Tools, conceptions of mathematics and goals in undergraduate engineering courses: An Activity Theory approach

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In this paper we present and discuss the results of a survey from our investigations into the kind of resources that engineering undergraduates use, their conceptions of mathematics and their goals when studying mathematics. By adopting an Activity Theory perspective, we performed correlational analysis between the components of the basic mediational triangle: the subject (conceptions of mathematics), tools (resources) and the object (goals). We found that most of the students in our sample hold a cohesive conception of mathematics, that institutionally-led resources dominate students' practice and that getting a high mark is the most popular goal among students. Correlations between the components of the mediational triangle were weak but yielded interesting relationships between the kind of resources that students use and the goals they set when studying mathematics.

Keywords: Educational resources; conceptions of mathematics; goals; activity theory

Introduction

Historical records suggest that using tools has always been inseparable from expressing and doing mathematics (Roberts, Leung, & Lins, 2013). A well-developed theoretical account of the human praxis which emphasises the role of physical tools is second generation Activity Theory (AT) (Leontiev, 1978). From an AT perspective, our relationship with the "objective" world is mediated by tools: the central role of tool mediation within this framework is due to the fact that tools shape the ways we interact with reality and they reflect past people's experiences and practices (Kaptelinin & Nardi, 2006). The structural relationships between individuals acting within the world, are usually represented by the basic mediational triangle which has three components: the person acting (subject), what he/she want to achieve (object) and the means used (tools) (Cole, 1998). By adopting this perspective, our aim was to explore the relationships between certain aspects of students' learning corresponding to the mediational triangle's components: the resources they use when studying mathematics (tools), their conceptions of mathematics (subject) and the goals they set for their mathematics modules (object). Some of these aspects have been studied separately and have been identified to influence students' mathematical activity but their relationships (if any) has remained unexplored. A brief summary of our literature review in each of these three areas is now presented.

In its current state, our literature review has revealed a lack of empirical studies exploring the kind of resources that students *actually* use when studying mathematics, with previous studies focusing mostly on digital/online or institutionally-led resources. Conole, de Laat, Dillon and Darby (2008) found that undergraduates use extensively the web and communication technologies (e.g. instant messaging); and that students are beginning to use resources beyond their institution's virtual learning environment (VLE). Inglis, Palipana, Trenholm and Ward (2011) found that students were making heavy use of only one of the resources provided with (live lectures, recorded lectures, support centre) or weren't using any of them at all. Rønning's (2014) survey is among the small number of studies adopting a more holistic approach by acknowledging a variety of resources that students have at their disposal. His survey showed that although students are provided with a large variety of resources they prefer to use more frequently the traditional ones (textbook, lectures).

Conceptions of mathematics (COM) is a construct referring to the views that students have about the nature of mathematics and relevant research (Crawford, Gordon, Nicholas and Prosser, 1994; 1998a) has identified a narrow view (fragmented, e.g. mathematics is numbers, rules and formulae) and a broad view (cohesive e.g. mathematics is a way of thinking). Fragmented conceptions of mathematics have been linked with surface approaches to learning, and lower examination performance while cohesive have been linked with deep approaches to learning and higher achievement in examinations (Crawford et al., 1994; 1998b; Cano and Berbén, 2009).

Reid, Wood, Smith and Petocz (2005) identified three orientations when it comes to students' goals when studying mathematics: the techniques orientation (related with the extrinsic and practical features of learning mathematics with a focus on mathematical skills); the subject orientation (related with the learning of mathematics itself) and; life orientation (intentions beyond the discipline of mathematics).

