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ARTICLE

# Boredom due to being over- or under-challenged in mathematics: A latent profile analysis

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## Abstract

**Background:** Recent research on boredom suggests that it can emerge in situations characterized by over- and under-challenge. In learning contexts, this implies that high boredom may be experienced both by low- and high-achieving students.

**Aims:** This research aimed to explore the existence and prevalence of boredom due to being over- and under-challenged in mathematics, for which empirical evidence is lacking.

**Sample:** We employed a sample of 1.407 students (fifth to ninth graders) from all three secondary school tracks (lower, middle and upper) in Bavaria (Germany).

**Methods:** Boredom was assessed via self-report and achievement via a standardized mathematics test. We used latent profile analysis to identify groups characterized by different levels of boredom and achievement, and we additionally examined gender and school track as group membership predictors.

**Results:** Results revealed four distinct groups, of which two showed considerably high boredom. One was coupled with low achievement on the test (i.e. 'over-challenged group', 13% of the total sample), and one was coupled with high achievement (i.e. 'under-challenged group', 21%). Furthermore, we found a low boredom and high achievement (i.e. 'well-off group', 27%) and a relatively low boredom low achievement group (i.e. 'indifferent group', 39%). Girls were overrepresented in the over-challenged group, and students from the upper school track were underrepresented in the under-challenged group.

**Conclusion:** Our research emphasizes the need to openly discuss and further investigate boredom due to being over- and under-challenged.

**KEYWORDS**
achievement emotions, boredom, mathematics achievement

# INTRODUCTION

There is no universally accepted definition of boredom, but a consensus that boredom experiences are typically characterized by a certain degree of negative valence, coupled with attentional issues, the perception of time passing slowly, and insufficient and dissatisfactory stimulation, challenge and meaning (Goetz et al., 2014). Boredom is one of the most commonly experienced emotions in educational settings, including mathematics classes (Goetz, Stempfer, et al., 2023) and a major predictor of performance with stronger effects on performance than gender, age, academic ability and personality traits (Pekrun et al., 2023). In school, boredom is linked with several problematic outcomes, such as reduced motivation and effort (Eren & Coskun, 2016; Pekrun et al., 2002, 2010) and dropping out of school (Grazia et al., 2021). Since boredom in school has been shown to be highly domain-specific (Goetz et al., 2007), recent studies on academic boredom focused on the subject of mathematics (Feuchter & Preckel, 2022; Putwain et al., 2018), which is important for a wide range of professions (Bieg et al., 2014) and a predictor of expected future salary (Organization for Economic Cooperation and Development, 2014).

In the tradition of Csikszentmihalyi (1975), it has long been argued that boredom arises when someone's skills are greater than the situational demands—thus, in under-challenging situations (e.g. Larson & Richards, 1991). However, Pekrun et al. (2002) argued that boredom can also arise when task demands are too high, implying over-challenge. According to Pekrun's (Pekrun, 2006) control-value theory, boredom at school can arise when students view their tasks as unimportant and when these task demands are either below their skills (high perceived control; i.e. under-challenged) or above their skills (low perceived control; i.e. over-challenged). Accordingly, a differentiation between boredom due to over-challenge vs. boredom due to under-challenge has been considered in research on academic boredom (e.g. Acee et al., 2010; Goetz, Bieleke, et al., 2023; Goetz, Stempfer, et al., 2023). Empirical research shows that indeed, strong boredom experiences can be initiated both through highly challenging and poorly challenging situations (Daschmann et al., 2011). Prior research indicates that the context plays an important role in boredom in mathematics both due to over- and under-challenge to evolve. For example, studies have shown that adolescents receiving no special education support in general mathematics classrooms reported more boredom when the proportion of classmates receiving special education support was higher (e.g. over-challenged; Holm, Björn, et al., 2020). Moreover, according to the big-fish-little-pond effect, adolescents in higher-performing classrooms may experience more unpleasant mathematics-related achievement emotions due to unfavourable upward social comparison (Pekrun et al., 2019); and adolescents who outperform their peers in mathematics report more boredom in mathematically higher-performing classrooms (e.g. under-challenged; Holm, Korhonen, et al., 2020). However, to date, there is scarce empirical evidence for the prevalence of boredom due to over- and under-challenge among learners in regular school contexts. As such, little is known about the typical proportions of students who are affected by boredom due to over- or under-challenge.

