STUDENTS' SENSE OF BELONGING TO MATHEMATICS IN THE SECONDARY-TERTIARY TRANSITION

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A "sense of belonging to math" (SBM) scale has been shown to predict undergraduate mathematics students' intent to study mathematics in the future. In this study, we use the scale to examine the impact of the transition from secondary school to university on 33 first year undergraduate students' SBM. Using a cluster analysis, we identify three clusters: students in both Cluster 1 (n=21) and Cluster 2 (n=9) display a strong SBM at secondary school. Following the transition, those in Cluster 1 exhibit a decrease in SBM, while those in Cluster 2 show only a marginal decrease. Students in Cluster 3 (n=3) show a strong increase in their SBM, but they started with the lowest SBM initially. From an analysis of interviews with seven of the students, factors that might impact students' SBM during the transition are discussed.

INTRODUCTION

A "sense of belonging to math" (SBM) scale has been shown to predict undergraduate students' intent to study mathematics in the future (Good, Rattan, & Dweck, 2011). A person's SBM relates to whether one feels a member of a mathematical community, and feels valued and accepted by that community. Other factors influencing one's SBM are: affect - the feelings and emotions surrounding learning mathematics; trust that members of the community have one's best interests at heart; and, a willingness to actively participate in the community (Good et al., 2012).

In this paper, we focus on examining the impact that the transition from secondary school to university mathematics has on students' SBM. The students in this study are first-year undergraduates enrolled to a Science programme at a university in Ireland. They are "high-achievers" in mathematics in that most have taken higher level mathematics at school, and have chosen first year university subjects which make them eligible to pursue a mathematics (or related) degree. The structure of the Science programme means that they do not commit to a major until the end of second year - consequently, they can opt out of mathematics at the end of first or second year. Given the emphasis in Ireland on increasing capacity in the mathematics pipeline

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(Department of Education and Science, 2017), it is important to investigate the effect that the transition to university mathematics has on students' SBM, the factors which may impact it, and in turn, affect a student's decision to continue pursuing mathematics. We address the following research question:

- How does the transition from secondary mathematics to university mathematics, affect high-achieving students' SBM?

LITERATURE REVIEW

Good et al. (2011) conceptualise SBM as involving "one's personal feelings of membership and acceptance in an academic community in which positive affect, trust levels, and willingness to engage remain high" (p. 3). They created and validated a 28-item SBM scale containing five subscales. Two of these relate to feelings of membership of, and acceptance by, one's mathematical community. As positive emotions towards a subject are likely to be linked to a feeling of belonging, the third subscale relates to affect. The final two subscales relate to trust and a desire to fade. Trusting that peers and teachers/professors in the mathematical community have your best interests at heart, and wanting to actively participate in the community, are likely to contribute to a positive SBM. In a study of undergraduate mathematics students, Good et al. (2011) showed that SBM reliably predicted one's intention to study mathematics in the future.

Given the ability of the SBM scale to predict one's intention to study further mathematics, it is important to examine factors that build, or erode, one's SBM. In a longitudinal study of Calculus students, Good et al. (2011) examined the effect that students' perceptions of two messages from the environment had on their SBM. The message that mathematical ability is fixed, together with a stereotype message that men have higher ability than women in mathematics, was found to adversely affect the SBM of women over the semester but not men. However, female students who internally believed that mathematical ability could be improved with work, seemed immune to the stereotype message and their SBM remained high.

A person who believes that ability is something you cannot change, is said to have a fixed mindset, or an entity theory of intelligence, while someone who believes that ability is malleable is said to have a growth mindset, or an incremental theory of intelligence (Dweck, 2006). Implicit theories of intelligence and their impact on achievement, learning, motivation, and resilience have been studied extensively by Dweck and colleagues (see for example Dweck, 2006). One particular study examined how implicit theories of intelligence impacted seventh grade students' mathematical transition to middle school (Blackwell, Trzesniewski, & Dweck, 2007). It is common for seventh grade students' mathematics grades to drop, and this was observed in the control group. However, in the group of who received the incremental theory intervention, the decrease in results was reversed and by the end of the year had almost returned to the levels reported at the beginning. A growth mindset seemed to provide students with the resilience to navigate this mathematical transition.

