Understanding STEM students' difficulties with mathematics

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Among the thousands of freshmen enrolled at STEM university courses all over the world at the beginning of the semester, around 40% of them would dropout in a few weeks. The phenomenon of STEM-related dropout has received increasing attention in literature. Tinto (2010) has proposed a theory of academic persistence that is of inspiration for subsequent studies, since students' persistence is affected by a number of factors, as skills, abilities, and prior schooling, as well as by experiences at university. Interestingly, it seems possible to predict students' academic success by looking at their first days at university. To this respect, Larose et al. (2019) stress that students should adjust to a new context, a new program, new teaching practices, and a new institution, and they list a number of variables that should be considered to understand students' adjustment in the school-university transition. Among them, gender, students' expectations, coping strategies and school of provenience are the most relevant. University mathematics, specifically, causes difficulties to students with STEM majors in general and to Engineering students in particular (Gomez-Chacon et al., 2015).

The main goal of our research is, thus, to investigate whether different approaches to mathematics at school are related to different performances in mathematics. To that end, we measure success at first impact with university with high scores in math tests and we collect data about students' views about mathematics to identify different communities of students. Our presentation focuses on a Bridge Course (i.e., a course offered to freshmen to recap the essential mathematics), held at Polytechnic of Milan in 2017. The Bridge Course is hybrid: in the online part, the students recap essential mathematics using the Massive Open Online Course (MOOC), produced by Polytechnic of Milan and hosted on www.pok.polimi.it; in the in-presence part, students are involved in group activities focused on problem solving. Students are invited to attend the MOOC before the in-presence course. The data for this study come from a questionnaire (administered on the first day), which investigates personal-level features such as gender and high school provenience, attitude towards the use of digital resources, and affective dimensions, such as the mathematical views. Moreover, four close-end tests were administered (during the in-presence part), which measure cognitive factors, assessing students' mathematical knowledge.

The heterogeneous data were analysed resorting to nonparametric methods that do not rely on strong assumptions on the structure of data, nor on linearity of connections. To understand the interplay of personal-level features and test performance, and to identify how students clusterize according to their views of mathematics, we resort to the community detection, as described by Kock et al. (2020), combined with the classification trees to investigate the interplay between personal-level features, the belonging to a community and the mathematical test performances.

Community analysis identifies 3 clusters. The first cluster is populated by students (majority of males) with a strong mathematical curriculum in high school, and who have a rather procedural view of mathematics. Their math performance in tests is good, but they declare to seek for the teacher's help when facing difficult problems, instead of employing more self-directed modalities. We expect that these students will face difficulties in the first semester, as also observed in Andrà et al. (2011). A second cluster is as well populated by students with a strong curriculum in mathematics, but they are used to a more conceptual approach. These students have partly attended the MOOC. Our interpretation is that they selected the contents they actually felt useful, being able to not lose time and showing self-regulation. Finally, students in the third cluster are aware that their mathematical knowledge is not enough to attend the first year, and they start to work hard to bridge the gap: thus, they attend both the MOOC and the in-presence course. According to Andrà et al. (2011), these students have a probability of getting the degree on time that is comparable to the one of the students in the second community. The results confirm that the mathematical background plays a key role in determining the success of a student in mathematics, and a strong mathematical curriculum predicts success (Andrà et al., 2011; Roesken et al., 2011). However, also students' beliefs are worth of consideration (Daskalogianni and Simpson, 2001). Moreover, our findings have two elements of novelty: the first consists in taking into account students' attitudes towards online learning, the second is the idea of clustering students with respect to both personal-level characteristics and their views of mathematics, to explain their performances. To conclude, we have a first indication that mathematical knowledge is important, but students' awareness about their weaknesses is also crucial for success in undergraduate STEM studies. We are further planning, in the next future, to analyze the interplay between personal level features, performance in mathematics and mathematical views using more advanced machine learning techniques.

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