Freshmen engineering students: are they all the same?

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This paper focuses on freshmen engineering students who attend a preparatory course before the beginning of the first semester. The course recapitulates the basic math knowledge learned at school and is made of an eLearning part and an attendance part. Data come from a questionnaire, which investigates affective factors, given to the students at the very beginning of the attendance part and at the end of it. We also consider data coming from a test given at the end of the attendance course, which investigates mathematical knowledge. The students come from different school types, they are assigned to tutors with different teaching styles and have attended the MOOC course or not: we examine the role of these differences in the transition from secondary school to university.

Keywords: Secondary-to-tertiary education transition, affective factors, minorities.

Introduction and background

University mathematics causes difficulties to students with STEM majors in general and to engineering students in particular (e.g., Gomez-Chacon, Griese, Rosken-Winter & Gonzales-Guillen, 2015). These difficulties can be traced back to several aspects (see Gueudet, 2008, and references therein), and preparatory courses are available from universities almost all around the world. The goal for such courses is to bridge the gaps between school and university, supporting freshmen students to recapitulate certain mathematical topics. This study focuses on the bridging course led at the Polytechnic of Milan for undergraduate engineering students.

Besides the cognitive factors, there is an increasing number of studies focusing on the crucial role of *affect* in undergraduate mathematics learning. Roesken, Hannula & Pehkonen (2011) present a questionnaire aimed at studying students' views of themselves as learners of mathematics. This study has for us many sources of interest. First of all, it discusses from a theoretical point of view the concept of "view of mathematics" and the related concept of "beliefs about mathematics". The authors state they choose the term "view of mathematics" because it captures the structural properties of the affect-cognition interplay, saying that "students' beliefs, wants and feelings are part of their view of mathematics". Secondly, the authors argue that students with different school backgrounds, different math curricula and different views and expectations come to attend a preparatory course and they experience mathematical activities. Daskalogianni & Simpson (2001) discuss the concept of "beliefs overhang": some beliefs, developed during schooldays, are carried forward in university, and this may cause difficulties. The study points out the crucial role of beliefs (about mathematics) in determining university success or failure. This is also confirmed by Andrà, Magnano & Morselli (2013), who analyse undergraduate mathematics students' career at university and find that cognitive factors as well as affective ones contribute to determine 'success' (taking the degree) or 'failure' (drop out). Specifically to the Italian context, Lombardo (2015) has proved that the kind of high school influences both cognitive and affective factors in the transition. In Italy, three main kinds of high school are present: scientific (SC), with an excellent curriculum in science and math; humanistic (HU) with a curriculum devoted to Italian literature, history, history of philosophy, ancient Greek, Latin and history of art; and technical (TE) with a focus on applications.

In their fundamental study, Clark and Lovric (2008) contend that at the basis of the leap between secondary and tertiary studies there is a shock: from procedural mathematics to conceptual understanding that university mathematics entails. According to Hiebert & Lefevre (1986), *conceptual knowledge* describes knowledge of the principles and relations between pieces of information in a certain domain. Hiebert & Lefevre (1986) define *procedural knowledge* as knowledge of the ways in which to solve problems quickly and efficiently. Pettersson and Scheja (2008) discovered that students developed their knowledge in an algorithmic way, not because of misconceptions, but because it was more suitable for them and enabled them to deal functionally and successfully with the presented tasks. Some researchers (e.g., Garner & Garner, 2001) found that teacher-centered methods (TO) favour the development of procedural knowledge while student-centered methods (SO) favour the development of conceptual knowledge. We understand the difference between TO and SO in terms of Barthes' (1975) schema, which in the context of reading texts distinguishes between readily texts, which deliver to the receiver a fixed, pre-determined reading (as well as teacher-centered lesson provide the students with a linear and organised exposition of knowledge), and writerly texts. *Writerly texts* force the reader to produce a meaning or set of meanings that are inevitably other than final or "authorized"—they are personal and provisional, not universal and absolute, as we see for student-centered lessons.

Figure 1 summarises the background of our research: students from different schools (different colors in the figure) attend a university preparatory course, which can be either TO or SO. TO fosters P (procedural learning) since they mostly make exercises and is readerly since they mostly copy the blackboard; SO fosters C (conceptual learning) since they are prompted to reflect on general properties and is writerly because they organise their work and discuss with peers. We aim at investigating whether the school type, the teaching format and the MOOC attendance have an impact on students' knowledge and views.

