Approaches to Learning of Undergraduate Mathematicians

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The approaches to learning (ATLs) adopted by undergraduate students have been heavily researched, particularly since Marton and Säljö (1984) first wrote of a deep/surface approach dichotomy. Using this terminology, a study was conducted which aimed to research the ATLs of first-year undergraduate mathematicians, specifically relating to what these are and the ways in which the students themselves perceived them to have evolved over time. The results revealed that an overwhelming majority of undergraduate mathematicians at Oxford University adopt strategic ATLs, which they claimed were due to the nature of university study. It was established that it was in fact the nature of their specific course that resulted in this approach, as the nature of the new mathematics being studied, assessment demands and question formats in their department were contributing factors. In this article, I shall detail the findings of the quantitative research conducted using the ASSIST (Tait, Entwistle and McCune 1998) questionnaire.

Keywords: undergraduate, approach to learning

Approaches to learning

Approaches to learning are defined by Diseth and Martinsen to be the "individual differences in intentions and motives when facing a learning situation, and the utilisation of corresponding strategies" (2003, 195). The most common distinction which has been made in the literature is that between a deep and a surface ATL. A crude distinction could be made as follows:

Approach	Deep	Surface
Intention	Understanding	Memorisation
Strategy	Seeking comprehension	Rote learning

Table 1 – Distinction between deep and surface ATLs.

Deep approaches are characterised by learning strategies that focus on meaning, directed towards understanding by critically relating new ideas to previous knowledge and experience (Ramsden 1983). In mathematics, this should see the learner making connections between particular mathematical topics and methods and being aware of relationships between them in terms of their roots and their uses. Conversely, surface approaches focus on memorising information without considering its implications in relation to other knowledge (Trigwell and Prosser 1991). Such an approach has the potential to jeopardise success if what is learnt by rote is forgotten or cannot be adapted for use in solving unfamiliar, non-standard questions (Novak 1978) because the concept loses any sense of meaning.

It should be noted, however, that whilst a deep ATL is perhaps more desirable, it does not mean that it is always the most successful approach for every student

(Lonka, Olkinuora and Mäkinen 2004). Furthermore, the memorisation techniques characteristic of a surface approach may be implemented as techniques for a deep approach (Entwistle 1997). In mathematics, this may involve the rote memorisation of a definition in order to be able to fully understand subsequent reasoning or the application of a theorem or procedure.

The notion of a deep and surface ATL was written about at a time when various other dichotomies were mooted. For example, Ausubel (1963) contrasted meaningful and rote learning, Pask and Scott (1972) compared holists and serialists, and Skemp (1976) famously wrote of an instrumental versus a relational understanding.

However, it seemed that for the purposes of this study, these dichotomies lacked a certain something. Specifically, they lack an awareness of appreciation of how a student may adopt approaches and methods synonymous with both the deep and surface approaches in order to achieve the best academic outcome. Those with a *strategic* approach to studying have been described as using this combination based on "a competitive form of motivation… combined with vocational motivation within an achieving motivation" (Entwistle and Tait 1990, 171). Hence, it has been asserted that one may be both a deep and strategic learner or a surface and strategic learner but with deep and surface being mutually exclusive because "it is not possible to focus and not to focus on meaning at the same time (Diseth and Martinsen 2003, 196). Those with strategic ATLs are very organised and manage their time in order to achieve as highly as possible, playing "the assessment game" (Entwistle, Hanley and Ratcliffe 1979, 366). Consequently, it has been claimed that such an approach may be prompted by the demands of academic institutions (Biggs 1978).

Various correlates have been found between ATLs and contextual factors. It is possible to group these into one of four categories:

1. **Personality**: From analysing quantitative data, Diseth (2003) suggested that unstable extroverts have a greater propensity towards adopting what may be considered to be inappropriate study methods than their stable introvert counterparts. Students with surface approaches have been found to have lower self-concepts as learners, with those who have an inclination towards deep approaches tending to be more confident with a greater self-motivation to learn (Dart et al. 1999).
2. **Teaching**: It appears from the literature that the relationship between ATLs and pedagogy is reactive, with each influencing the other. A preference for particular approaches results in students preferring certain courses, teaching styles and assessment methods (Entwistle and Tait 1990; Trigwell and Prosser 1991). Furthermore, students have been found to adapt their ATL to suit the pedagogy and teaching on offer (Eley 1992).
3. **Assessment**: Students have also been found to make adaptations according to assessment demands, with a perceived excessive workload causing students to regress to surface approaches (Ramsden 1983; Trigwell and Prosser 1991).
4. **Attainment**: A deep ATL has been found to result in higher attainment and the converse with surface approaches, with positive relationships between attainment and strategic approaches suggesting that they achieve their purpose in being a means towards good grades (Diseth and Martinsen 2003; Ramsden 1983).

Method and sample

The Approaches and Study Skills Inventory for Students (ASSIST) (Tait, Entwistle and McCune 1998) was used as a means of collecting quantitative data relating to students' ATLs. Unlike other options available, the ASSIST incorporates the inclusion of the strategic approach to studying into its questions, and has a wider theoretical base (Speth, Namuth and Lee 2007) with good reliability and validity (Entwistle, Tait and McCune 2000) and test-retest reliability (Richardson 1990).

It is a 52-item Likert scale, self-response questionnaire which asks respondents to show their level of agreement with particular statements regarding the way in which they learn. Each statement relates to only one of the three ATLs between which the ASSIST distinguishes – deep, surface and strategic.