Method

During November-December 2015, a paper-based questionnaire was administered to four different groups of second year engineering students in Loughborough university and in total 201 completed it. Loughborough has one of the largest cohorts of engineering students (over 3000 undergraduates) in the UK and is a leader in the provision of Mathematics Support. It has also led on significant projects producing high quality printed material (e.g. the HELM project). The questionnaire consists of three main parts and it was specifically designed for depicting the three components of the meditational triangle. Part I (subject) explored students' conceptions of mathematics (5-point semantic scale: 1/Disagree, 2, 3, 4, 5/Agree) and it is based on Crawford et al.'s (1998a) COM questionnaire. Part II (tools) asked students to identify how often they use a list of resources (14 items, 6-point semantic scale: 1/Never, 2, 3, 4, 5, 6/Always) and it was based on our literature review, five in depth interviews with undergraduates conducted in 2015 and the resources that Loughborough University offers to students e.g. the Learn website (university's VLE). Part III (object) invited students to identify their goals, aims and intentions for their mathematics module from a list (10 items, 6-point semantic scale: 1/Disagree, 2, 3, 4, 5, 6/Agree). The list of goals was based on our literature review and five in depth interviews with students conducted in 2015. The list of resources was carefully generated and encompasses a great variety of tools available to students; in this way it reflects -to a certain degree- students' reality as learners when it comes to the resources they use.

Results

What do students think about mathematics (conceptions of mathematics)?

Students received a cohesive and a fragmented score (max cohesive score = 5, max fragmented score = 5), with the means of each score ($\bar{X}_{\text{cohesive}}$ = 4.11, N=200; $\bar{X}_{\text{fragmented}}$ = 3.38, N=196) and the mean of the difference of these scores ($\bar{X}_{\text{difference}}$ = 0.73, N=196) suggesting that students hold mostly a cohesive conception of mathematics. This can be also seen in Figure 1 which shows that most students' cohesive score is greater than their fragmented (red line indicates where the score difference is zero).

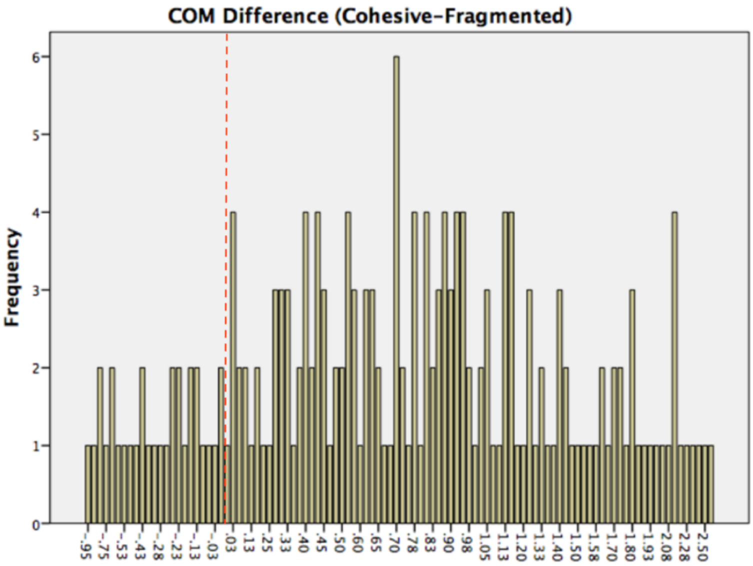

Figure 1: A frequency chart of individual students' difference between cohesive and fragmented score (Y axis: frequency (number of students), X axis: difference between cohesive and fragmented score).

What kind of resources do students use and what is their reported usage?

Results for Part II (tools) are presented in Figure 2. By using each resource's mean, we categorised them into three main groups: resources with a mean greater than or equal to 4.5 were characterised as *high-use* resources, those with a mean between 3 and 4.5 were assigned into the *mid-use* group while resources with a mean between 1.5 and 3 were put into the *low-use* group.