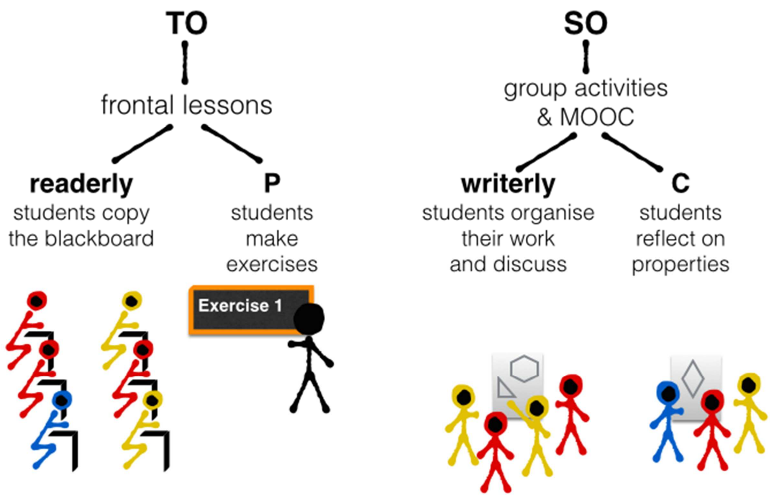

Figure 1: The background of our study.

Methodology

The bridging course at the Polytechnic of Milan is made of a MOOC course and of a 2-weeks-long attendance course of 32 hours at the Polytechnic. The MOOC course is structured in 6 weeks, one for each of the following topics: arithmetics, algebra, geometry, logics, functions, probability. Students who enroll at university are invited to attend the MOOC course before the attendance one. With Niegemann *et al.* (2008), we maintain that the bridging course combines self-directed (i.e., MOOC) and externally-regulated (i.e., attendance) learning types of instructional formats. There's a need for the latter, since learners are new at the university, they have to acclimatise with the new learning environment and attendance helps them to familiarize with the new didactical contract and the new organisation of courses. There's a need for the former, since learners at university have to be more self-directed and eLearning helps to adapt their learning behaviour (Mandl & Kopp, 2006).

Two kinds of attendance courses were held: SO and TO. In SO classes, the tutors valued MOOCs and group works, with a little emphasis on routine exercises, and the students were exposed to *writerly* activities, for instance the students were prompt to interact with the videos, go back to them, point out what is relevant, answer questions working in small groups, discuss with peers, in order to make sense of mathematics. In TO classes, the tutors privileged teacher-centered and routine-exercise style of the lesson. Brief theoretical explanations play the role of MOOC videos and, thus, do not encourage the students to attend the MOOC. Both TO and SO courses refer to the same syllabus, which is in accordance with the MOOC structure. The students were divided randomly and evenly into TO and SO classes.

On the first day of the attendance course the students were invited to fill in an affective questionnaire. It is anonymous, but the students can be identified for the kind of high school attended (SC, HU, TE) and for their use of the MOOC ('yes' and 'no'). On the first-to-last day of the attendance course the students were invited to fill in a similar questionnaire, with some questions that are in common with the previous ones, and others that are different. The day after, the students were engaged in a math test with 12 multiple-choice math questions, which have been classified on the basis of their C (4 questions) or P (8) nature. The number of C and P questions is not balanced, since the final test has been designed on the basis of the entrance test to university, and such a test is mostly P.

Question 1 (Q1) in the *initial questionnaire* asked: "In high school, mathematics for you had been.." and the students had to choose up to two answers in a list of 8 alternatives. 4 ones have been classified as P (they are: "formulas to apply", "formulas to memorize", "problems to solve", "exercises to repeat"), since they refer to *knowledge of the ways in which to solve problems quickly and efficiently* (Hiebert & Lefevre, 1986). The other four have been classified as C: "reasoning", "theorems to prove", "theorems to memorise", "definitions". These answers refer to *knowledge of the principles and relations between pieces of information* (Hiebert & Lefevre, 1986).

Q2 asked "With respect to high school, what do you expect university math to be?", and had 5 alternatives. 2 ones have been classified as P: "more difficult exercises" and "more use of PC"; 3 ones as C: "new topics", "to go deep in topics already seen" and "to use it in other fields".