105 first-year undergraduates from the University of Oxford Mathematical Institute completed the ASSIST in order to help to answer two research questions:

1. What ATLs do undergraduate mathematicians typically have?
2. Do any significant relationships exist between groups (e.g. gender, age)?

In addition to the standard questions asked by the ASSIST, a number of additional statements were made in order to further probe the situation for mathematics students, as the questionnaire is not subject-specific.

The sample comprised 46% of the cohort, with gender distribution and numbers on joint honours courses representative of the year group. Students were reached through direct contact in a lecture for a compulsory course where they were given paper copies of the questionnaire, as well as online in order to reach the students who were not present. It was thought that students who failed to attend the lecture may have displayed particular characteristics which may have skewed the results; specifically, students who failed to attend may have done so because they were struggling with the course, found its content too easy, were disorganised, or were disillusioned, for example. One could assert that any of these possibilities may result in a learner having a greater propensity towards a particular ATL.

Results

Analysis of the ASSIST revealed a strategic ATL to be the most commonly adopted by the participants, with 76% scoring most highly on this scale. This was followed by 16% scoring highest on the deep scale and 8% on surface.

Women scored significantly higher on the surface scale ($p<.05$) than their male counterparts. However, there was no significant difference in the number of students who scored highest on one particular scale. Furthermore, no significant differences were identified between course of study and approach.

The mathematics-specific supplementary statements yielded responses as follows:

Statement	[Strongly] Agree	Neither Agree Nor Disagree	[Strongly] Disagree	Sig.
Practising example questions is the best way to prepare for examinations.	81	12	7	-
I cannot do proofs on my own so I memorise and reproduce them.	3	28	33	p=.025 strategic
When constructing proofs, I try to find similar examples and edit those into a proof for the theorem in question.	88	9	3	p=.002 strategic

Table 2 – Results from mathematics-specific statements in the ASSIST.

Discussion

The results of this research appear to be rather encouraging in the sense that only 8% of participants displayed signs of primarily adopting surface ATLs. Average scores on each scale were 69.03 on strategic, 58.69 on deep and 45.94 on surface ATLs. These findings appear to be in line with Diseth and Martinsen's (2003) study which used a similarly-sized sample of psychology undergraduates. As here, the highest average score was on the strategic scale (M=70.59) and the lowest on the surface scale (M=41.18). Equally, a study by Speth, Namuth and Lee (2007) found strategic approaches to be the most commonly used. However, Ramsden (1983) found only slight differences in the average scores of students in science, social science and the arts, neglecting mathematics and its particular and unique challenges. Since very few studies have used the ASSIST in this capacity, so it is difficult to ascertain just how typical the responses collected here are of the greater undergraduate population, let alone undergraduate *mathematics* population as it has yet to be used on such a sample.

The only gender difference identified in this study was between average scores on the surface scale. Men averaged a score of 42.22 and women 50.60, consistent with other studies of this kind (Severiens and Ten Dam 1994). One may attribute this to women often requiring more external help and reassurance (Lotwick, Simon and Ward 1981), having poorer self-concept as learners (Dart et al. 1999) or their greater tendency to experience mathematics anxiety (Betz 1978). This is a concern since women aspire to a deeper understanding of mathematics than men (Solomon 2007). However, they have also exhibited signs of hiding failures in this area to avoid embarrassment (Solomon 2011), perhaps leaving them susceptible to adopting study approaches which permit this.

The additional mathematics-specific statements in the questionnaire revealed how memorisation might play a role in undergraduate mathematics. It has been widely suggested that rote learning and memorisation in undergraduate mathematics has a negative impact on attainment and understanding and, here, it can be see that this may be consistent with a strategic ATL. It is not necessarily that a student memorises and reproduces a proof because they cannot possibly do it another way; rather, they may choose this as the easiest means by which they may best answer a question demanding that they prove the Intermediate Value Theorem, for example.

Conclusion

Whilst much research in this area is based in the 1970s, it is still of interest in considering learning in higher education and may contribute towards shedding light on the undergraduate mathematics experience. The results of this study suggest that most first-year undergraduate mathematicians at Oxford University adopt strategic approaches to studying as defined by the ASSIST. The exact reasons behind this are a matter for further research, as is the question over whether they exhibit a marked change in their habits between studying A-level mathematics and undergraduate mathematics as the content of these two levels of study are often remarked as being markedly different and demanding of different skills and understanding.

The results of this study have limitations, as any research conducted on students at Oxford University may be considered atypical of the wider population – these students were subject to the highest entry requirements, with additional examinations and interviews to ensure that they were best-prepared for this level of study. However, such findings will surely still be of interest to educators at other institutions who are interested in the experiences of their students, the challenges which they face, and the means by which they overcome them, if at all. The questionnaire proved to be a useful instrument to make distinctions which were borne out in the mathematics-specific questions and provide a basis for further research questions about the relationship between ATLs, athe nature of the subject and the Oxford course.

More generally, it is possible that students adopt different ATLs with different types of mathematics. For example, more computational, applied courses have the potential to demand more surface ATLs than analysis, as the emphasis on understanding certain elements of the mathematics is different in each course. Therefore, there is room to wonder what mathematics students were mentally focussing on when choosing their responses on the Likert scale on the ASSIST.

Students of all backgrounds and abilities are afforded the opportunity to study independently at university, so it is important for all educators to be aware that there is a chance that they will have students who approach their learning in ways which may not be in the best interest of their intellectual development of understanding, even if they perform well in assessment. For us to enjoy the economic benefits that each cohort of graduating mathematicians has to offer, it is essential that those within it fully understand and appreciate what they have learnt and can put their skills and knowledge into practice.

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