SBM is a complex construct and implicit theories of intelligence are just one of many factors that may affect a student's SBM at the secondary or university level. For example, Boaler (2002) argues that the mathematical practices students engage in, shape not only their mathematical identity, but the "disciplinary relationships" (p. 119) they develop. The mathematical transition from secondary to university mathematics is similarly complex and multi-faceted, involving transitions at the individual, socio-cultural, and institutional levels, with students facing difficulties in many areas from how they think about, and communicate, the subject, to grappling with the different didactical contracts of school and university (Gueudot, 2008).

Mathematical community on the SBM scale is described as "the broad group of people involved in that field, including the students in a math course" and participants are informed that they could consider themselves a member "by virtue of having taken many math courses, both in highschool and/or [university]" (Good et al., p.18). At university, one would expect to find a community of practice of mathematicians (Wenger, 1998) and ideally the undergraduate mathematics student should be a legitimate peripheral participant of this community (Lave and Wenger, 1992). In a study of twelve first year mathematics undergraduates, Solomon (2007) found that a student identity of apprentice to this community of practice was rare. Experiencing mathematics as rules to be followed without understanding, not feeling ownership over the mathematical knowledge, and feeling vulnerable to failure due to fixed-ability beliefs about mathematics, all contributed to feelings of not belonging.

METHODOLOGY

The students in this study were enrolled to the first year of a Science degree programme at a university in Ireland in 2014-15. In first year, students are free to pursue modules in their area(s) of interest, for example, in biology, chemistry, mathematical sciences, physics, and/or mathematics education. In second year, they choose more specialist modules, and at the end of this year they commit to one of twenty-six degree majors. Students registered to the first-year mathematics education module (n=40) were invited to take part in the study and 33 participated, of which 20 were female and 13 were male. All but three of these were enrolled to modules that made them eligible to continue the study of mathematics in second year if they wished.

In Ireland, for the final two years at secondary school (17-19 years), students study the Leaving Certificate Curriculum and sit the terminal state examination in six to eight subjects. These examinations are high-stakes as the total number of “points” received for a maximum of six subjects determines students’ entry to university. Almost all students take mathematics which is offered at three levels: Foundation, Ordinary and Higher. In this study, 31 students had taken higher level mathematics, with the remaining two entering university via a different route. For this reason, the majority can be considered as “high-achievers” in mathematics.

A survey was administered in class towards the end of their first year. Students were asked to complete the SBM scale found in Good et al. (2012) twice – first as it related to when they were “in a maths setting at school”, and secondly, as it related to when they “are in a maths setting at university”, and state what subjects they intended to purse in Stage 2. They were also invited to participate in follow-up interviews. Seven students (four female and three male) agreed and these were conducted a few weeks later. The interviews were aimed at gaining more insight into the factors impacting a students’ SBM. In relation to both school and university mathematics, students were asked about their experiences of studying mathematics, how confident they felt, and whether they felt a sense of belonging to the mathematics community.

The SBM scale contains both negatively and positively worded items on a 5-point Likert scale (1=strongly disagree; 5=strongly agree). For the purpose of quantitative analysis, the negative items were reversed and the internal consistency of the SBM scale was investigated for each factor (membership, acceptance, affect, desire to fade and trust) as well as the composite SBM. As in Good et al. (2012), the composite SBM was created through developing subscale averages for each of the five factors and then averaging them to achieve an overall SBM score at both levels. SBM achieved a Cronbach alpha of=0.83 for school and α=0.87 for university.

To analyze the change in students’ SBM in the transition from secondary to university, students’ subscale averages for each factor for both secondary school and university were clustered using mixed-model clustering (Scrucca et al., 2016). mclust is more flexible than K-means clustering as it allows for varying volume, orientation, and shape of clusters. Cluster analysis, based on the Bayesian Information Criterion, identified a three-cluster solution as the optimal solution.

Finally, the interview audio-recordings were transcribed and analyzed thematically (Braun & Clarke, 2006).

