PREDICTING EARLY DROPOUT FROM UNIVERSITY MATHEMATICS: A MEASURE OF MATHEMATICS-SPECIFIC ACADEMIC BUOYANCY

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At University, mathematics freshmen often drop their studies as a consequence of the excessive demands that they felt not able to cope with. Academic buoyancy describes students' ability to effectively handle academic challenges and setbacks and may therefore be an important factor to be considered when examining freshmen dropout. As a consequence, we conceptualized academic buoyancy in the context of college mathematics. This study focuses on the development and initial empirical evaluation of an 11-item questionnaire assessing mathematics-specific academic buoyancy. Analyses on internal consistency and on structural, content, predictive, convergent and discriminant validity are reported. Overall, our findings suggest the instrument to provide reliable and valid measures of mathematics-specific academic buoyancy.

INTRODUCTION

For mathematics studies, universities have to face high dropout rates (Heublein, Hutzsch, Schreiber, Sommer, & Besuch, 2010; Chen, 2009). In Germany, for instance, about 38% of college students leave their studies during the first year (Dieter, 2012). Students often explain their decision to quit with the excessive demands they encountered and not felt able to cope with (Heublein et al., 2010). Therefore, persisting the study of mathematics not only seems to be due to cognitive abilities, but also due to the individual's ability to handle challenges encountered during the studies. With respect to education in school, an individual's ability to cope with everyday setbacks, challenges, and pressures in a learning context has been defined as academic buoyancy (Martin & Marsh, 2008). Having said this, the idea of academic buoyancy might be helpful to describe mathematics freshmen's ability to handle challenging circumstances, as well.

THEORETICAL BACKGROUND

In the transition from school to university mathematics students often recognize major changes in the way of learning mathematics; and, not rarely, these changes lead to difficulties students have with the studies of mathematics (Hoyles, Newman, & Noss, 2001). The goal of college mathematics, for example, is to promote the character of mathematics as a scientific discipline, whereas the goal of school mathematics is to promote general education; likewise, college students need proving skills and deductive logic as tools of the trade, whereas school students at school mostly focus on performing calculation schemes (Hoyles et al., 2001; Rach & Heinze, 2011). Among first semester students, however, proving skills are often only poorly developed and as a consequence, difficulties in writing proofs occur (Brandell, Hemmi, &

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Thunberg, 2008). This situation is aggravated by the fact that students are often obligated to work on weekly homework assignments (Rach & Heinze, 2011). With respect to the scientific nature of college mathematics, those assignments usually require proving skills and can therefore be very challenging. Overall, mathematics freshmen seem to encounter major challenges concerning the character of mathematics and in particular the character of mathematical exercise assignments.

In the context of school education, the construct of academic buoyancy has been introduced to describe “students’ ability to successfully deal with academic setbacks and challenges that are typical of the ordinary course of school life” that is “students’ everyday academic resilience” (Martin & Marsh, 2008, p. 53). Academic buoyancy therefore refers to everyday adversities, setbacks and pressures experienced by students in an educational context such as poor grades, difficult schoolwork, competing deadlines or exam pressure (Martin & Marsh, 2008). Up to now, however, research on academic buoyancy has only focused on school students and has only been operationalized from a general perspective. What is missing, are conceptualizations of academic buoyancy in the context of college education, and specified for particular disciplines. Given the fact that for many mathematics freshmen at university everyday adversities seem to affect their decision to quit the studies, and given the lack of research on academic buoyancy for this target sample, the present study reframes the concept of academic buoyancy for the context of college mathematics by introducing the construct of mathematics-specific academic buoyancy.