Scattered research further suggests gender disparities in mathematics boredom, with boys tending to experience higher levels of boredom than girls (Goetz et al., 2013; Pekrun et al., 2010, 2017). One study that explicitly looked at the effects of mathematics performance and gender on boredom was Holm et al. (2017). They looked at three specific performance groups, that is, students with mathematics difficulties, students with low and students with typical mathematics performance. Their findings indicated that females with mathematics difficulties reported higher levels of boredom than males with mathematics difficulties, but there were no gender differences in the other performance groups. As such, this study suggests that girls may be more susceptible to boredom due to over-challenge in mathematics than boys.

## Students' profiles of boredom and academic achievement

There are several studies investigating students' profiles of boredom-related constructs, such as students' strategies for coping with boredom (Daniels et al., 2015; Nett et al., 2010; Tze et al., 2013), students' emotional profiles and learning outcomes (Ganotice et al., 2016), or different types of boredom based on degrees of valence and arousal (Goetz et al., 2014). Another more recent study exploring students' profiles of boredom was performed by Grazia et al. (2021), who identified four distinct profiles of boredom trajectories over one school year (starting not bored and [1] increasing or [2] rearing up; starting bored and [3] decreasing or [4] maintaining). However, to the best of our knowledge, to date, there are no studies that investigated profiles of students' boredom in conjunction with their mathematics achievement in a standardized test.

We seek to add to the literature on boredom due to over- and under-challenge (e.g. Acee et al., 2010; Daschmann et al., 2011) by selecting school mathematics as an applied learning domain. We propose that students who show high competence in mathematics and report high levels of mathematics boredom can be classified as bored due to under-challenge, while students who show poor competence in mathematics and report high mathematics boredom can be classified as bored due to over-challenge.

Existing research linking boredom and performance in the academic domain typically followed variable-centred approaches, reporting small-sized negative correlations between boredom and performance (Camacho-Morles et al., 2021). This negative correlation implies that with higher competence, students tend to report less boredom. However, given the typically small size of boredom-performance correlations, it is to be expected that there are also students 'off the main diagonal'. For example, students who perform well and still experience high levels of boredom. Considering the above-mentioned evidence and theorizing on boredom due to under-challenge, the existence of such a group of students is to be expected (see also Schwartze et al., 2020).

We used latent profile analysis (LPA) for our analyses and additionally examined gender and school track as predictors. LPA is a categorical latent variable modelling approach that aims to identify subpopulations within a population based on certain variable combinations (Spurk et al., 2020). It assumes that people can be categorized by different attributes with a certain probability.

## The present study

Our first aim was to provide empirical evidence for the prevalence of boredom due to over- and under-challenge among learners. By adopting a person-centred approach, the present study explores possible combinations of self-reported boredom and competence among learners of mathematics. To gain insight into the prevalence of correspondingly differing subpopulations within learners of mathematics, we assessed students' mathematics abilities using a standardized mathematics test. Based on prior evidence regarding boredom due to over- and under-challenge (Daschmann et al., 2011), we expected to find at least four distinct boredom profiles (Hypothesis 1). First, we expect to find a profile that is characterized by high boredom and low achievement (i.e. an 'over-challenged group') and one characterized by high boredom and high achievement (i.e. an 'under-challenged group'). In addition, as implied by the overall negative correlation between boredom and performance (Camacho-Morles et al., 2021), we expected to find a profile characterized by low boredom and high achievement (i.e. a 'well-off group'). Finally, we expected an 'indifferent group' to demonstrate average levels of all variables included in the profile analysis. By using LPA, which identifies subpopulations within a population based on certain variable combinations (Spurk et al., 2020), we expect to find evidence regarding the relative sizes of those proposed groups characterized by different levels of boredom and achievement within our sample, thus gaining insight into the prevalence of boredom due to over- and under-challenge in the population of secondary school students. Our study findings are of high practical relevance as they provide teachers with empirical evidence of the expected prevalence of students in their classes who likely are bored due to over- vs. under-challenge.