RESULTS

On analyzing the change in students' SBM from secondary school to university, cluster analysis identified a three-cluster solution as optimal. Each cluster can be discussed in terms of the change in students' SBM over the transition (see Figure 1).

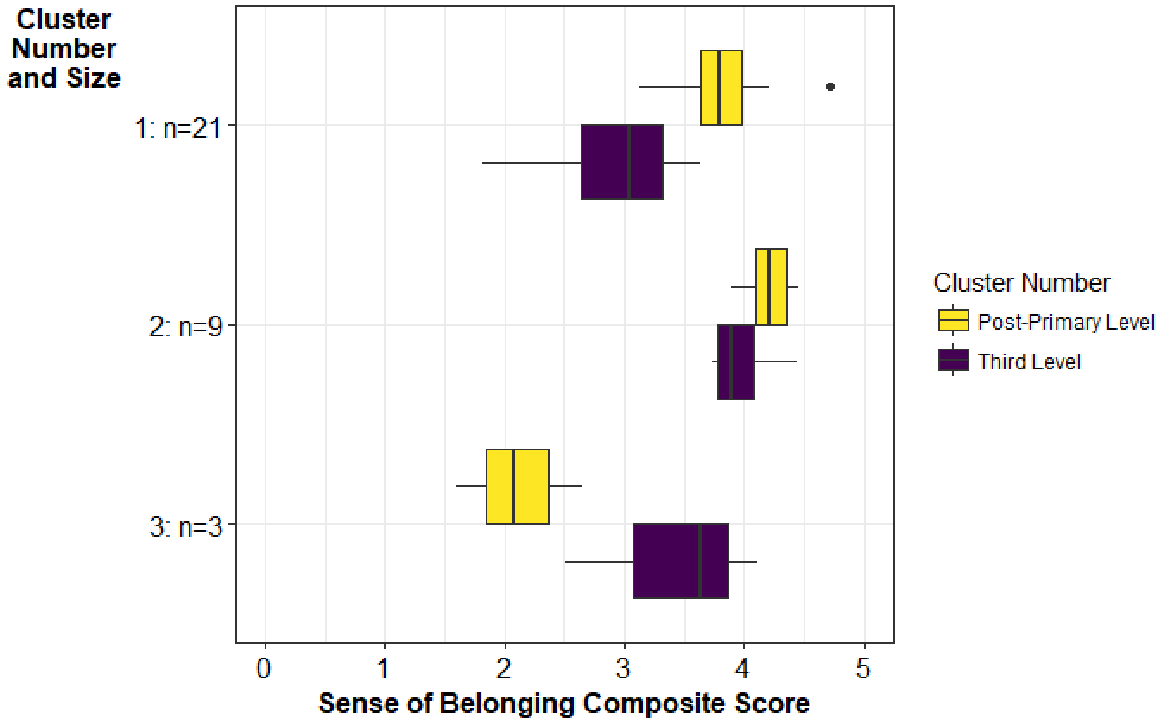

Figure 1: Boxplot of students' composite sense of belonging for each cluster and for secondary school and university

Students in the first cluster (n=21) display a strong SBM at secondary school that decreases following the transition. In comparison, students in the second cluster (n=9) have a strong SBM at school, however, this marginally decreases following the transition. Students in the third cluster (n=3) show a strong increase in their SBM, but these students started with the weakest SBM initially. In addition, two of these students had chosen subjects which made them ineligible to study mathematics in second year.

In the following academic year 2015-16, 8 of the 9 students in Cluster 2 and 10 of the 21 students in Cluster 1 were studying mathematics modules. No-one from Cluster 3 studied mathematics in Stage 2.

Of the seven students interviewed, four were from Cluster 1 (Grace, Joe, Julie and Lucy), two from Cluster 2 (Kate and Sean), and one was from Cluster 3 (Charlie).

Grace, Lucy, Kate and Sean all continued to study mathematics in second year. (Pseudonames were assigned to the participants.)