MEASURING MATHEMATICS-SPECIFIC ACADEMIC BUOYANCY

Assuming that most of the mathematics freshmen experience setbacks and frustration due to the compulsory homework assignments, we conceptualized mathematics-specific academic buoyancy in the context of these assignments. In particular, we conceptualized five situations, in which we think mathematics-specific academic buoyancy comes into play: 1) When students keep working on an exercise persistently even when there is no perceptible progress in learning or solving the exercise, 2) when students start working on exercises again and again even if they failed on these exercises before, 3) when students work persistently on exercises (as in 1 and 2) even if they are not interested in the content of the exercise or 4) the learning goal is unclear, and 5) when students keep studying mathematics despite of difficulties in solving the given assignments. Based on this conceptualization, we developed a self-evaluation questionnaire, the “Measure of Academic Buoyancy – Mathematics (MAB-M)”. The MAB-M consists of eleven items addressing the five above-noted aspects (see Table 1). Each item contains a statement and a 7-point rating-scale (1 = “strongly disagree”, 7 = “strongly agree”).

Given the fact that academic buoyancy has not been investigated in the context of university education so far, and, thus, no instrument assessing mathematics-specific academic buoyancy is known yet, the quality of the newly developed instrument above needs to be investigated in-depth. In particular, there is no evidence available on whether there is something like mathematics-specific academic buoyancy or how it can be measured from an empirical perspective. Hence, the present study focussed on an initial empirical evaluation of the MAB-M and approached the following research question: To what extent does the MAB-M provide reliable and valid measures of mathematics freshmen's mathematics-specific academic buoyancy?

Item No.	Statement
1	Math problems which need hours just for the basic idea how to solve them are not for me.
2	I don't mind spending a whole afternoon or longer on a complicated math problem.
3	I don't like to start extremely difficult assignments that even with a team require several sessions to solve.
4	Even if I don't know how to solve a difficult math problem after several tries, I keep trying to solve it.
5	If I don't see any progress in solving a math problem even after three attempts, I give up.
6	I am quick to drop a less interesting math problem if I don't know how to approach it.
7	Even if the problem is from a less fascinating mathematical topic, I won't drop an assignment after several failed attempts.
8	I persistently work on a math assignments even if I don't deem them useful.
9	If I don't see a learning objective of a difficult math assignment, I'll just drop it after 1 or 2 attempts.
10	If after some weeks' time I am still unable to solve advanced problems as well, I'll give up on studying mathematics.
11	Even if I fail difficult assignments again and again, that won't stop me from studying mathematics.

Table 1: Items of the MAB-M

METHODS

Design and Sample

In order to gain insight in the empirical quality of the newly developed instrument, we gathered data of N = 661 mathematics freshmen (57% females, 42% males, 1% missing; mean age 20.4 years, SD = 3.6 years). The overall sample is made up by two sub-samples, which will be described in more detail.

Sample 1 contained mathematics freshmen, who started their studies in 2014 at Kiel University (Germany). Here, data were collected in scope of a mathematics preparatory course prior to the first semester (measurement T1, $N = 85$) and at the beginning of the second semester (measurement T2, $N = 91$, 48 of these participated in measurement T1 and T2). At T2, data collection was performed in scope of the calculus tutorials, which are obligatory for every student who intends to complete the first year. The data of $N = 48$ students who participated in data collection of both T1 and T2 were used for longitudinal analyses.

Sample 2 included mathematics freshmen from Munich University ($N = 292$), the Royal Institute of Technology in Stockholm ($N = 50$), and from Kiel University ($N = 234$), who started their studies in autumn 2015. Data were collected in the first weeks of the semester. A second assessment for longitudinal analyses will be performed in spring 2016 (i.e. by the end of the first semester, or the beginning of the second semester respectively).

Instruments

Additional to the MAB-M, we employed five other instruments in order to investigate different validity aspects. To investigate convergent and discriminant validity, we administered four self-evaluation instruments, (1) a well-established questionnaire assessing general resilience (see Wagnild & Young, 1993; $\alpha = .83$), (2) Big Five personality scales (see John, Donahue, & Kentle, 1991; α from .68 to .81), (3) a measure on mathematics-specific self-concept (Kauper et al., 2012; i.e. "I am good at mathematics"; $\alpha = .8$), and (4) a measure on interest in mathematics (adapted from Köller, Baumert, & Schnabel, 2001; i.e. "I enjoy working on mathematical problems"; $\alpha = .83$). Instruments (1) and (2) were employed in both samples, instruments (3) and (4) in a subsample of sample 2 only (that is within $N = 526$ students from Kiel and Munich University). All instruments were employed at the first measurement, that is, at the beginning of the first semester 2014 or 2015 respectively. Each item of the employed instruments consisted of a statement and a Likert-scale (instruments 1 and 2: 7-point scale; instruments 3 and 4: 4-point scale).