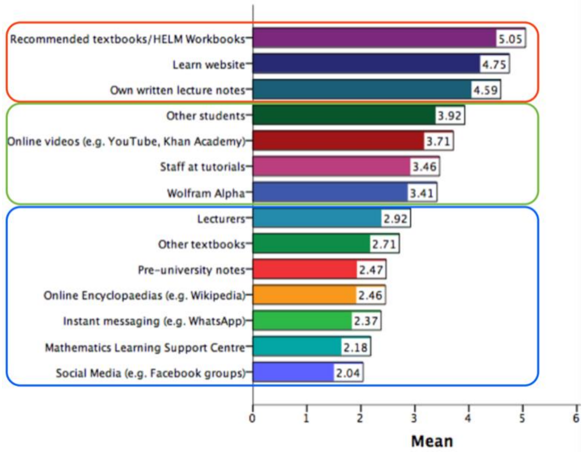

Figure 2: Tools and their grouping based on their mean (high-use: red, mid-use: green, low-use: blue).

An exploratory Factor analysis with oblique rotation on the 14 items for tools (KMO = .711, $\chi^2(91)$ = 505.591, $p<.001$) suggested 4 factors. This was followed by a principal components analysis on 11 items (variables excluded: “Own written notes”, “Learn website”, “HELM Workbooks”) with oblique rotation (KMO = .72, $\chi^2(55)$ = 413.471, $p<.001$). The 4 obtained factors explained 62.45% of the variance. Both the pattern and structure matrices were interpreted and factors were labelled as: ***university staff tools*** (“lecturers”, “MLSC”, “staff at tutorials”); ***peers and social apps tools*** (“other students”, “social media”, “instant messaging”); ***online tools*** (“online videos”, “online encyclopaedias”) and; ***reference tools*** (“pre-university notes”, “other textbooks”, “Wolfram Alpha”). Factors were named according to the nature of the tools they included and our initial analysis from 7 follow-up interviews (not reported here).

What kind of goals do students set for their mathematics modules?

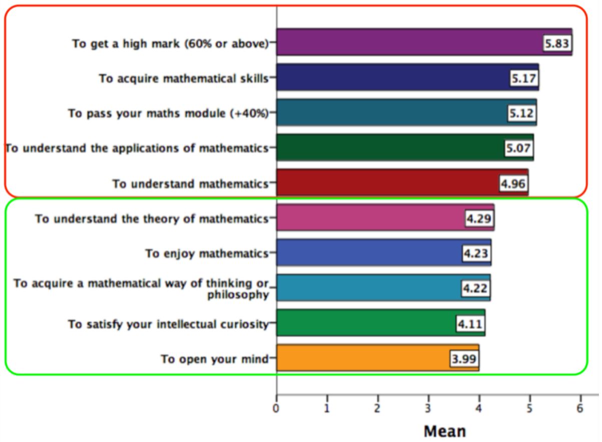

Figure 3: Students’ goals and their grouping based on their mean (high-value: red, mid-value: green).

Results from Part III (object) are presented in Figure 3. Based on their mean, we categorised students’ goals into two main groups: goals with a mean greater than 4.5 were characterised as *high-value* goals and those with a mean between 3 and 4.5 were assigned into the *mid-value* group.

An exploratory Factor analysis with oblique rotation on the 10 items for goals suggested 2 factors (KMO = .879, $\chi^2(45)$ = 894.610, $p<.001$). This was followed by a principal components analysis on 8 items (variables excluded: “to get a high mark”, “to pass your maths module”) with oblique rotation (KMO = .905, $\chi^2(28)$ = 846.471, $p<.001$). The obtained 2 components explained 69.80% of the variance. Both pattern and structure matrices were interpreted and factors were labelled as: ***life-goals*** (“to open your mind”, ”to satisfy your intellectual curiosity”, “to enjoy mathematics”, “to acquire a mathematical way of thinking or philosophy”) and; ***applications-goals*** (“to understand the applications of mathematics”, “to acquire mathematical skills”, “to understand mathematics”, “to understand the theory of mathematics”). Factors were named according to the nature of the goals they included and Reid et al.’s findings (2005).

What are the relationships between conceptions of mathematics, tools and goals?