Q3 asked: "Which purpose do think a problem similar to one you have already solved serves to?". The students had to choose up to two answers in a list of 8 alternatives: 4 are P: "to practice", "to provide a further example", "to apply what I have studied" and "to improve my calculation skills";

2 are C: “to deepen my knowledge” and “to introduce a new theorem”; 2 ones are S: “to create confusion” and “to loose time”.

Q4 asked: “What do you do when you face a difficult math problem?”. One alternative is P: “I apply formulas”; 2 ones are C: “I search for a related theorem” and “I think about a simpler problem”; and 2 ones are labelled S: “I surf the web” and “I give up”.

Since the students could choose up to 2 alternatives, their answers have been classified into: C - conceptual, P - procedural, CP - one conceptual and one procedural, or S. Q1 allows us to know how students see the math they have experienced at school, to confirm Clark and Lovric’s (2008) contention that students are exposed to P math at school. Q2 opens a window on the students’ expectations about math at university, to see whether the students are aware that more C math is present at university (Clark & Lovric, 2008). Q3 and Q4 investigate whether the students have been exposed to writerly learning formats, where problems serve the purpose to introduce new math: P answers would reveal that the students were exposed to problems to serve the purpose of increasing their ability to *solve problems quickly and efficiently*, and that they experienced math in a readerly way; C answers would reveal that problem solving activities at school have raised the students’ awareness about problems as means to reflect on math properties and to generalise.

In the *final questionnaire*, Q1 asked: “During this course, have you seen new topics, or topics dealt with in a different way?” and Q2 asked: “During this course, the problems were different from what you were used to?” Students could answer yes or no. Since Q1 asked whether they faced new math topics, it can be interpreted as C, and since Q2 asked whether they saw exercises formulated in a different way, it can be interpreted as P. The answers to these questions would allow us to further investigate whether findings by Clark & Lovric (2008) are confirmed. Q3 was the same of Q3 in the initial questionnaire. Q4 and Q5 were dedicated to MOOC/course appreciation.

Q4: “If I could go back in time…”. 4 alternatives: “I would attend only the MOOC”, “I would attend only the course”, “I would attend the MOOC and the course”, “It’s too early to judge”.

Q5: “Thinking about the math exam in the next semester, I would appreciate that…”. 4 alternatives: “a support for my difficulties on the MOOC is present”, “some extra tutoring has the same style of this course”, “lessons, exercises and tutoring are completely different from this course and the MOOC”, “none of the previous answers”.

The data of our study consist of the responses given by the students to the two affective questionnaires and to the final test. 524 students participated to the initial affective questionnaire, 395 to the final affective one and 286 to the final math test. SC students represent the majority (71%), while TE and HU students represent 17% and 12% of the whole population. We show the frequencies of the responses given by the entire population of engineering students and we also identify the differences that emerge (if any) in subgroups of students who are a priori identified: SC, HU and TE high school background, MOOC attendance and the teaching format (TO/SO). To investigate whether TO/SO had influenced the results in the final math test, we take into account two tutors, Anna and Bob. Anna is representative for SO, since she promoted the use of MOOC and used merely an interactive approach based on group works and on problem solving. Bob is representative for TO, since he performed mostly frontal lessons by proposing an exercise and solving it at the blackboard.

Data and analysis

Tables 1 and 2 show the frequencies of the entire population of students' answers to the initial and final questionnaires. Table 3 presents the performance at the final math test for Anna's and Bob's students only. Table 4 divides Anna's and Bob's students with respect to the kind of high school and the MOOC attendance.

Q1	P (106)			C (83)			CP (297)						missing (38)
HighSchool	SC (59)	HU (15)	TE (31)	SC (62)	HU (12)	TE (10)	SC (223)	HU (31)	TE (43)				
Q2	**P (138)**			**C (265)**			**CP (75)**						**missing (46)**
HighSchool	SC (87)	HU (19)	TE (32)	SC (200)	HU (28)	TE (37)	SC (18)	HU (9)	TE (14)				
Q3	**P (304)**			**C (113)**			**CP (49)**			**S (10)**			**missing (48)**
HighSchool	SC (216)	HU (39)	TE (49)	SC (82)	HU (13)	TE (18)	SC (37)	HU (5)	TE (7)	SC (3)	HU (1)	TE (6)	
Q4	**P (104)**			**C (283)**			**CP (27)**			**S (51)**			**missing (59)**
HighSchool	SC (71)	HU (16)	TE (17)	SC (215)	HU (27)	TE (41)	SC (18)	HU (6)	TE (3)	SC (28)	HU (6)	TE (17)	

Table 1: the whole population of students' answers to the initial affective questionnaire.

