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Shortcomings of the ‘Approaches to Learning’ Framework in the Context of Undergraduate Mathematics

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Shortcomings of the ‘Approaches to Learning’ Framework in the Context of Undergraduate Mathematics

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Abstract

Students’ approaches to learning are heavily researched in higher education and are of particular concern in the field of mathematics where many students have been found to struggle with the transition to university mathematics. This article outlines a mixed methods study which sought to describe undergraduate mathematicians’ approaches to learning using the deep-surface-strategic ‘trichotomy’ using the Approaches and Study Skills Inventory for Students with 414 mathematics students and semi-structured interviews with a subset of 13 at a leading British university. Analysis found that neither the ‘approaches to learning’ framework nor the inventory can effectively describe students’ study practices and conceal important elements of how students learn advanced mathematics for examinations. Therefore, it is important that educators do not try to oversimplify students’ methods using quantitative questionnaires but do seek to support those who would otherwise rely solely on memorisation as a means of passing high-stakes examinations.

Keywords: Mathematics, approaches to learning, transition, assessment



Carencias dentro del Marco de los “Métodos de Aprendizaje” en el Contexto de las Matemáticas a Nivel de Licenciatura

Ellie Darlington
Cambridge Assessment Admissions Testing

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Resumen

Las técnicas de aprendizaje utilizadas por estudiantes son objeto frecuente de investigación académica. Este artículo describe un estudio que utiliza un método mixto para describir las técnicas de aprendizaje de matemáticas utilizadas por universitarios. Se basa en la tricotomía *deep-surface-strategic* (aprendizaje en profundidad / superficial / estratégico), usando el cuestionario *Approaches and Study Skills Inventory for Students*. El cuestionario lo completaron 414 estudiantes de matemáticas y además se realizaron entrevistas semi-estructuradas con un subgrupo de 13 estudiantes en una en una destacada universidad británica. El análisis de los resultados reveló que ni la configuración *deep-surface-strategic* ni el cuestionario son descriptores eficaces de las técnicas utilizadas por los estudiantes. Tienden a ocultar elementos importantes de cómo aprenden matemáticas avanzadas para aprobar exámenes. Por lo tanto, es importante que los educadores no intenten simplificar los métodos de los estudiantes vía cuestionarios cuantitativos, sino que deben procurar apoyar a aquellos estudiantes que de otro modo se limitarían a memorizar como medio de pasar exámenes importantes.

Palabras clave: Matemáticas, métodos de aprendizaje, transición, evaluación

The seminal work on defining ‘approaches to learning’ was done by Marton and Säljö (1984), who distinguished between ‘deep’ and ‘surface’ approaches to learning. Research in this area is over 30 years old, and definitions and ideas have been suggested and refined over the years. In addition, a ‘strategic’ approach emerged during the evolution of the approaches to learning (ATL) framework.

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). A student with a deep approach seeks to understand a concept and, whilst they may remember it as a consequence, “this is viewed as an almost unintentional by-product” (Kember, 1996, p. 343). Furthermore, a student who learns with an *intention* to understand may not always *achieve* a deep understanding if material is too difficult (Entwistle, Hanley, & Hounsell, 1979). For example, one may need to memorise mathematical definitions in order to effectively make use of them in order to understand or prove a mathematical theorem. Therefore, memorisation can act as “a necessary precursor to understanding, and for other purposes it is a way of reinforcing understanding” (Entwistle, 1997, p. 216).

Conversely, surface approaches focus on memorising without reflecting on the task or thinking about its implications in relation to other knowledge (Trigwell & Prosser, 1991). Such approaches jeopardise success in mathematics if what is learnt by rote is forgotten or cannot be adapted to be used in problem-solving (Novak, 1978) because it is detached from mathematical meaning. If a mathematics student with a surface approach only remembers fragments of information in the short-term, they may “memory dump” (Anderson, Austin, Barnard, & Jagger, 1998, p. 417) what they have learned, thus preventing the construction of solid foundations from which to build the understanding of new concepts. However, it is not necessarily the case that a student with a surface approach will not achieve as high grades as a student with a deep approach. If a student with a deep approach “who is not particularly competent [will] perform less well than a student with a ‘highly polished’ surface approach” (Cuthbert, 2005, p. 244).

