degree earned) in addition to other teacher characteristics (teacher experience, major field of study, and gender) were related to attitudes towards advanced mathematics and perceptions of engaged teaching among students enrolled in advanced mathematics courses. To these ends, the following research questions were posed:

- **RQ1:** To what extent are teacher characteristics (highest educational credentials, teaching experience, major field of study, and gender) related to students’ liking of advanced mathematics?
- **RQ2:** To what extent are teacher characteristics (highest educational credentials, teaching experience, major field of study, and gender) related to students’ valuing of advanced mathematics?
- **RQ3:** To what extent are teacher characteristics (highest educational credentials, teaching experience, major field of study, and gender) related to students’ perceptions of engaged teaching?

Because the sample used in this study consisted of students enrolled in advanced mathematics courses during their final year of high school, we assumed that most students would have positive attitudes towards mathematics. However, we still expected variability in these outcomes, but did not have specific directional hypotheses regarding how this variability would be explained by the teacher characteristics.

**Method**

This study makes use of the Trends in International Mathematics and Science Study (TIMSS) 2015 “Advanced” data set (Martin et al., 2016). The TIMSS Advanced data contain information on 12th grade student enrolled in an advanced mathematics or science courses. Variables in the data set assess maths and science achievement, teacher background, student background, and school background. Specifically, we used data from the “Advanced Mathematics Population” (Martin et al., p. 3.4). These data were collected from U.S. students in their final year of secondary school (12th grade) who had enrolled in an advanced mathematics course (i.e. AP, IB, or another advanced mathematics course), as well as data from their associated advanced mathematics teacher. Students in the TIMSS sample were selected from the population of 12th grade advanced mathematics students using a two-stage stratified cluster sampling procedure where the first stage constituted a random sample of schools, and the second stage involved the selection of students using a random systematic approach (Martin et al.). Notably, the second-stage selection of students for the TIMSS 2015 Advanced U.S. sample differed from the TIMSS sampling strategy for other countries, where intact classes were randomly selected rather than students. As with other TIMSS samples, however, school type (e.g. public vs. private) and location (e.g. metropolitan, non-metropolitan), and school performance on national exams served as stratification
variables. Additionally, in the current study data from the teachers of the students’ advanced mathematics courses were considered (highest degree obtained, years of teaching experience, and gender). To facilitate analysis, for students who had more than one reported advanced mathematics teacher, we randomly selected one teacher per student for inclusion in the analytic sample. Table 1 provides demographic information for the teachers and students in the analytic sample (N = 2445). Teachers in this sample were slightly more likely to be male (50.2%) than female (49.8%), most (73.6%) had a master’s or doctoral degree, and a slight majority (54.1%) had college majors in both maths and maths education. Additionally, among the mathematics teachers, the mean number of years teaching was M = 18.53 (SD = 9.73), so these teachers had fairly extensive experience. Among the students, many came from families where at least one parent had a college degree (68.0%) and at least one parent was professionally employed (75.9%). Student gender was close-to-uniformly distributed (51.5% female). When the distributions of the outcome variable indicators were considered (Tables 2–4), it was apparent that students had strong intrinsic motivation to learn maths and strongly valued maths. They also had positive views about the teaching engagement of their maths teachers.

As attitudinal outcomes in in this study, two measures of attitude towards mathematics – the Students Like Learning Advanced Mathematics (SLM) scale and the Students Value Advanced Mathematics (SVM) scale, and one measure of student
perception of engaged teaching – the Students’ Views on Engaging Teaching in Advanced Mathematics Lessons (SVET) – were considered as outcome variables: These measures were based on student responses to 12 items (SLM scale), 9 items (SVM scale), and 14 items (SVET) pertaining to the corresponding constructs (see Tables 2–4). Each scale item was associated with four Likert response options (Agree a lot to Disagree a lot). The scale developers created composite scores from the scales using item response theory (IRT) procedures (see Martin et al., 2016), and these composite scores are included in the TIMSS data set. Scores from each scale have demonstrated good evidence of reliability for the U.S. sample, with alpha = .91 (SLM scale), alpha = .81 (SVM scale), and alpha = .94 (SVET scale). The highest degree attainment of each maths teacher (bachelor’s or equivalent, master’s or equivalent, or doctoral or equivalent), as well as years of teaching experience and teacher gender were assessed by items in the TIMSS Teacher Questionnaire. Because of the small number of teachers (n = 4) who reported possessing a doctoral degree, an aggregate category was created by combining this group of teachers with those who reported possessing a master’s degree.