Our second aim was to explore the role of gender. Mathematics is a strongly gender-stereotyped domain (e.g. Keller, 2001), and girls have been shown to report more boredom due to over-challenge, while boys report more boredom due to under-challenge when asked directly about those challenge-implied boredom experiences (Daschmann et al., 2011). Accordingly, we assume that girls could be overrepresented in the low achievement/high boredom group (i.e. over-challenged), while boys should be overrepresented in the high achievement/high boredom group (i.e. under-challenged; Hypothesis 2). Lastly, the German three-tiered tracking system is designed to provide a match between students' intellectual potential and the cognitive demands of their school track. Therefore, we had no a priori expectations as to certain school tracks being more prevalent in any of the boredom groups. Nevertheless, it seemed relevant to explore if boredom due to over- or under-challenge is more prevalent at the lower, middle or upper track of the German secondary school system.

# MATERIALS AND METHODS

## Participants

To test our hypotheses, we used data collected in the context of a longitudinal field study in the subject of mathematics (Forschung zum Emotionalen Erleben im Lehr-Lern-Kontext [research on emotional experiences in the teaching-learning context; FEEL project], see also Burić & Frenzel, 2023). The initial sample size of students from grades 5 to 9 consisted of 1.460 students. Of those, 53 students had missing values for both the mathematics achievement scores and the boredom self-report scores on both measurement occasions, so they had to be excluded from the analysis. Our final sample for analysis thus consisted of $N = 1.407$ secondary school students (51% girls, $n = 717$; 49% boys, $n = 690$) from 91 classes in 30 schools in Bavaria, Germany. Due to being absent from class, missing consent forms, or a belated decision to participate in the study, 165 of those participants were missing at $T_1$, and 136 were missing at $T_2$. At $T_1$, students were between 9 and 17 years old, with a mean age of 12.89 years ($SD_{age} = 1.27$). All tracks of the Bavarian three-tiered secondary education system were represented, with 25% ($n = 354$) from the lower track, 27% ($n = 375$) from the middle track, and 48% ($n = 678$) from the upper track. This distribution across tracks is equivalent to the Bavarian secondary student statistics (LfStat, 2018). The students were in the fifth ($n = 185$), sixth ($n = 203$), seventh ($n = 577$), eighth ($n = 301$) and ninth grade ($n = 141$). Most of the students (81%, $n = 1.205$) were born in Germany. Twenty-six per cent of the students had at least one foreign-born parent ($n_{mother} = 186$, $n_{father} = 184$, $n_{both} = 123$).

## Procedure

The data collection took place in the school year of 2018/2019 in September ($T_1$) and February ($T_2$). At both time points, boredom and mathematics achievement were measured. The data collection was administered by trained research assistants, and both the boredom questionnaire and mathematics achievement test were filled out during regular class time.

## Measures

### Mathematics achievement

Mathematics achievement was measured using the Bielefeld Math Achievement Test for Secondary Education, which is an extension of the PALMA Mathematics Achievement Test (e.g. Murayama et al., 2013). This test measures mathematical skills (declarative, procedural and conceptual) with complex multiple-choice, single-choice items and short text responses, which are scored based on a fully standardized rubric. The test is linked with anchoring items throughout grades 5–9 and across both measurement time points. It consisted of 15–17 items for grades 5–9 that cover the mathematics curriculum, such as algebra, functions and geometry. The percentage of correct responses in relation to all valid responses for each item varied between 22% and 96%, with an average of 64% correct responses (SD = 16%). The item difficulties were estimated by scoring all missing values as incorrect and constraining the mean of the ability distribution to zero. The estimated item difficulties ranged from −2.06 to 4.78 DIF and were examined by exploring whether measurement invariance is violated for gender with no substantial differences (delta Mantel–Haenszel main effect of 1.5 logits). All items combined represent a highly reliable composite mathematics achievement score for the overall mathematics achievement in the form of a Rasch-scaled person parameter (test–retest reliability across $T_1$ and $T_2$ = .78).