Q1	Yes (257)			No (134)									missing (4)
HighSchool	SC (134)	HU (59)	TE (64)	SC (119)	HU (10)	TE (5)							
Class	SO (125)	TO (132)		SO (72)	TO (62)								
MOOC	NO (91)	YES (166)		NO (62)	YES (72)								
Q2	**Yes (177)**			**No (208)**									**missing (10)**
HighSchool	SC (90)	HU (40)	TE (47)	SC (159)	HU (28)	TE (21)							
Class	SO (84)	TO (93)		SO (111)	TO (97)								
MOOC	NO (62)	YES (115)		NO (89)	YES (119)								
Q3	**P (241)**			**C (69)**			**CP (75)**			**S (2)**			**missing (8)**
HighSchool	SC (149)	HU (46)	TE (46)	SC (48)	HU (12)	TE (9)	SC (53)	HU (11)	TE (11)	SC (2)	HU (0)	TE (0)	
Class	SO (120)	TO (121)		SO (35)	TO (34)		SO (40)	TO (35)		SO (2)	TO (0)		
MOOC	NO (97)	YES (144)		NO (29)	YES (40)		NO (25)	YES (50)		NO (0)	YES (2)		
Q4	**MOOC only (16)**			**Course only (67)**			**both (179)**			**dont know (126)**			**missing (7)**
HighSchool	SC (11)	HU (3)	TE (2)	SC (50)	HU (11)	TE (6)	SC (99)	HU (38)	TE (42)	SC (92)	HU (18)	TE (16)	
Class	SO (11)	TO (5)		SO (17)	TO (50)		SO (97)	TO (82)		SO (72)	TO (54)		
MOOC	NO (0)	YES (16)		NO (45)	YES (22)		NO (42)	YES (137)		NO (62)	YES (64)		
Q5	**Support on MOOC (142)**			**Style of this course (188)**			**Completely different (6)**			**None (30)**			**missing (29)**
HighSchool	SC (87)	HU (24)	TE (31)	SC (122)	HU (34)	TE (32)	SC (3)	HU (3)	TE (0)	SC (27)	HU (1)	TE (2)	
Class	SO (69)	TO (73)		SO (101)	TO (87)		SO (0)	TO (6)		SO (13)	TO (17)		
MOOC	NO (57)	YES (85)		NO (76)	YES (112)		NO (5)	YES (1)		NO (13)	YES (17)		

Table 2: the whole population of students' answers to the final affective questionnaire.

Final Grade	Low (8)			Medium (19)			High (43)			none
HighSchool	SC (1)	HU (2)	TE (5)	SC (12)	HU (3)	TE (4)	SC (37)	HU (2)	TE (4)	
Class	SO (5)	TO (3)		SO (12)	TO (7)		SO (17)	TO (26)		
MOOC	NO (3)	YES (4)		NO (11)	YES (6)		NO (23)	YES (18)		5

Table 3: Anna's and Bob's students' performances at the final math test (last day of the course).

	MOOC no (49)	MOOC yes (76)	SC (84)	HU (22)	TE (20)
Anna (57)	20	36	43	4	10
Bob (69)	29	40	41	18	10

	SC (84)	HU (22)	TE (20)
MOOC no (49)	42	4	3
MOOC yes (76)	42	18	16

Table 4. Anna's and Bob's students splitted into SC, HU and TE, and with respect to MOOC attendance. Numbers refer to the day of the final affective questionnaire, not to the day of the final math test.

Conceptual and procedural at high school and at university

In the initial questionnaire, the students polarize to CP in Q1 (school math) but the majority expects C math at university (Q2) and resorts to C strategies when they face a difficult math problem (Q4), but gives P answers to the question about the role of a problem similar to one already seen (Q3).

If we compute the frequencies relative to the kind of school, we see that, compared to their HU and TE mates, SC students have been less exposed to P math in school, and they resort more to C strategies when face a difficult problem. TE students have been more exposed to P math in school.

In the final questionnaire, SC students split almost equally between *yes* and *no* to Q1 (134/253=53% *yes* and 119/253=47% *no*), but 63% of them answer *no* to Q2. This means that a minority of them dealt with exercises different from the ones they were used to in high school, but half of them experienced new topics. The situation for HU students is different: 85% answered *yes* to Q1 and 59% to Q2. The difference is even more striking for TE students: 93% and 69% of them answered *yes* to Q1 and Q2 respectively. Q1, Q2 and Q4 in the initial questionnaire have evidenced that TE students tend to give more P answers with respect to their SC and HU mates, and Q1 and Q2 in the final questionnaire confirm that for these students the course has represented a difference with respect to the math they were used to, more than their HU mates, and much more than their SC mates.