Table 2. Items on TIMSS students like learning advanced mathematics.

| Item                                                                 | Percent responding either Agree at Little or Agree a Lot |
|---------------------------------------------------------------------|----------------------------------------------------------|
| How much do you agree with these statements about the mathematics you are studying? |                                                          |
| When I do mathematics problems, I sometimes get completely absorbed  | 78.8                                                     |
| I get a sense of satisfaction when I solve mathematics problems     | 93.8                                                     |
| I feel bored when I do my mathematics schoolwork*                   | 60.0                                                     |
| I like studying for my mathematics class outside of school          | 31.6                                                     |
| It is interesting to learn mathematics theory                       | 56.8                                                     |
| I dread my mathematics class*                                        | 32.7                                                     |
| I am studying mathematics because I like to learn new things        | 69.2                                                     |
| I enjoy figuring out challenging mathematics                         | 80.5                                                     |
| Mathematics is one of my favourite subjects                         | 66.8                                                     |
| Jobs that require advanced mathematics skills seem interesting to me | 62.2                                                     |
| I wish I did not have to study mathematics*                         | 27.7                                                     |
| I enjoy thinking about the world in terms of mathematical relationships | 51.0                                                     |

*Reverse-coded. Response options for each item are Agree a lot, Agree a little, Disagree a little, and Disagree a lot. For composite score, M = 9.98, SD = 2.08.

Table 3. Items on TIMSS students value advanced mathematics.

| Item                                                                 | Percent responding either Agree at Little or Agree a Lot |
|---------------------------------------------------------------------|----------------------------------------------------------|
| How much do you agree with these statements about the mathematics you are studying? |                                                          |
| Learning mathematics will help me get ahead in the world            | 93.4                                                     |
| It is important to do well in my mathematics class                 | 96.7                                                     |
| The mathematics I am studying is not useful for my future*          | 34.8                                                     |
| My parents are pleased that I am taking advanced mathematics        | 96.4                                                     |
| Doing well in mathematics will help me get into the university of my choice | 95.3                                                     |
| Learning advanced mathematics does not seem to be a worthwhile exercise* | 20.5                                                     |
| My parents think that it is important that I do well in my mathematics class | 98.1                                                     |
| I like telling people I am studying advanced mathematics            | 74.7                                                     |
| Learning advanced mathematics will give me more job opportunities   | 90.1                                                     |

*Reverse-coded. Response options for each item are Agree a lot, Agree a little, Disagree a little, and Disagree a lot. For composite score, M = 11.23, SD = 2.05.
Table 4. Items on TIMSS students’ views on engaging teaching in advanced mathematics lessons scale.

| Item                                                                 | Percent responding |
|----------------------------------------------------------------------|---------------------|
| How much do you agree with these statements about your advanced mathematics lessons? |                     |
| The teacher clearly communicates the purpose of each mathematics lesson | 85.2                |
| I know what my teacher expects me to do                               | 94.2                |
| My teacher is easy to understand                                      | 84.1                |
| I am interested in what my teacher says                               | 78.7                |
| My teacher gives me interesting things to do                          | 66.7                |
| My teacher asks me thought provoking questions                        | 74.8                |
| My teacher has clear answers to my questions                         | 82.4                |
| My teacher links new content to what I already know                   | 88.8                |
| My teacher is good at explaining advanced mathematics                 | 87.7                |
| My teacher provides the opportunity for me to show what I have learned| 90.5                |
| My teacher encourages me to keep working on advanced mathematics problems until I solve them | 91.6 |
| My teacher provides helpful feedback on my schoolwork (including homework) | 78.1                |
| My teacher uses a variety of teaching methods, tasks, and activities to help us learn | 72.4                |
| My teacher believes that I can learn difficult advanced mathematics material | 94.6                |

Response options for each item are Agree a lot, Agree a little, Disagree a little, and Disagree a lot. For composite score, $M = 10.43$, $SD = 2.15$.