To investigate content validity, we designed a special questionnaire (5) for the second measurement (i.e. at the end of the first semester resp. the beginning of the second): Based on a list of 8 key challenges, which mathematics freshmen have to face in their mathematics studies (e.g. preparing for the examinations, visiting the lectures, working on homework assignments), the participants were asked to indicate the extent to which those activities stress them on a 10-point rating scale. Besides, at measurement T2, we also assessed students' grades in the final examinations of the first semester to investigate predictive validity. Since the calculus tutorials – where we performed the second study – are compulsory for second semester students, we additionally used the presence in these tutorials as an indicator for dropout. Note, that data on the rating of challenges, the grades and the presence in tutorials is, by now, only available for sample 1, but will be collected for sample 2 in spring 2016 as well.

RESULTS

In order to address the research question, we analysed the gathered data with respect to structural, convergent, discriminant, content and predictive validity and reliability.

Structural validity

To investigate the structure of the newly developed instrument, we performed a principal component analysis (PCA). Prior to that, we checked and found the sample adequate (Kaiser-Mayer-Olkin test, KMO = .9) and the correlation matrix significantly differing from the identity (Bartlett test, $\chi^2(55) = 2674.5$, $p < .001$). The actual PCA then indicated a one-factor structure of the instrument. The factor loadings of the items were > .52 and the identified component explained 44% of the variance.

Convergent and discriminant validity

To investigate convergent and discriminant validity, we correlated students' mathematics-specific buoyancy measures with their measures of general resilience and the Big Five personality traits (Table 2). We found the MAB-M to correlate with general resilience ($r = .37$, $p < .001$) and conscientiousness ($r = .34$, $p < .001$). These findings indicate that the respective constructs are related but clearly distinct from each other. Evidence for discriminant validity was provided by the fact that there were no more than weak correlations of the MAB-M with extraversion, openness, neuroticism and agreeableness. Furthermore, we found only moderate correlations of MAB-M with mathematics specific self-concept ($r = .33$, $p < .001$) and students' interest in mathematics ($r = .59$, $p < .001$) in a subsample of sample 2 ($N = 526$ students from Kiel and Munich University).

	(1)	(2)	(3)	(4)	(5)	(6)
(1) MAB-M						
(2) General Resilience	$.37^{***}$					
(3) Conscientiousness	$.34^{***}$	$.41^{***}$				
(4) Extraversion	–.01	$.27^{***}$	$.08^{*}$			
(5) Openness	$.19^{***}$	$.34^{***}$	$.12^{***}$	$.15^{***}$		
(6) Neuroticism	$–.13^{***}$	$–.22^{***}$	.01	$–.11^{**}$	.00	
(7) Agreeableness	$.10^{**}$	$.21^{***}$	$.16^{***}$	.07	$.10^{**}$	–.06

Table 2: Pearson correlations for MAB-M, General Resilience and personality scales; Key: * $p < .05$; ** $p < .01$; *** $p < .001$.

Content validity

In order to investigate to which degree the weekly exercises in fact are viewed as a main factor of pressure in the first semester, we asked $N = 91$ second semester students of sample 1 to indicate to which extent they were challenged by different key aspects of the mathematics studies. The results suggest that, from the view of mathematics students, the most challenging activities in the first semester are preparing for examinations ($M = 8.5$) and working on homework assignments ($M = 8.3$). None of the other aspects were rated comparably high ($M < 5.5$). Since it can be assumed that the preparation for examinations may be a daily activity but not a daily pressure, this finding underpins the hypothesis that the weekly exercises are the most pressing daily activity of the first semester.