We compare Q3 (the role of a problem similar to one already seen) in the initial and in final questionnaires. The percentage of SC students who give P answers diminishes (from 64% in the initial to 59% in the final ones), C diminishes as well (from 24% to 19%), while CP increases (from 11% to 21%). For HU students, P and C remain the same, while CP increases (from 9% to 16%).

The final math test and appreciation of the course

Bob's and Anna's classes (table 4) are distributed almost evenly with respect to MOOC attendance, but Bob has more HU students. Some data, not present in tables 1-4, need to be added at this point: Bob students' answers to the initial questionnaire were 148 (Anna: 43), to the final one were 69 (Anna: 57). Bob has lost 79 students, while Anna has gained some students. Specifically, Bob had lost SC students. Anna had gained some TE. 25% of Bob students declared to have attended the MOOC before the beginning of the course and 58% attended it during Bob's course. 5% of Anna's students attended the MOOC before the beginning of the course, and the percentage increases to 63% during Anna's course. Anna actually encouraged MOOC attendance.

Q4 in the final questionnaire reveals that the majority of students, namely 179, would attend both the course and the MOOC: roughly half come from SO and the other half from TO classes. But 77% of them (i.e., 137) have attended the MOOC.

Q5 gives us more information about MOOC and course appreciation: only 6 students wish to encounter teaching experiences very different from bot MOOC and the course (they all come from TO class and almost all have not attended the MOOC).

The results in the final test (Table 3) reveal that Bob's students performed better than Anna's ones, while to attend the MOOC or not does not discriminate the students about the performance.

Discussion

Dealing with novelty, coming from different schools

Bob is TO and his lectures foster P and readerly learning. Anna is SO and fosters C and writerly learning. SC and TE students are distributed almost evenly between Anna's and Bob's classes, while Bob has more HU. SC students have experienced more C math, while TE and HU students have performed more P: hence, Bob's students in all have experienced more P. Thus, Bob's lessons are more in accordance with the math experienced by the students at school, while Anna's lectures could represent a shock (Clark & Lovric, 2008) for the students attending her classes. The answers to Q1 and Q2 in the final questionnaire reveal that expecially for HU and TE students the course (regardless with TO or SO) had represented a difference with respect to math experienced in school: for HU students the difference concerns C, for TE it concerns both P and C math.

Conceptual and procedural math, and success at the math test

SC students performed better in the math test: SC students had more C math and performed better in a P test. HU and TE had more P math and performed worse in a P test. C math, which refers to *knowledge of the principles and relations between pieces of information* (Hiebert & Lefevre, 1986), allows the students to better deal with P tests. In other words, to teach P math, namely to teach to *solve problems quickly and efficiently* (Hiebert & Lefevre, 1986) may not represent an advantage for the students even when they face problems that need to be solved quickly and efficiently.

Bob's students performed better than Anna's ones, even if Anna had less HU students. Since the test was P, and since Bob was TO, this confirms Gardner & Gardner's (2001) contention that TO fosters P. With Petterson & Scheja (2008), we also see that Bob's students developed P math that allowed them to deal functionally and efficiently with the math test.

Conclusions

Should we tell Anna to teach like Bob, or should we tell Bob to copy Anna? Considering these data, we should tell Bob to change for the following reasons: (i) with Clark and Lovric (2008), the students should be exposed to C math in order to deal with the transition more smoothly and the results in the math test in our study confirm that students who were exposed more to C math *at school* performed better; (ii) students appreciated both TO and SO classes, but students exposed to SO represent a greater percentage of those who would like to have tutoring of the same style of SO lessons; (iii) with Mandl & Kopp (2006), Anna's teaching format provides the students with an opportunity to change their behavior and adapt to the new context. It is true that Anna's students, even if more equipped with C math, performed worse than Bob's ones and we interpret this fact as follows: the students *need time* to adjust to the new teaching format. Anna's students' performance was worse in the test, but they started to acclimatise with the novelty earlier with respect to Bob's students. We expect that Bob's student would face more difficulties in the math exam at the end of the semester, since they started to get acquainted with university math later.

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