A strategic approach marries aspects of the deep and surface ATLs, with an achieving motivation aimed at playing “the assessment game” (Entwistle et al., 1979, p. 366). Reid, Duvall, and Evans (2007) describe a strategic approach as involving “organised studying and good time management [...]

driven by the desire for high achievement” (p. 754). Hence, this approach could be influenced by the demands of assessment, meaning that many have commented that strategic approaches to learning – and, to a lesser extent, surface ATLs – tend to be instigated by institutional demands (Lindblom-Ylänne & Lonka, 2000). Those who commonly utilise strategic ATLs tend to be conscientious (Heinström, 2000) and perform well in assessment (e.g. Diseth, 2003).

Theoretical Framework

Positive links between achievement in assessment have not only been made with strategic approaches, but also deep approaches, and negative links with surface approaches (e.g. Marton & Säljö, 1984; Reid et al., 2007). Hence, it would seem important to facilitate the development of more productive ATLs in students, particularly in a subject such as mathematics which takes on a very different, much more abstract form at university to at school (Alcock, 2013; Tall, 1991).

Pedagogy also differs at undergraduate level, with most mathematics courses being taught in lectures, occasionally with supplementary tutorials depending on the university. Pedagogy has been found to influence students’ ATLs (Prosser & Trigwell, 1999), with Trigwell and Prosser (1991) describing ATLs as “a function of both the student and the context” (p. 254). Indeed, assessment has been found to influence students’ ATLs. For example, open-book examinations can stimulate a deep approach, and closed-book examinations a surface approach (Heijne-Penninga, Kuks, Hofman, & Cohen-Schotanus, 2008). Overbearing workloads, in particular, have been associated with students adopting surface ATLs (e.g. Lizzio, Wilson, & Simons, 2002).

Furthermore, some contextual dependence (Cassidy, 2004) and influence on students’ approaches to learning mean that Reid et al. (2007) caution that deep and surface approaches “are not mutually exclusive” (p. 754) and so learners can switch between them (Byrne, Flood, & Willis, 2009). A students’ ATL may also differ between subjects. At the secondary level, a student may adopt a different approach for learning a Science, but quite a different one to History. Mathematics may be no different, with a student perhaps taking different approaches to learning Analysis to Algebra.

However, the ‘approaches to learning’ framework has been subjected to a lot of criticism (e.g. Haggis, 2003, 2009; Malcolm & Zukas, 2001; Webb, 1997) based on both the concept of an ATL and whether it could be ‘measured’, and regarding what could and should be ‘done’ with information regarding a learner’s ATL. Richardson (2000) describes approaches to learning as a cliché in educational research, with the fervent use of ATLs in higher education research meaning that “there has been an inevitable degree of conceptual slippage” (Marshall & Case, 2005, p. 258). Given the research outlined above, this is problematic given one cannot and certainly should not characterise a student as either a surface or a deep learner (Lucas & Mladenovic, 2004).

Bean (1982) describes the theory as “a simplified version of reality, in which the minutiae and detail are stripped away, leaving what are assumed to be important factors” (p. 18). Furthermore, much research regarding ATLs in higher education does not take into account the specific nature of the subject being studied by the participants. In fact, there is also research which groups mathematics with other subjects such as Physics and Engineering, *as if* they present the same challenges to students and therefore would have the same influences on ATLs. This is not the case and, as such, interpretations of such research for the mathematics-specific context must be made with caution.

Indeed, in mathematics, surface approaches have even been found to result in good learning outcomes. Research by Kember (2000) found that some high-achieving pupils used memorisation as a route to understanding (although this was conducted in Asia and so cultural differences should be considered). At the undergraduate level, mathematics assessment challenges students in a number of ways, and examinations assess students’ memorisation of mathematical definitions, as well as their ability to use such definitions to draw mathematical conclusions and prove theorems. This is a significant shift from secondary-level mathematics assessment, which predominantly requires students to perform routine procedures and calculations and hence does not rely on precise factual recall (Darlington, 2014).

ASSIST

A further criticism of the ‘approaches to learning’ framework concerns the use of self-report inventories which aim to establish a learner’s predominant

ATL. Case and Marshall (2004) claim that these do not “adequately address contextual subtleties [as] there are contextual nuances and unexpected findings that cannot be captured by this method” (p. 260). Hence, combining the use of an instrument such as Tait et al.’s (1998) Approaches and Study Skills Inventory for Students (ASSIST) with qualitative work is required to contextualise its quantitative data.