To address each research question, a set of multilevel regression analyses were carried out predicting each of the three outcomes (SLM, SVM, and SVET). Students served as the level-1 unit of analysis, and these students were clustered into classes taught by specific teachers (the level-2 units). Level-2 predictors of interest included each teacher’s highest earned degree (with two categories: bachelor’s or equivalent, master’s or equivalent or higher), years of teaching experience, gender, and major area of study (with four categories: maths major but not maths education major, maths education major but not maths major, both maths and maths education major, or all other majors). To control for effects of student socio-economic differences, the highest educational level and occupational level of each student’s parents were used as level-1 covariates and, based on prior literature showing gender differences in student attitudes towards mathematics (see, for example, Else-Quest, Hyde, & Linn, 2010), student gender also was employed as a level-1 covariate. For all regression analyses, supplied student-level sampling weights were used. Analyses were carried out using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) in R (R Core Team, 2020).

Results

Tables 5–7 show results for multilevel regression analyses predicting Students Like Learning Advanced Mathematics (SLM), Students Value Advanced Mathematics (SVM), and Students’ Views on Engaging Teaching in Advanced Mathematics Lessons (SVET) from the level-1 and level-2 predictors. For each analysis, the regression assumptions of linearity, homoscedasticity, and normality both level-1 and level-2 residuals were assessed and met. Excessive multicollinearity among regressors was not evident, with no VIF values exceeding 2.0. Null models fitted to each of the outcomes
showed intraclass correlation coefficient (ICC) values of .10, .09, and .23 for SLM, SVM, and SVET, respectively, and observed design effects (DEFFs) were 1.66, 1.64, and 2.61.

When the set of models predicting student liking of advanced mathematics (SLM) were fitted (Table 5), results showed that, among the Level-1 predictors, female student gender was a statistically significant, negative predictor of student’s liking of mathematics ($\gamma_{30} = -0.48, p < .001$ for Model 3-SLM). Models including level-2 predictors, however, showed no statistically significant effects for teacher experience, teacher education, or teacher major. Additionally, a multilevel regression model assessing the curvilinear effect of teacher experience (Model 4-SLM in Table 5), in accordance with prior findings of Clotfelter et al. (2006) and Hanushek et al. (2005), revealed no quadratic effect for this predictor ($\gamma_{07} = 0.00, p = .999$).

The next set of multilevel models, which predicted students’ valuing of advanced mathematics (SVM, Table 6), showed that parental education emerged as the only statistically significant student-level predictor, with a positive effect ($\gamma_{10} = 0.12, p = .008$ in Model 3-SVM). Higher levels of parental education were associated with increased valuing of advanced mathematics by students. Among the teacher-level predictors, no statistically significant effects were observed for teacher education, teacher major, or for the linear or quadratic effects of teacher experience. However, a statistically significant, positive effect for teacher gender on SVM was observed ($\gamma_{01} = 0.23, p = .039$ for Model 3-SVM), with students of female teachers showing higher perceived value of advanced mathematics than students of male teachers. We additionally fitted a follow-up multilevel model to assess whether teacher gender exerted any cross-level moderating effect on the level-1 fixed effect of student gender on students’ valuing of mathematics. This model, however, showed no statistically significant cross-level moderation effect ($\gamma_{31} = 0.23, p = .258$), indicating that the gender of the teacher had no effect on the relationship between student gender and student valuing of advanced mathematics.

Finally, the set of multilevel models predicting students’ views of engaged teaching of advanced mathematics (SVET) were evaluated (Table 7). These regression models showed no statistically significant effects for any level-1 or level-2 predictors. However, a marginally significant positive effect was observed for teachers majoring in maths, but not maths education ($\gamma_{05} = 0.61, p = .058$ for Model 3-SVET) on student views of engaged teaching when compared to teachers from all other, non-maths majors.

**Discussion**

Although a number of studies have examined the effects of teacher characteristics on student achievement outcomes, relatively few have examined these effects on students’ attitudes – particularly the attitudes of students in advanced mathematics courses towards the field. The present study examines these effects – both on students’ attitudes towards advanced mathematics and on student perceptions of teaching engagement.