Predictive validity

In order to investigate predictive validity, we analysed the data of $N = 85$ students of sample 1 from the first measurement T1 and the second measurement T2 regarding dropout in the first semester. We identified 48 students in both, T1 and T2, thus indicating that these students persisted in the studying of mathematics. The remaining 37 did not participate in a compulsory course of the second semester at the time of measurement. Logistic regression revealed that students' probability of participating in the second semester is significantly higher with higher academic buoyancy measures at the beginning of the first semester ($\exp(B) = 1.66$, $SD = 1.28$, $p < .05$). This corresponds to a significant biserial correlation of $r_b = .3$ ($p < .05$) between the MAB-M measures and the persisting in mathematics studies. These findings should be considered only tentatively indicating predictive validity, given the only small number of data at hand.

Reliability

The MAB-M showed a good internal consistency (Cronbach's $\alpha = .87$). The internal consistency did not increase if one of the items was excluded from the measurement. We therefore kept the instrument as is.

DISCUSSION AND CONCLUSIONS

The main aim of the present study was to adapt the construct of academic buoyancy to the context of mathematics freshmen, and to provide an instrument assessing this construct. Applying the newly developed instrument, a principal component analysis showed that the MAB-M can be considered as unidimensional. Moderate correlations of the MAB-M with a valid and reliable measure of general resilience indicated evidence for convergent validity. The fact that we did not find a higher correlation may be explained by the theory that resilience concepts (e.g. academic buoyancy) depend on the context of the challenges (e.g. Weber, Glück, Sassenrath, & Heiss, 2003). Hence, a student may behave resilient in one situation and vulnerable in another. Additionally, the MAB-M correlated moderately with the Big Five factor conscientiousness. Given the fact that conscientiousness includes facets like self-discipline, dutifulness and achievement striving (Costa, McCrae, & Dye, 1991), the found correlation provides evidence for convergent validity as well. The other Big Five personality scales were found to correlate with the MAB-M only weakly, if at all; this finding provides evidence for discriminant validity of the MAB-M. Furthermore, it was possible to separate the MAB-M measures from students' interest in mathematics and mathematics-specific self-concept. A survey of second semester students revealed that homework assignments actually are the most pressing daily activity in the first semester, indicating content validity of the instrument. First evidence for predictive validity was found since the MAB-M proved to be able to predict students' dropout in the first semester. A good internal consistency revealed evidence for the reliability of the questionnaire. Overall, our findings indicate that mathematics-specific buoyancy, in fact, seems to be a latent ability to successfully deal with everyday academic setbacks and challenges that are typical of mathematics studies. Moreover, the respective newly developed MAB-M seems to provide valid and reliable measures of this new construct.

Despite these promising findings, our study faces some limitations. The most pressing limitation lies within the only small sample we consulted for the search for predictive and content validity. These evidences should therefore be considered as only tentative with the need for corroboration in larger samples as well. Such corroboration may be found in the data still to be collected for sample 2 at the second measurement.

Nevertheless, our study provides first evidence that the MAB-M could be helpful to identify mathematics-specific academic buoyancy as an important factor of mathematics students' success in the first semester. In particular, our study suggests that academic buoyancy could turn out an important factor in modelling college dropout. Hence, future research on academic buoyancy could be useful to counteract the problem of dropout from mathematics studies. As such, our study contributes implications for further research. For example, little is known about whether mathematics-specific academic buoyancy can be trained. To this end, an experimental study could employ a treatment fostering freshmen's mathematics-specific academic buoyancy compared to a control group and investigate whether the treatment in fact results in higher buoyancy measures and smaller dropout rates. Likewise, future research should investigate in even more detail which learning conditions and demands exactly are challenging for mathematics freshmen. Both these ideas also imply practical contributions. For example, if the treatment on mathematics-specific buoyancy is in fact effective, it could be included as an element of bridge courses or tutorials in the first year of study. Knowing more about the challenging learning conditions might influence how college teaching of mathematics could be improved to decrease the need for mathematics-specific academic buoyancy. Hence, with better support and adequate demands put on them, even students with low academic buoyancy could be able to master this crucial phase of the mathematics studies and exploit their whole potential as future mathematicians and mathematics teachers.

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