The ASSIST is a multiple choice, Likert scale questionnaire which was developed over the course of nearly twenty years as a means of quantifying and categorising student ATLs. It was specifically developed for use with tertiary students, unlike many other scales described in the educational research literature and is a product of revisions to the Approaches to Studying Inventory (Entwistle & Ramsden, 1993).

Such testing and revisions increase its reliability and validity, which have been found to be good (Byrne, Flood, & Willis, 2004; Reid, Wood, Smith, & Petocz, 2005), as has its test-retest reliability (Richardson, 1990) and factor structure (McCune & Entwistle, 2000). Furthermore, an analysis of instruments which measure ATLs by Coffield, Moseley, Hall, and Ecclestone (2004) described the ASSIST as “a sound basis for discussing effective and ineffective strategies for learning and for diagnosing students’ existing approaches” (p. 56).

However, the ASSIST has not been used in mathematics education research before, though has been used extensively with students of other subject areas which require mathematical understanding such as accounting (Byrne et al., 2004), science (Reid et al., 2007), geography (Maguire, Evans, & Dyas, 2001) and social science (Diseth & Martinesen, 2003).

Methodology

Objectives

The differences between secondary and tertiary mathematics are well-documented, though students’ expectations about the nature of mathematics often do not match their experiences at university (Crawford, Gordon, Nicholas, & Prosser, 1998) and these differences have been found to result in students becoming disaffected (Daskalogianni & Simpson, 2002) or adopting rote memorisation practices in order to pass examinations (Anderson et al., 1998). To be able to begin to support students in the

transition between school and university mathematics is important, and their approaches to its learning are an important component of this. Hence, this study sought to identify and explore undergraduate mathematicians ATLs in order to gain an insight into the studying and learning habits of these students.

Methods

Two methods of data collection were used for this study. Quantitative data were collected through distributing the ASSIST to current undergraduate mathematicians at a leading British university, and this was supplemented by qualitative data from student interviews. As well as using each method to describe students' ATLs, this mixed methods approach acted as a means of establishing whether and how the ASSIST data were reflected in students' qualitative descriptions of their approaches.

All undergraduate mathematicians were contacted via their departmental mailing list with an outline of the research and a link to an online form of the ASSIST, as well as being invited to participate in further interviews.

Quantitative Data

Data from the ASSIST were collected twice, in two "sweeps." To distinguish between them:

- Sweep 1: Data collected from first-year students only at the beginning of their first term at university.
- Sweep 2: Data collected from students across all year-groups at the end of the academic year. First-years who participated in sweep 1 were encouraged to do so again in sweep 2.

ASSIST data were collected from students across all of the four year-groups in order to contrast responses by year group. Furthermore, repetitious participation of first-year students in sweeps 1 and 2 facilitated comparison of ATLs upon arrival at university, before they had to take any examinations or do any assignments, and their ATLs after having taken their first-year examinations.

Participants' responses to the 52 items from 1='strongly disagree' to 5='agree' was summed for items aligned with each of deep, strategic and surface ATLs. Examples of the items on the ASSIST are:

- Deep approach scale

- I usually set out to understand for myself the meaning of what we have to learn
- Often, I find myself questioning things I hear in lectures or read in books
- Strategic approach scale
 - I think I’m quite systematic and organised when it comes to revising for exams
 - When working on an assignment, I’m keeping in mind how best to impress the marker
- Surface approach scale
 - There’s not much of the work here that I find interesting or relevant
 - I concentrate on learning just those bits of information I have to know to pass

Qualitative Data

Thirteen students volunteered to participate in qualitative interviews after completing the ASSIST. All year-groups and genders were represented (see Table 1).

Table 1
Interview participants’ background characteristics

| Year | Highest ATL Scale | | | Gender | | Total |
|-------|-------------------|-----------|---------|--------|--------|-------|
| | Deep | Strategic | Surface | Male | Female | |
| 1 | 3 | 1 | 0 | 3 | 1 | 4 |
| 2 | 1 | 1 | 1 | 1 | 2 | 3 |
| 3 | 1 | 3 | 0 | 1 | 3 | 4 |
| 4 | 1 | 1 | 0 | 1 | 1 | 2 |
| Total | 6 | 6 | 1 | 6 | 7 | 13 |

Interviews were semi-structured with the aim of questioning participants on topics relating to their experiences of, and approaches to, learning mathematics at school and university. Four main areas were covered:

1. Their experience of school mathematics

2. Their preparation for entry to university
3. Their current (and past, if a student beyond the first year) experiences of mathematics and pedagogy; and
4. Any changes experienced or anticipated in their mathematics studying and learning.