Results from this study showed no statistically significant effects of teachers’ educational credentials on student liking/valuing of mathematics. It may be that these attitudinal perceptual characteristics are developed over a longer span of the student’s educational trajectory, and may not be easily malleable by a particular teacher or by a particular and relatively brief class experience. Additionally, however,
Table 5. Results from multilevel regression models predicting students like advance mathematics (N = 2445 Students, J = 307 Teachers).

| Fixed Effects                        | Null Model SLM | Model 1-SLM | Model 2-SLM | Model 3-SLM | Model 4-SLM |
|--------------------------------------|----------------|-------------|-------------|-------------|-------------|
| Estimate                             | S.E.           | Estimate    | S.E.        | Estimate    | S.E.        |
| Intercept (γ₀₀)                      | 10.04***       | 10.28***    | 10.15***    | 10.04***    | 10.04***    |
| S.E.                                 | 0.06           | 0.07        | 0.14        | 0.26        | 0.31        |
| Parent education (γ₁₀)               |                | -0.04       | -0.04       | -0.04       | -0.04       |
| S.E.                                 |                | 0.05        | 0.05        | 0.05        | 0.05        |
| Parent occupation (γ₂₀)              | 0.02           | -0.02       | -0.02       | -0.02       | -0.02       |
| S.E.                                 | 0.03           | 0.03        | 0.03        | 0.03        | 0.03        |
| Student gender (female) (γ₃₀)        |                | -0.48***    | -0.48***    | -0.48***    | -0.48**    |
| S.E.                                 |                | 0.08        | 0.08        | 0.08        | 0.08        |
| Teacher gender (female) (γ₀₁)        |                | 0.08        | 0.08        | 0.08        | 0.08        |
| S.E.                                 |                | 0.12        | 0.12        | 0.12        | 0.12        |
| Teacher experience (γ₀₂)             |                | 0.01        | 0.01        | 0.01        | 0.01        |
| S.E.                                 |                | 0.01        | 0.01        | 0.01        | 0.01        |
| Teacher educ. (Master’s deg. or higher) (γ₀₃) |        | -0.03       | -0.03       | -0.03       | -0.03       |
| S.E.                                 |                | 0.13        | 0.13        | 0.13        | 0.13        |
| Teacher major (Maths or Maths Ed.) (γ₀₄) | 0.08        | 0.23        | 0.08        | 0.23        | 0.23        |
| S.E.                                 |                | 0.20        | 0.20        | 0.20        | 0.20        |
| Teacher major (Maths but not Maths Ed.) (γ₀₅) | 0.18        | 0.27        | 0.18        | 0.27        | 0.27        |
| S.E.                                 |                | 0.18        | 0.18        | 0.18        | 0.18        |
| Teacher major (Maths Ed. but not Maths) (γ₀₆) |            | 0.00        | 0.00        | 0.00        | 0.00        |
| S.E.                                 |                | 0.00        | 0.00        | 0.00        | 0.00        |
| Random Effects                        |                |             |             |             |             |
| σ²                                    | 3.82           | 3.77        | 3.77        | 3.77        | 3.77        |
| τ₀₀                                   | 0.40           | 0.40        | 0.40        | 0.40        | 0.40        |
| ICC                                   | 0.10           | 0.09        | 0.10        | 0.10        | 0.10        |
| Marginal R²/Conditional R²            | .014/.095      | .014/.108   | .015/.109   | .016/.111   | .016/.111   |
| Deviance                              | 11051.46       | 11015.40    | 11014.16    | 11012.86    | 11012.88    |
Table 6. Results from multilevel regression models predicting students’ value advance mathematics (N = 2445 Students, J = 307 Teachers).