DISCUSSION AND CONCLUSION

The secondary-tertiary transition is complex and involves many types of transitions. For this reason, Gueudot (2008) suggests that research dealing with issues faced by students in the last two years of school, and the first two years of university, may all contribute to our effort to better understand the transition. SBM is also complex, comprising of one's feelings of membership and acceptance by a mathematical community, trust that the community has your best interests at heart, affect, and one's willingness to activity participate in the community (Good et al., 2012). Even the notion of community is complex, as students may belong to several, and sometimes conflicting, local communities of practice (Solomon, 2002). It is with this backdrop that we discuss our findings, and attempt to gain some insight into factors that may affect mathematical high-achievers' SBM in the secondary-tertiary transition.

In terms of Cluster 3, two of the students were enrolled to two, core "general" mathematics modules which made them ineligible to study mathematics in second year. The third had not taken the Irish Leaving Certificate. None continued to study mathematics in second year. It is interesting to examine Charlie's experience of studying higher level mathematics at school, which ultimately turned him away from the subject. He described his teacher as "absolutely disastrous" and said: "he didn't know any of our names, even in sixth year". In his final year, he, along with "half my class", had to pay for private tuition. Therefore, while his SBM did exhibit the largest overall increase in going from school to university, he was starting from a very low base and at university, just wanted to do the core mathematics "to get it out of the way". It is not surprising that he did not wish to study mathematics at university.

In relation to Clusters 1 and 2, it is not surprising that students' SBM at secondary school was high. Most of these students had studied higher level mathematics, had gained entry to a highly competitive science programme, and 29 of the 30 had voluntarily chosen higher level mathematics modules in their first year at university, making them eligible to study mathematics in second year. From the interviews of the six students from Clusters 1 and 2, a picture of successful, top-set students emerges. They came from schools where teachers knew them well and knew what they were capable of, and on occasions motivated them to do better. Most described themselves as being in the top higher mathematics class, and being confident at mathematics.

When asked about their experiences of studying mathematics at university most mention: the impersonal large lecture setting and adapting to the resulting teaching style; the increased level of difficulty of mathematics; and, working independently. One could see how these factors might erode a student's SBM as they progress through first year, which makes the cases of Kate and Sean interesting. Despite experiencing these challenges their SBM decreased only marginally. Due to space constraints, we will briefly highlight two possible contributory factors in the case of Sean.

Sean was the only student, who when asked about a sense of community at university, said there "is definitely" a "maths community" and gave a description most closely resembling that of a community of practice of mathematicians (Wenger, 1998). He explained that there are "so many more lecturers" compared to only three or four mathematics teachers at school. He is a member of the student *Maths Society* and has been to some of their events. In terms of participation, he said he has been settling in and has been a "bit quiet" but is "determined to get more involved next year". He has also "chatted" to one of his lecturers a few times after class, and visited another in his office a few times. Sean's recognition of the community of mathematicians, and desire to become more involved, suggests an identity of legitimate peripheral participant, which can be rare among first year mathematics undergraduates (Solomon, 2002).

Secondly, Sean exhibits a growth mindset (Dweck, 2006). At school, he embraced challenging problems: "I actually love to sit there and like even if it took two hours, just to sit there and try and get my head around doing it". At university, despite struggling to understand some of the mathematical concepts, and feeling "confused" and "frustrated", his reaction is to acknowledge that it is all new, seek help, and put in the work. When speaking about Analysis he admitted "for the first time ever in a maths exam, I am genuinely one hundred percent frightened". However, he explains that he is "just not used to" Analysis and has actively sought help from the university *Maths Support Centre* and looked up videos on *Khan Academy*. He acknowledged the amount of independent work he was putting in: "There has been an awful lot more of my own work going in" but he felt that was "natural" at university. His growth mindset seems to have given him the resilience to persist through challenges (Yeager & Dweck, 2012) and help him navigate the difficult mathematical transition (Blackwell et al., 2007).

In conclusion, we have used the SBM scale (Good et al., 2011) to examine the impact of the secondary-tertiary transition on students' SBM. Further qualitative analysis and research is required to better understand the many factors that might erode, or protect, a students' SBM during this transition.

Acknowledgements

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