### Mathematics boredom

Class-related mathematics boredom was measured through students' self-reports with six items of the Achievement Emotions Questionnaire—Mathematics (e.g. 'I can't concentrate because I am so bored'; AEQ-M, Pekrun et al., 2011). Students responded to all items on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Across our sample, students reported medium levels of boredom that are positively skewed with a negative excess kurtosis at $T_1$ ($M$ = 2.45, 95%-CI [2.42, 2.48], SD = 1.01, skewness = .53, kurtosis = −.48) and $T_2$ ($M$ = 2.63, 95%-CI [2.60, 2.66], SD = 1.06, skewness = .40, kurtosis = −.72). Cronbach's alpha and test–retest reliability estimates were satisfactory ($\alpha_{T1}$ = .88 and $\alpha_{T2}$ = .89, $r$ = .60 for the test–retest reliability).

## Analyses

We used Mplus 8.6 (Muthén & Muthén, 1998–2017) and LPA with the default estimator for mixture models (maximum likelihood with robust standard errors; MLR) to identify categorical latent variables that represent classes of students who share similar combinations of boredom and mathematics achievement level profiles across both time points. To acknowledge that the sample of students had a nested structure (with students nested in classrooms), we used the classroom variable as a cluster indicator in the LPA by using the Mplus variable option cluster. We used both time points to obtain more robust cluster solutions, given that both variables were highly stable across the two timepoints which were only a few months apart (see Schwartze et al., 2021 for measurement invariance of boredom across $T_1$ and $T_2$ of the data). We standardized the mathematics achievement scores based on the school track and class levels for each timepoint, as we intended to consider student ability relative to their age- and school-based reference group. Boredom was standardized for the whole sample for each timepoint.

To determine the most appropriate number of groups, we iteratively tested the fit of 1–5 groups, using Akaike's (Akaike, 1987) Information Criterion (AIC), Schwarz's (Schwarz, 1978) Bayesian Information Criterion (BIC) and the corrected Akaike's information criterion (AICC, Hurvich & Tsai, 1989), where lower values indicate a better fit of the data. We also used the Lo–Mendell–Rubin adjusted likelihood ratio test (LMRT) and Vuong-Lo–Mendell–Rubin likelihood ratio test (VLMR), which compare whether a $k$-class solution fits better than a $k$-1 class solution (Tein et al., 2013). We furthermore examined entropy, a standardized index of model-based classification accuracy, where high values of entropy indicate better classification (Wang et al., 2017). Additionally, to explore whether gender and school track were linked with class membership, we tested our final class solution for both variables separately as latent class predictors using the 3-step method (R3STEP; Asparouhov & Muthén, 2014).

# RESULTS

Regarding our first aim, as indicated by lower AIC, BIC and AICC values, the 4-class solution fitted the data better than the 1 to 3-class solutions. Even though it had lower AIC, BIC and AICC values, a better entropy, and (barely) not statistically significant LMRT and VLMR *p*-values (see Table 1), the 5-class model was rejected because it did not reveal another qualitatively distinct group. The entropy of the selected 4-class solution (.63) suggests at least a 20% error rate, but it should be noted that entropy values decrease and the classification error rates increase as sample size increases, and entropy can get volatile under large sample sizes (Wang et al., 2017).

In line with our Hypothesis 1, we found four distinct and theoretically meaningful classes which showed qualitatively varying profiles of boredom and mathematics achievement levels. In line with our expectations, we found one group in which students showed high boredom and low mathematics achievement at both time points (class 1, the over-challenged group). Additionally, we found one group with students who showed high boredom and high mathematics achievement (class 4, the under-challenged group). Moreover, we found a group in which students showed low boredom and high mathematics achievement (class 2, the well-off group). Lastly, the data revealed one group with relatively low boredom and low mathematics achievement (class 3, which we labelled indifferent group; see Figure 1). Importantly, since mathematics achievement values were standardized based on the school track and class levels, students' levels of mathematics achievement in said groups are low or high relative to their same-grade and same-track peers. Table 2 depicts the descriptive statistics for mathematics achievement and boredom levels at $T_1$ and $T_2$, respectively, for each of the four groups.