Participants were briefed before the interview regarding the nature of the research, topics to be covered and issues relating to confidentiality. Transcripts were sent to interviewees after the interviews for them to check and verify.

After transcription, the interview data was subjected to thematic analysis. This appeared to be the most appropriate method of analysis given the interviews themselves were undertaken in order to explore the phenomenon that is the undergraduate mathematics learning experience. Emerging patterns were identified in the transcripts which were used to organise and describe the students' comments in rich detail using guidelines set out by Braun and Clarke (2006) to provide a consistent, reliable framework.

For the purposes of this article, participants' comments relating to their ATLS will be used to provide evidence regarding whether the ASSIST and ATL framework apply to the undergraduate mathematics context. Fuller analysis using the thematic analysis of the interviews is available in Darlington (2013).

Results

Data from ASSIST

Approximately 65% of the first-year cohort completed the ASSIST in sweep 1, and over 40% of all four year-groups in sweep 2. The sample was reasonably representative of the entire undergraduate cohort at the participating university (see Table 2).

Table 2
Sample for ASSIST

| | Sweep 1 % of 176 | Sweep 2 % of 238 | Proportion of Cohort (%) |
|----------------------------------|---------------------|---------------------|-----------------------------|
| Gender | | | |
| Male | 67.0 | 65.8 | 71.1 |
| Female | 33.0 | 34.2 | 28.9 |
| Course | | | |
| Mathematics | 84.7 | 88.2 | 72.3 |
| Mathematics + other ¹ | 15.3 | 11.8 | 27.7 |
| Year | | | |
| 1 st | 100.0 | 30.3 | 26.4 |
| 2 nd | 0.0 | 28.9 | 27.0 |
| 3 rd | 0.0 | 21.9 | 26.1 |
| 4 th | 0.0 | 19.0 | 20.5 |
| Qualifications | | | |
| A-levels ² | 77.3 | 86.8 | 74.4 |
| Other | 22.7 | 13.1 | 25.6 |

Participants' median³ scores varied on the deep ATL between sweeps 1 (first year only) and 2 (all years), but those of the surface and strategic scales were reasonably consistent (see Table 3).

Table 3
Average scores on deep, strategic and surface scales in each sweep

| ATL | Sweep | N | Median | Minimum | Maximum |
|-----------|-------|-----|--------|---------|---------|
| Deep | 1 | 176 | 48 | 31 | 62 |
| | 2 | 228 | 61 | 16 | 77 |
| Strategic | 1 | 176 | 71 | 34 | 89 |
| | 2 | 228 | 71 | 29 | 95 |
| Surface | 1 | 176 | 49 | 20 | 67 |
| | 2 | 228 | 45 | 20 | 75 |

The data for sweep 2 are depicted in the box and whisker plots of Figure 1. Students generally scored highest on the strategic scale and lowest on the surface scale, with overlapping ranges of scores demonstrating why it is inappropriate to describe someone as a deep/surface/strategic learner purely based on the highest score of the subscales. A number of participants' scores on two or more subscales were either equal or very close.

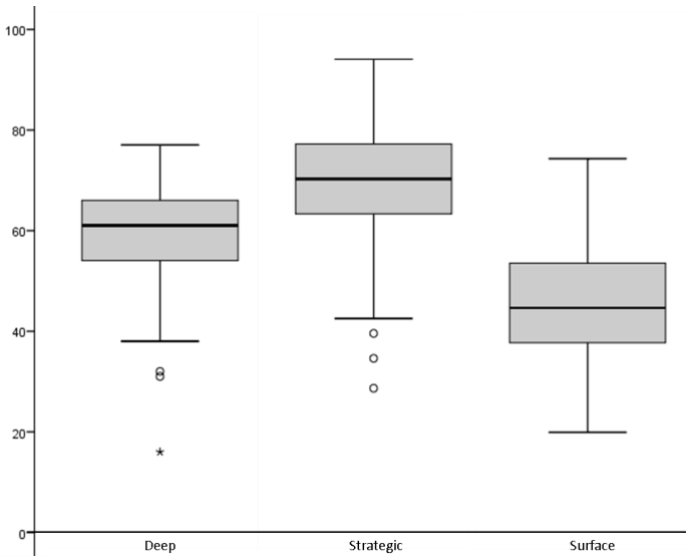


Figure 1. Boxplot of participants' scores on each scale in sweep 2 (N=238)

Whilst some of the literature suggests that it is possible for students' ATLs to 'change' in response to changes in environment, pedagogy and assessment, the data here contradicts that. No statistically significant differences were identified between first-years' responses in sweeps 1 and 2.