| Fixed Effects                                      | Null Model SVM | Model 1-SVM | Model 2-SVM | Model 3-SVM | Model 4-SVM |
|----------------------------------------------------|----------------|-------------|-------------|-------------|-------------|
| Intercept (γ₀₀)                                     | 11.33***       | 11.34***    | 11.29***    | 11.07***    | 11.17***    | 0.30        |
| Parent education (γ₁₀)                             | 0.12**         | 0.12**      | 0.12**      | 0.12**      | 0.12**      | 0.04        |
| Parent occupation (γ₂₀)                            | −0.05          | −0.04       | −0.04       | −0.04       | −0.04       | 0.03        |
| Student gender (female) (γ₃₀)                       | −0.05          | −0.05       | −0.05       | −0.05       | −0.05       | 0.03        |
| Teacher gender (female) (γ₀₁)                      | 0.25*          | 0.23*       | 0.23*       | 0.24*       | 0.24*       | 0.11        |
| Teacher experience (γ₀₂)                            | −0.00          | −0.00       | −0.00       | −0.00       | −0.02       | 0.02        |
| Teacher educ. (Master’s deg. or higher) (γ₀₃)      | 0.05           | 0.05        | 0.05        | 0.05        | 0.13        | 0.13        |
| Teacher major (Maths or Maths Ed.) (γ₀₄)           | 0.19           | 0.19        | 0.19        | 0.19        | 0.23        | 0.23        |
| Teacher major (Maths but not Maths Ed.) (γ₀₅)      | 0.06           | 0.21        | 0.24        | 0.20        | 0.24        | 0.24        |
| Teacher major (Maths Ed. but not Maths) (γ₀₆)      | 0.36           | 0.36        | 0.36        | 0.36        | 0.27        | 0.27        |
| Teacher experience² (γ₀₇)                           | 0.00           | 0.00        | 0.00        | 0.00        | 0.52        | 0.52        |
| Random Effects                                      |                |             |             |             |             |
| σ²                                                  | 3.71           | 3.70        | 3.71        | 3.71        | 3.71        | 3.71        |
| τ₀₀                                                 | 0.37           | 0.38        | 0.36        | 0.36        | 0.36        | 0.36        |
| ICC                                                 | 0.09           | 0.09        | 0.09        | 0.09        | 0.09        | 0.09        |
| Marginal R²/Conditional R²                           | .000/.091      | .004/.096   | .008/.096   | .009/.097   | .010/.098   | .010/.098   |
| Deviance                                            | 10975.31       | 10966.95    | 10961.67    | 10959.65    | 10959.24    |              |

***p < .001, **p < .01, *p < .05.
Table 7. Results from multilevel regression models predicting students’ views of engaged teaching (N = 2445 Students, J = 307 Teachers).

| Fixed Effects | Null Model SVET | Estimate | S.E. | Model 1-SVET | Estimate | S.E. | Model 2-SVET | Estimate | S.E. | Model 3-SVET | Estimate | S.E. | Model 4-SVET | Estimate | S.E. |
|---------------|-----------------|----------|------|-------------|----------|------|-------------|----------|------|-------------|----------|------|-------------|----------|------|
| Intercept ($y_{00}$) | 10.44*** | 0.07 | 10.42*** | 0.08 | 10.36 | 0.18 | 10.04*** | 0.34 | 10.03*** | 0.40 |
| Parent education ($y_{10}$) | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Parent occupation ($y_{20}$) | 0.01 | 0.03 | 0.01 | 0.03 | 0.01 | 0.03 | 0.01 | 0.03 | 0.01 | 0.03 |
| Student gender (female) ($y_{30}$) | 0.05 | 0.08 | 0.05 | 0.08 | 0.05 | 0.08 | 0.05 | 0.08 | 0.05 | 0.08 |
| Teacher gender (female) ($y_{01}$) | −0.06 | 0.15 | −0.06 | 0.15 | −0.06 | 0.15 | −0.06 | 0.15 | −0.06 | 0.15 |
| Teacher experience ($y_{02}$) | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Teacher educ. (Master’s deg. or higher) ($y_{03}$) | 0.37 | 0.30 | 0.37 | 0.30 | 0.37 | 0.30 | 0.37 | 0.30 | 0.37 | 0.30 |
| Teacher major (Maths or Maths Ed.) ($y_{04}$) | 0.61 | 0.32 | 0.61 | 0.32 | 0.61 | 0.32 | 0.61 | 0.32 | 0.61 | 0.32 |
| Teacher major (Maths but not Maths Ed.) ($y_{05}$) | 0.24 | 0.36 | 0.24 | 0.36 | 0.24 | 0.36 | 0.24 | 0.36 | 0.24 | 0.36 |
| Teacher experience$^2$ ($y_{07}$) | −0.00 | 0.00 | −0.00 | 0.00 | −0.00 | 0.00 | −0.00 | 0.00 | −0.00 | 0.00 |
| Random Effects | | | | | | | | | | |
| $\sigma^2$ | 3.49 | 3.49 | 3.48 | 3.49 | 3.49 | 3.49 | 3.49 | 3.49 | 3.49 |
| $\tau_{00}$ | 1.05 | 1.05 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 |
| ICC | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| Marginal $R^2$/Conditional $R^2$ | .000/.231 | .001/.233 | .002/.235 | .008/238 | .008/239 |
| Deviance | 10988.28 | 10986.52 | 10985.96 | 10980.42 | 10980.44 |