Regarding our second aim, using gender as a latent class predictor showed that the likelihood of being in the over-challenged group relative to the indifferent or well-off group was significantly higher for girls (class 3 relative to class 1; $p = .046$, $b = -.561$, OR = .571 and class 3 relative to class 2; $p = .001$, $b = -1.015$, OR = .362). While this is in line with our Hypothesis 2, boys where not significantly overrepresented in the under-challenged group. Using school track as a latent class predictor showed that the likelihood of being in the under-challenged group relative to the indifferent or well-off group

**TABLE 1** LPA results.

| *N* latent classes | AIC | BIC | AICC | VLMR *p*-value | LMRT *p*-value | Entropy | Class size: *n* (%) |
|---|---|---|---|---|---|---|---|
| 1 | 14285.09 | 14327.08 | 14285.19 | – | – | – | Class 1: 1.407 (100%) |
| 2 | 13721.44 | 13789.68 | 13721.70 | 0 | 0 | .715 | Class 1: 944 (67%)<br>Class 2: 463 (33%) |
| 3 | 13586.96 | 13681.44 | 13587.45 | .0884 | .0946 | .571 | Class 1: 445 (32%)<br>Class 2: 512 (36%)<br>Class 3: 450 (32%) |
| **4** | **13447.28** | **13568.01** | **13448.08** | **.0525** | **.0556** | **.627** | **Class 1: 554 (39%, 52% girls)**<br>**Class 2: 375 (27%, 44% girls)**<br>**Class 3: 184 (13%, 63% girls)**<br>**Class 4: 294 (21%, 52% girls)** |
| 5 | 13375.06 | 13522.04 | 13376.24 | .1412 | .1465 | .669 | Class 1: 221 (16%)<br>Class 2: 112 (8%)<br>Class 3: 718 (51%)<br>Class 4: 234 (17%)<br>Class 5: 122 (8%) |

*Note*: The selected model is printed in boldface.

Abbreviations: AIC, Akaike information criterion; AICC, corrected Akaike's information criterion; BIC, Bayesian information criterion; LMRT, Lo–Mendell–Rubin adjusted likelihood ratio test; VLMR, Vuong-Lo–Mendell–Rubin likelihood ratio test.

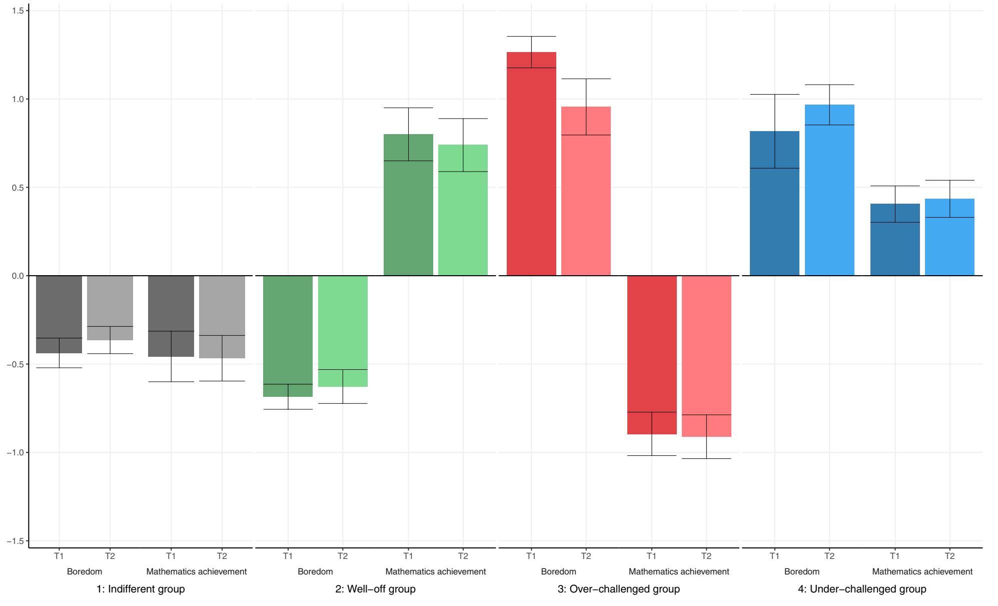


**FIGURE 1** Estimated boredom and mathematics achievement means and standard errors of the four boredom profiles at both time points.