Results from correlation analysis are presented in Figure 4. From COM only the cohesive score was correlated with either tools (only “students’ notes”) or goals ("applications", "life"). Three correlations were detected between "high mark" and tools and all were negative in nature. "Life" goals were correlated with four tools while "applications" goals with only one. "Reference tools" were negatively correlated with both "life" and "high mark" goals. "University staff" was positively correlated with "life" but negatively with "high mark". The "Learn website" was correlated only with "life" goals and "online tools" only with "high mark". "Notes" were correlated only with "applications" and "life" goals.

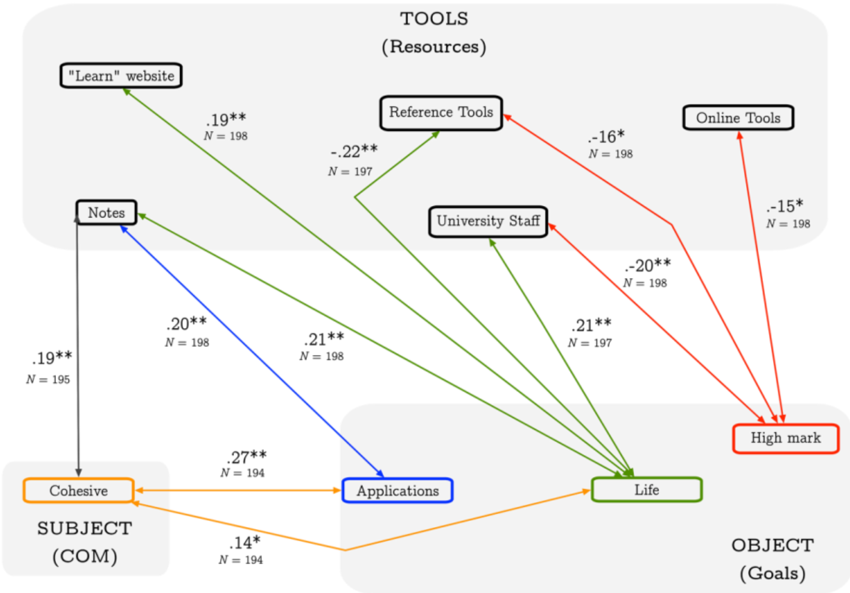

Figure 4: Pearson correlation coefficients for students' conceptions of mathematics, resources and goals (Only correlations between COM, resources and goals are reported. Non significant correlations are omitted. $^{**}p < 0.01$, $^{*}\ p < 0.05$).

Discussion

The results of this study shed light into two previously unexplored areas, namely the kind of resources that undergraduates *actually* use -whether these are online/digital, traditional or humans- and the relationships between these tools, students' goals and COM. Our investigations into the resources that students use, revealed a landscape dominated by university-led tools: all the resources in the high-use group (except students' own notes) are provided to students by their university. Only two non-institutional resources were relatively popular (online videos, Wolfram Alpha) while the others are not used frequently. Another noticeable result was the presence of teaching/support staff only in the mid-use ("staff at tutorials") and low-use ("lecturers", the "MLSC") group of resources. The dominance of university-led tools might be related with the goals that students set for their mathematics modules: "to get a high mark" is the most popular goal among students and initial analysis of 7 follow-up interviews with students (not reported here) provide support for this claim.

All the identified correlations are weak but we believe that results yield some interesting insights, namely: (1) students who aim for a high mark tend to use less frequently "university staff", "online tools" and "reference tools" into their practice, a fact that might also explain the dominance of institutional-led resources; (2) on the contrary, students with "life" goals tend to use more "university staff" and; (3) both students who aim for a high mark or "life" goals tend to use less "reference tools" ("pre-university notes", "other textbooks", Wolfram Alpha). Students in our sample are second year engineers and they mostly hold a cohesive conception of mathematics; relevant research supports that undergraduates are indeed more likely to hold a broader conception in their later study years (Wood, Petocz and Reid, 2012). In fact, this may have limited our exploration since only the cohesive score was correlated (with 1 tool and 2 goals). At the same time this could mean that an Activity Theory based (i.e. goal-based) investigation into the ways that undergraduates use resources when studying mathematics affords more meaningful results.

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