***p < .001, **p < .01, *p < .05.
no significant effects of teacher credentials were observed on another outcome that more plausibly might immediately be malleable – student perception of engaged teaching. These results are, for the most part, consistent with the lack of meaningful effects of teacher educational credentials on student achievement reported by Clotfelter et al. (2007), although these authors did find a negative effect of a teacher’s doctoral degree on student achievement – an effect that was not assessed in the current study due to limited sample size for the group. Perhaps, then, in terms of these attitudinal perceptual outcomes, the educational credentials of the teacher indeed do not matter.

Similarly, when major field of study for the teacher was considered, no statistically significant effects were evident. However, a marginally significant positive effect ($p = .058$) was observed, with students of teachers who majored in maths (but not maths education) showing more positive views of engaged teaching than students of teachers who majored in non-maths fields.

Teacher experience also showed no significant linear or quadratic effects on any of the three attitudinal outcomes. This contrasts with the summary of studies provided by Clotfelter et al. (2006). The current study, however, involved a very particular subset of students – those in their final year of high school who were enrolled in advanced mathematics courses. It is possible that these students may differ in their perceptions and attitudes when compared to a more general sample of high school students. Additionally, the teachers in this sample appeared to be relatively experienced (mean years of experience = 18.53), and it is possible that more experienced teachers in the U.S. may be drawn towards teaching advanced (versus introductory) mathematics courses. This may have affected the potential impact that teacher experience exerted on these attitudes.

Analyses of these data revealed an interesting effect that was not a specific focus of the study—the positive effect of female teacher gender on students’ level of valuing advanced mathematics. This effect, however, was small in magnitude, with standardised mean difference in scores $d = 0.16$. Nonetheless, it suggests that there may be at least a small, meaningful effect of having a class taught by female teacher of advanced mathematics. Although the outcome is different (valuing mathematics as opposed to mathematics achievement), these results are consistent with the findings of Winters, Haight, Swaim, and Pickering (2013), who found a positive effect of female teacher gender on middle and high school students’ mathematics achievement.

There was no statistically significant interactive effect of teacher gender on the relationship between student gender and any of the three attitudinal outcomes. This would seem to suggest that deliberate or incidental “matching” (or, alternatively, mismatching) student-teacher genders in the classroom may not necessarily have observable effects on these outcomes. This is in contrast to the findings of Dee (2007), who found positive effects for such matching on teacher’s perceptions of student engagement, as well as on student achievement and teacher perceptions of student performance. Results from Sansone’s (2017) analysis of the 2009 High School Longitudinal Study, however, found that – although female maths and science teachers were associated with increases in female students’ STEM self-efficacy and decreases in male students’ STEM interest – these effects became non-significant when other teacher characteristics were included in the regression model. The current study’s findings
appear to align with the notion that teacher gender effects on attitudinal outcomes may be minimal or may be involve additional complexities.

In the current study, significant, positive effects also were seen for parental education on students’ valuing of advanced mathematics. Higher levels of parental education were associated with higher student levels of valuing mathematics. This is not surprising, and likely reflects a family or home culture that implicitly or explicitly places high value on science and mathematics specifically, or on education more broadly. Interestingly, no similar effects of parental education were apparent for the outcomes of liking advanced mathematics or students’ views of engaged teaching of advanced mathematics. In the former case, liking mathematics may be a more difficult construct than valuing mathematics for parents and families to instil and, in the latter case, a student’s views of engaged teaching likely is very teacher-specific, and influenced to a lesser extent by parental characteristics.

Identifying factors that might facilitate positive attitude is important – both to increase the likelihood that students will choose and be retained in mathematics and STEM education and career fields, as well as to facilitate a more general interest and curiosity about the natural world, resulting in an engaged and informed population. The current study was limited to students enrolled in advanced mathematics courses in their senior year of high school in the U.S. It would be important to expand such research to include a more diverse population of students who are enrolled in general (rather than advanced) mathematics courses and/or are at other grade levels.