**TABLE 2** Descriptive statistics of the four boredom profiles.

| | 1: Indifferent | 2: Well-off | 3: Over-challenged | 4: Under-challenged |
|---|---|---|---|---|
| Boredom *M* (SD) | | | | |
| $T_1$ | −.437 (.084) | −.685 (.071) | 1.265 (.089) | .817 (.209) |
| $T_2$ | −.364 (.077) | −.627 (.096) | .955 (.159) | .967 (.114) |
| Mathematics achievement *M* (SD) | | | | |
| $T_1$ | −.457 (.143) | .800 (.150) | −.895 (.123) | .405 (.103) |
| $T_2$ | −.467 (.129) | .739 (.150) | −.911 (.124) | .435 (.105) |
| Profile size (Percent of total sample) | $n=554$ (39%) | $n=375$ (27%) | $n=184$ (13%) | $n=294$ (21%) |
| Girls/boys | 52/48% | 44/56% | 63/37% | 52/48% |
| Lower/middle/upper school track | 22/25/53% | 20/29/51% | 28/29/43% | 36/26/38% |

*Note*: The sample consisted of $N=1.407$ students, of which 51% identified as female and 49% as male; 25% attended the lower track, 27% the middle track and 48% the upper track.

was significantly lower for students from the upper school track (class 1 relative to class 4; $p=.002$, $b=-1.165$, OR = .312 and class 2 relative to class 4; $p=.002$, $b=-1.124$, OR = .325).

# DISCUSSION

This study is the first to explore the prevalence of qualitatively different boredom types in terms of over- versus under-challenge in learning contexts. The goal of the present study was to explore students' profiles of boredom in mathematics classes in conjunction with their mathematic ability, as measured by a standardized test, using LPA. To approach the question of boredom due to over-challenge versus boredom due to under-challenge empirically, our first aim was to explore the prevalence of high boredom among students who scored low versus high on a standardized mathematics achievement test while our second aim was to explore the role of gender and school track.

## The prevalence of boredom due to over- and under-challenge

In line with Hypothesis 1, we found two distinct profiles that showed considerably high levels of boredom, but at varying mathematics achievement levels; high boredom coupled with low achievement (over-challenged group) as well as high boredom coupled with relatively high achievement (under-challenged group). The over-challenged group consisted of students who were considerably low performing (almost −1 SD relative to their age and school track comparison group) while showing considerably high levels of boredom (around +1 SD relative to the other students). At the same time, the under-challenged group consisted of students who were considerably high performing (around +.5 SD) while showing considerably high levels of boredom (almost +1 SD). Based on this, we assume that the high levels of boredom reported by these students are mostly due to the –for them– either excessive or too low demands in mathematics lessons.

Furthermore, two groups with relatively low boredom emerged, one of which was characterized by low boredom and high ability, which we propose to be a well-off group. These students demonstrated high competence in the standardized test (equally well as the under-challenged group) yet seemed to be successful at finding value and challenge in mathematics at school and thus respond with low mathematics boredom. Lastly, we observed a group with low boredom and low achievement, which we propose to be seen as an indifferent group. Those students performed relatively poorly on the standardized test (−.5 SD), but they did not seem to react to this with experiences of over-challenge during their mathematics classes, as they did not report elevated levels of boredom relative to their peers (−.5 SD).

Regarding our first aim, to explore the prevalence of boredom due to over- vs. under-challenge, our key finding is that as many as 21% ($n = 294$) of the students in our sample were identified as the under-challenged group, and as many as 13% ($n = 184$) constituted the over-challenged group. As such, a third of the students were classified as highly bored, coupled with either low or high mathematics achievement scores. This result is in line with previous studies, showing a high proportion of students reporting feelings of non-adequate challenge (Krannich et al., 2019). Overall, considering the growing shortage of STEM professionals (Anger et al., 2021), the potential waste of resources and missing opportunities to promote the talent of many students who most likely withdraw from mathematics as it seems overly boring to them seems unfortunate.

## The role of gender and school type

Our second aim was to explore the role of gender and school track. Confirming Hypothesis 2, our findings showed that girls were overrepresented in the over-challenged group (63%). This result is in line with previous studies, showing that girls are more likely to be bored due to over-challenge (e.g. Daschmann et al., 2011; Goetz & Frenzel, 2010). While girls underperforming in mathematics is one of the most resistant gender gaps in modern societies, a large part of the gender gap is due to social stereotypes, and it is expected that institutions can durably modify these stereotypes (Lippmann & Senik, 2018). This gender stereotype apparently also leads to experiences of being over-challenged, to which quite some girls seem to react with feelings of boredom. However, boys were not significantly overrepresented in the under-challenged group.