Student Interviews

In order to find out more about students' approaches to learning mathematics at both school and university, qualitative interviews with a self-selecting sample of 13 current undergraduates (see Table 1) were conducted.

Quantitative analysis from the ASSIST suggested that students generally took a strategic ATL, with fewer using surface ATLs.

Descriptions given by the students of their revision practices appeared to be shaped by the nature of their examinations (see earlier), particularly because they identified patterns in examination questions posed over the years. As particular question types were more common than others, students approached revision in a way which prioritised topics and question types which they believed to be likely:

The structure of the exams hasn't changed [...] Some courses will have very similar questions year-to-year. (Isaac⁴)

This practice is consistent with a strategic ATL, though the students also described the basis of their revision practices as being based on consolidating understanding, and even making efforts to *begin* to understand lecture material. This was often the first step involved in students' revision processes, as they strove to understand the mathematical concepts in order that they would later be able to answer examination questions on them.

Consistent with a deep ATL, this was in stark contrast to their school experiences, where they did not struggle to understand what they were taught or what they were revising:

I try and understand what I'm doing by reading through everything carefully, but I didn't really need to even try to do that at school because it just... happened. (Malcolm⁵)

The revision practices that the participants described themselves as engaging in at school are very different to those which they described at university. At school, they described no effort to *learn* mathematics, but to *practise* it in order to pass examinations. Also consistent in a strategic ATL, students described themselves or their peers as engaging in revision methods at university which involved revisiting lecture material which they would “have to read a million times to get your head around” (Isaac) before engaging in some active memorisation and practising of past questions. Unlike at school, where past question practice formed the largest part of revision, completing past papers was secondary to consolidating understanding and memorisation at university:

Uni maths, I spent most of my revision trying to understand it, which sadly doesn't leave much time for actually getting used to questions. (Sabrina⁶)

Three distinct purposes of memorisation were described by the students, the first of which being justified by all as the only way to be able to understand mathematical concepts, to be able to answer in-depth questions, and because it was necessary in order to answer questions which required them to recall mathematical facts precisely. According to Christina⁷, this is the first time that she had “to remember stuff” for a mathematics examination.

You need to memorise so-and-so’s theorem and so-and-so’s lemma because a lot of questions in the exams ask you to state those. (Ryans)

Sometimes I just had to rewrite the answers [to assignment questions] again and again until I could remember. (Brian⁹)

Brian’s attempt to memorise the answers to past papers and problem sheets in anticipation of these questions appearing in his examinations is consistent with a surface ATL. He described himself as memorising facts without understanding them in the hope that he could reproduce them in examinations. This can sometimes be successful.

I can tell you it and prove to you that I know the proof. But I can’t prove to you that I understand the proof if you just get me to write the proof. (Isaac)

Memorisation of proofs was something not only reported by Brian, however, as many participants described it as being necessary because of their complexity, and because they believed that they were not capable of writing the proof for themselves using mathematical principles.

I also spend more time memorising bookwork, again probably because I don’t have the conceptual understanding to be able to derive it in the exam. (Juliette¹⁰)

However, whilst students may initially employ memorisation as a means of answering questions which they expect in examinations without actually having a thorough understanding of the mathematical concepts and/or an ability to prove a mathematical truth, some participants reported that they used memorisation as a route to understanding:

Regurgitating the maths each time helps me deepen my understanding of it because I think about the maths each time I read it and write it down. (Priya¹¹)

This is confirmed by Kember (1996), Watkins and Biggs (1996) and Entwistle (1997), who states that it is possible for memorisation to act as “a necessary precursor to understanding, and for other purposes it is a way of

reinforcing understanding” (p. 216). However, knowing a definition precisely is very important in mathematics in that

[A] mathematical definition [has] the property that everything satisfying it belongs to the corresponding category and that everything belonging to the category satisfies the definition. Deductions made from the definitions provide us with theorems that hold for every member of the category and, in the context of the problems provided by those lecturing to first year undergraduates, any theorem a student is asked to prove can be deduced from the definitions. (Alcock & Simpson, 2002, p. 28)

Therefore, it could be argued that active memorisation of mathematical facts is a necessary precursor for being able to do any mathematics. The distinction between its use in strategic and surface ATLs is that the understanding may come for those with strategic ATLs but not for those with surface ATLs.