It is important to keep in mind the limitations of this study. The results are based on secondary analysis of a large-scale data set, and particular contextual aspects cannot be fully captured by such analyses. The school system in the U.S., for example, is highly decentralised with strong local control over curricula and policies. Thus, students enrolled in advanced mathematics may enrol in these classes so for various reasons – some self-motivated and some externally induced. Some students may have great personal discretion to choose such courses, while other students may be induced by curricular guidelines, and some students may even be required to enrol in such courses. Similarly, among those students who enrol in multiple advanced mathematics courses, some (particularly those in small schools/districts) may experience the same teacher for each course while others (e.g. those in larger schools/districts) may have different teachers for each course. These variations and contextual aspects could affect relations between teacher/student characteristics and outcomes of motivation, value, and perceptions of engaged teaching.

Disclosure statement
No potential conflict of interest was reported by the authors.

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**References**

Aaronson, D., Barrow, L., & Sanders, W. (2003). *Teachers and student achievement in the Chicago Public High Schools* (Unpublished manuscript). Federal Reserve Bank of Chicago, Chicago, IL.

Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology, 52*(1), 27–58.

Akiba, M., LeTendre, G., & Scribner, J. (2007). Teacher quality, opportunity gap, and national achievement in 46 countries. *Educational Researcher, 36*(7), 369–387.

Ballou, D., Sanders, W., & Wright, P. (2004). Controlling for student background in value-added assessment of teachers. *Journal of Educational and Behavioral Statistics, 29*(1), 37–66.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48.

Blomeke, S., Olsen, R., & Suhl, U. (2016). Relation of student achievement to the quality of their teachers and instructional quality. In T. Nilsen & J. Gustafsson (Eds.), *Teacher quality, instructional quality and student outcomes*. IEA Research for Education (Vol. 2, pp. 21–50). Cham, Switzerland: Springer.

Burroughs, N., Gardner, J., Lee, Y., Guo, S., Touitou, I., Jansen, K., & Schmidt, W. (2019). *Teaching for excellence and equity: Analyzing teacher characteristics, behaviors and student outcomes with TIMSS* (Vol. 6). Cham, Switzerland: Springer.

Buxton, L. (1981). *Do you panic about maths?* London: Heinemann.

Çiftçi, Ş. K., & Yıldız, P. (2019). The effect of self-confidence on mathematics achievement: The meta-analysis of Trends in International Mathematics and Science Study (TIMSS). *International Journal of Statistical Software, 12*(2), 683–694.

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2006). Teacher-student matching and the assessment of teacher effectiveness. *The Journal of Human Resources, XLI*(4), 778–820.

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2007). Teacher credentials and student achievement: Longitudinal analysis with student fixed effects. *Economics of Education Review, 26*(6), 673–682.

Deci, E. L., & Ryan, R. M. (1995). Human autonomy: The basis for true self-esteem. In M. Kernis (Ed.), *Efficacy, agency, and self-esteem* (pp. 3149). New York: Plenum.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.
Dee, T. S. (2007). Teachers and the gender gaps in student achievement. *The Journal of Human Resources*, 42(3), 528–554.

Dickhauser, O., Dinger, F. C., Janke, S., Spinath, B., & Steinmayr, R. (2016). A prospective correlational analysis of achievement goals as mediating constructs linking distal motivational dispositions to intrinsic motivation and academic achievement. *Learning and Individual Differences*, 50, 30–41.

Ellis, J., Fosdick, B. K., & Rasmussen, C. (2016). Women 1.5 times more likely to leave STEM pipeline after calculus compared to men: Lack of mathematical confidence a potential culprit. *PLoS One*, 11(7), e0157447.

Else-Quest, N., Hyde, J. S., & Linn, M. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, 136(1), 103–127.

Gustafsson, J., & Nilsen, T. (2016). The impact of school climate and teacher quality on mathematics achievement: A difference-in-differences approach. In T. Nilsen & J. Gustafsson (Eds.), *Teacher quality, instructional quality and student outcomes*, IEA *Research for Education* (Vol. 2, pp. 81–95). Cham, Switzerland: Springer.

Hanushek, E., Kain, J., O’Brien, D., & Rivkin, S. (2005). *The market for teacher quality* (Unpublished manuscript). Palo Alto, CA: Stanford University.

Hanushek, E., & Luque, J. (2003). Efficiency and equity in schools around the world. *Economics of Education Review*, 22(5), 481–502.

Harris, D. N., & Sass, T. R. (2011). Teacher training, teacher quality and student achievement. *Journal of Public Economics*, 95(7–8), 798–812.

Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York, NY: Routledge.

Hooper, M., Mullis, I. V. S., Martin, M. O., & Fishbein, B. (2017). TIMSS 2019 context questionnaire framework. In I. V. S. Mullis, & M. O. Martin (Eds.), *TIMSS 2019 assessment frameworks* (pp. 57–78). Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College. Retrieved from: http://timssandpirls.bc.edu/timss2019/frameworks/

Kalaycioglu, D. B. (2015). The influence of socioeconomic status, self-efficacy, and anxiety on mathematics achievement in England, Greece, Hong Kong, the Netherlands, Turkey, and the USA. *Educational Sciences: Theory and Practice*, 15(5), 1391–1401.

Karakolidis, A., Pitsia, V., & Emvalotis, A. (2016). Examining students’ achievement in mathematics: A multilevel analysis of the Programme for International Student Assessment (PISA) 2012 data for Greece. *International Journal of Educational Research*, 79, 106–115.

Lee, J., & Stankov, L. (2018). Non-cognitive predictors of academic achievement: Evidence from TIMSS and PISA. *Learning and Individual Differences*, 65, 50–64.

Luschei, T., & Chudgar, A. (2011). Teachers, student achievement, and national income: A cross-national examination of relationships and interactions. *Prospects*, 41(4), 507–533.

Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education*, 28(1), 26–47.

Martin, M. O., Mullis, I. V. S., & Hooper, M. (2016). *Methods and procedures in TIMSS Advanced 2015*. Chestnut Hill: TIMSS & PIRLS International Study Center, Boston College.

Michaelides, M. P., Brown, G. T. L., Eklöf, H., & Papanastasiou, E. (2019). *Motivational profiles in TIMSS mathematics: Exploring student clusters across countries and time*. Cham, Switzerland: IEA Research for Education and Springer Open. ISBN: 978-3-030-26182-5.

Montt, G. (2011). Cross-national differences in educational achievement inequality. *Sociology of Education*, 84(1), 49–68.

Mullis, I. V. S., Martin, M. O., Gonzales, E. J., & Chrostowski, S. J. (2004). *TIMSS 2003 international mathematics report: Findings from IEA’s trends in international mathematics and science study at the fourth and eighth grades*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Nye, B., Konstantopoulos, S., & Hedges, L. V. (2004). How large are teacher effects? *Educational Evaluation and Policy Analysis*, 26(3), 237–257.
Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

R Core Team. (2020). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Rivkin, S., Hanushek, E., & Kain, J. (2005). Teachers, schools and academic achievement. *Econometrica, 73*(2), 418–458.

Rockoff, J. (2004). The impact of individual teachers on student achievement: Evidence from panel data. *American Economic Review, 94*(2), 247–252.

Rosenberg, M. J., & Hovland, C. I. (1960). Cognitive, affective, and behavioral components of attitudes. In M. Rosenberg, C. Hovland, W. McGuire, R. Abelson, & J. Brehm (Eds.), *Attitude organization and change* (pp. 1–14). New Haven, CT: Yale University Press.

Sansone, D. (2017). Why does teacher gender matter? *Economics of Education Review, 61*, 9–18.

Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., Bucklein, B. K., & Kibirige, J. (2017). Student attraction, persistence and retention in STEM programs: Successes and continuing challenges. *Higher Education Studies, 7*(1), 46–59.

Walberg, H. J. (1981). A psychological theory of educational productivity. In F. H. Farley & N. J. Gordon (Eds.), *Psychology and education*, 81–110. Chicago: National Society for the Study of Education.

Walberg, H. J. (1992). The knowledge base for educational productivity. *International Journal of Educational Reform, 7*(1), 5–15.

Winters, M. A., Haight, R. C., Swaim, T. T., & Pickering, K. A. (2013). The effect of same-gender teacher assignment on student achievement in the elementary and secondary grades: Evidence from panel data. *Economics of Education Review, 34*, 69–75.

Woessman, L. (2003). Schooling resources, educational institutions, and student performance: The international evidence. *Oxford Bulletin of Economics and Statistics, 65*(2), 117–170.

Yurt, E. (2015). Understanding Middle School Students’ Motivation in Math Class: The Expectancy-Value Model Perspective. *International Journal of Education in Mathematics, Science, and Technology, 3*(4), 288–297. doi:10.18404/ijemst.26938.