School track had no significant effect on class membership probability, with one exception. Thus, school type was equally represented in most groups, indicating that the German three-tiered tracking system is sufficiently functional, matching students' intellectual potential and the cognitive demand of their school track. One exception was that students from the upper school track were underrepresented in the under-challenged group. The main reason for that might be a more demanding curriculum in the upper school track that is less likely to under-challenge its students.

### Implications of the findings

Our findings underscore that there is a considerably high fraction of students who are confronted with a poor balance of challenge given their skill level in mathematics, thus responding with boredom (in total, 34%; 13% being over-challenged and 21% being under-challenged). We assume that this imbalance is potentially caused by teachers feeling obligated to strictly follow the state-imposed curriculum, thereby hindering their ability to provide adequately challenging learning opportunities for every student. The typically three-tiered German tracking system as of fifth grade also imposes the illusion of sufficient ability homogeneity within each school type, so the implementation of techniques such as differentiated and individualized teaching (e.g. Landrum & McDuffie, 2010) further grouping students by ability (e.g. Feuchter & Preckel, 2022), or utility-value interventions (Asher et al., 2023) which would help buffering effects of over- or under-challenge. With student perceptions of low-quality instructional design being one of the most reported reasons for boredom in class (Goetz & Frenzel, 2006), our findings also underscore the importance of offering a variety of teaching methods.

Further, we propose that our finding that girls are significantly more often bored due to over-challenge in German secondary mathematics than boys is alarming. Talent should be promoted regardless of gender, and refutation instructions designed to reduce distinct misconceptions may be a promising method to weaken math-gender stereotypes (Dersch et al., 2022; Goetz et al., 2013).

### Limitations and future directions

It is important to note that our results might be sample-dependent, and replication is needed with different samples to substantiate these findings. While latent profile analysis is a valuable tool for uncovering hidden structures within data, LPA has its limitations, like any analytical method. Interpreting the resulting profiles can sometimes be subjective, leading to potential bias in the identification and labelling of profiles. Therefore, validation studies are needed to assess the robustness of the LPA findings to ensure the stability and generalizability of the identified profiles. The present utilized a sample of German secondary school students. Further investigation is needed to determine if these findings are generalizable in other cultural and educational settings. Accordingly, future research could explore the prevalence of boredom due to over- vs. under-challenge in other achievement settings like elementary schools, other domains like languages and in cultural contexts beyond Western, educated, industrialized, rich and democratic cultures (cf. the predominance of psychological research in so-called WEIRD contexts; e.g. Henrich et al., 2010). In addition, the differentiation between and prevalence of boredom due to over-challenge vs. boredom due to under-challenge could also be investigated in domains beyond education, such as work and leisure time. Further, self-report measures were employed to evaluate boredom in this study. Future research endeavours could supplement this method with alternative data sources, including physiological and behavioural indicators, to comprehensively assess boredom.

## CONCLUSION

Our findings emphasize the need to openly discuss boredom in learning contexts and address coping strategies such as cognitive- and behavioural-approach strategies (Nett et al., 2010). This seems particularly relevant given that boredom coping strategies have been shown to be significantly related to graded high school performance (Eren & Coskun, 2016).

### AUTHOR CONTRIBUTIONS

**Manuel M. Schwartze:** Conceptualization; formal analysis; data curation; investigation; methodology; software; visualization; validation; writing – original draft; writing – review and editing. **Anne C. Frenzel:** Conceptualization; funding acquisition; project administration; supervision; resources;

writing – review and editing. **Thomas Goetz:** Writing – review and editing. **Annette Lohbeck:** Formal analysis; writing – review and editing. **David Bednorz:** Writing – review and editing; formal analysis. **Michael Kleine:** Methodology; resources. **Reinhard Pekrun:** Funding acquisition; project administration; writing – review and editing.

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## CONFLICT OF INTEREST STATEMENT

The authors report no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data presented in this study are openly available in OSF at [https://osf.io/qjesy/], reference number [DOI 10.17605/OSF.IO/QJESY].

## ETHICS APPROVAL

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Ludwig-Maximilian University of Munich (05 February 2018).

## CONSENT

Informed consent was obtained from all subjects, parents, or guardians, respectively, involved in the study, and no identifiers that could link individual participants to their results were obtained.

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