The comments made by participants in the interviews uncovered different activities in students’ ATLs which could both be considered to be strategic ATLs. At secondary levels, a strategic ATL appears to be characterised by practise of past papers, whereas at university it is characterised by combining the active memorisation of mathematical facts with consolidation of understanding of mathematical concepts in order to marry these two in order to write mathematical proofs.

Furthermore, the active memorisation used by students in this way could take different forms characteristic with two different ATLs. A student adopting a deep ATL may use active memorisation of mathematical definitions in order to manipulate them to produce proofs. However, a student with a strategic ATL may actively memorise these definitions, as well as proofs to well-known theorems in order to be able to reproduce them in examinations. Therefore, memorisation does not necessarily have to form part of a strategic or surface ATL in the context of mathematics.

Discussion

Whilst the nature of questions posed at A- and undergraduate-level, and the ATLs reported by students in the interviews, are very different, students’ scores on the deep/surface/strategic scales on the ASSIST did not highlight these differences. Students appeared to work strategically at both levels –

preparing for A-level examinations through exhaustive practice of similar questions and revising for undergraduate examinations by combining efforts to understand with varying degrees of memorisation driven by their mathematical understanding. At school, pupils memorise procedures and repeat them in examinations, whereas at university students may choose to memorise facts and/or someone else's mathematics.

The role of assessment in students' ATLs is clear in the case of upper-secondary and tertiary mathematics, specifically in terms of past examination papers and the nature of the questions posed in them. At A-level, the majority of questions require students to perform a rehearsed procedure; hence, practice of these questions would be an effective means of preparing for an examination. At university-level, many questions require students to reproduce mathematical facts or may be answered through reproducing elements of their lecture notes. Additionally, university examinations also require students to write unseen proofs, which cannot be done through memorisation. It is here where students who adopt surface ATLs may falter, and the motivation for memorisation distinguishes two types of approaches within strategic ATLs: those who memorise definitions and facts alone, and those who memorise past examination and assignment answers in case similar or identical questions appear in their examination.

Therefore, whilst the ASSIST data could be interpreted in the context of undergraduate mathematics and examples of the form that each may take in this context given, these examples highlight the shortcomings of the ATL framework in tertiary mathematics. Diseth and Martinesen (2003) describe rote learning as a "potentially safe strategy" (p. 204) supported by the large proportion of undergraduate examination questions which can be answered purely through memorisation (Darlington, 2014). A deep ATL does not necessarily need to be viewed as the 'best' or 'most appropriate' ATL in undergraduate mathematics – if a student cannot remember specific aspects of a mathematical definition then they will not be able to use it effectively in proofs which require its use and interpretation.

Having undergraduate mathematicians complete the ASSIST in order to investigate their ATLs would therefore be broadly unhelpful as the quantitative conclusions can point towards a number of different means of learning. What is important is that students are steered away from adopting surface ATLs as a consequence of failing to understand the mathematics that they are learning, and from over-relying on memorisation as part of a surface

approach. If universities are to tackle the high drop-out rates in undergraduate mathematics (Higher Education Statistics Agency, 2014) then it is essential that those academics who have close contact with students through small-group teaching take an interest in their students’ studying approaches so any students who struggle may be supported.

Notes

- 1 Joint honours courses were available with Statistics, Computer Science or Philosophy.
- 2 A-levels are post-compulsory qualifications taken by students at age 18 in England and Wales. Students typically take three or four subjects from a wide range, and mathematics is currently the most popular A-level subject.
- 3 The median is reported here rather than the mean, because it would not be accurate to suggest that participants considered the intervals between ‘agree’ and ‘somewhat agree’ to be equal to those between ‘somewhat disagree’ and ‘neither agree nor disagree’.
- 4 Third year mathematics student who scored highest on the strategic scale.
- 5 Fourth year mathematics student who scored highest on the strategic scale.
- 6 Second year mathematics student who scored highest on the deep scale.
- 7 Fourth year mathematics and philosophy student who scored highest on the deep scale.
- 8 First year mathematics student who scored highest on the deep scale (sweep 2).
- 9 Second year mathematics student who scored highest on the surface scale.
- 10 Second year mathematics student who scored highest on the strategic scale.
- 11 First year mathematics and statistics student who scored highest on the deep scale (sweep 2).

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