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Indications of Knowledge Retention in the Transition to Higher Education

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First year undergraduate courses in higher education tend to be designed based on assumptions of students' prior knowledge. Almost 600 undergraduates at five UK universities, studying biological sciences, were given an MCQ test in their first week at university, based on biology A-level (pre-university examination) core criteria. Results demonstrated low-level retention of basic concepts. There was variation between subject area and examination board and an inverse correlation between MCQ score and time since taking A-levels. By discovering what students remember from their pre-university learning, undergraduate courses can be designed to be more student-focused and so develop a deeper-learning teaching strategy. The results also suggest that, if A-levels are to be redesigned to enhance their impact for students entering higher education, creating programmes which encourage retention of key concepts should be a key factor to consider.

Keywords: *A-level; Retention; Facility; Deep learning; Pre-university; Examination; Knowledge transfer; Transition*

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Introduction

Universities expect their students to arrive with subject knowledge from the pre-university courses they have studied. As a consequence, the design of first year courses commonly incorporates assumptions about how much knowledge students retain from their previous education. Many undergraduates in the UK will have studied A-levels as preparation for university, and these courses are in part designed for this purpose, as are baccalaureates, the Cambridge pre-U diploma, access-to-HE courses and other alternatives to A-levels. However, Fee, Greenan, and Wall (2009) argue that universities increasingly need to teach academic skills not addressed by current A-levels, such as academic writing. They studied business and accounting students, investigating differences in the ways in which subjects were studied and assessed at school and university, and identified a significant skills gap. Jones (2011) explores how students' skills are well below expected levels for biological science undergraduates and examines ways in which this skills gap might be addressed through additional pre-university training in schools. Fee, Greenan, and Wall (2009) argue that the skills gap results, in part, from the pressure of league tables that have driven UK schools to 'teach to the test' in order to increase exam scores. Secondary education has become increasingly politicised, which involves greater emphasis on testing and results of tests, target setting and performance (Lumsden, McBryde-Wilding, and Rose 2010).

Where Fee, Greenan, and Wall (2009) discuss the skills gap between school and university, many studies test the retention of knowledge, for example Vadivelu (2008). However, the skills Fee et al. refer to, and the acquisition of knowledge, are linked. Students acquire knowledge through their experiences of the world. The constructivist model of learning suggests that students learn by effectively internalising information, which becomes knowledge to them. So knowledge is constructed individually by each student, as opposed to transmission of knowledge from teacher to student. The acquisition of knowledge is intricately linked to the skills the students have and the manner in which teachers help students use their skills to build up their knowledge (Applefield, Huber, and Moallem 2000). A teacher can impart knowledge, but for a student to gain knowledge they must construct their own knowledge base which will be derived from their own experience (Al-Huneidi and Schreurs 2013). In this way, knowledge, skills and independent study are all intricately linked and dependent on each other.

Those teaching medical courses are particularly concerned about basic knowledge retention by their students, and studies have shown varying levels in this regard. Vadivelu (2008) found that in assessment, students did show an ability to remember basic information, but when asked to apply this information they performed less well. In a review of the literature, Custers (2010) concluded that assumptions that most of the basic medical knowledge is lost are actually not supported, and that the figure is probably around 50% retention of basic information approximately two years after the information was acquired and assessed. However, a study of practising doctors not long after their leaving medical school revealed levels of approximately 40% retention of basic knowledge (Custers and Cate 2011). Landauer and Ainslie (1975) tested students for retention of basic information several times after a technical course. After six weeks test scores rose, but they dropped significantly one year after the course. They suggest that there is a problem when providing students with information if they then do not need that information for more than a year.

Concern about knowledge retention is not a recent consideration. Greene (1931) tested zoology, chemistry and psychology students for retention of knowledge through their high school courses in the US. Between their exams in June and the following October, students were found to have lost about half of the information they had correctly remembered in June. Differences were found between disciplines; Greene suggests this may be down to the different ways they were taught, but could offer no direct comparison of teaching methods which would have substantiated this suggestion. More recent studies have made more specific claims about reasons for low retention rates. Mazloomi et al. (2005) found a difference in retention rates between subjects relating to dentistry, and suggested low retention rates of information could be linked to students' poor study skills. There may also be a link between how a subject is taught, where teaching might be more to do with helping students think about a subject and enjoy learning, rather than filling a lecture full of information to be learned (DiCarlo 2009). DiCarlo argues that there is too much emphasis on content at the expense of deep understanding and the development of life-long skills. However, a report on the teaching of A-level material in a content-vs-context approach showed how a context approach can provide meaning for the students but does not necessarily result in higher grades (Braund et al. 2013). In contrast to Landauer and Ainslie (1975), Roediger and Karpicke (2006) observed rapid loss of retained knowledge, with as much as a 50% drop in one week. These authors noted that frequent testing and re-testing of content may lead to a significantly higher retention level than merely re-reading the material. They only assessed retention over a one-week period, however, which is considerably shorter than the gap between A-levels and the start of an undergraduate degree. During the three-month gap between completing A-levels and beginning a degree, it is unlikely that students will be reinforcing information by frequent self-testing.

Virtanen and Lindblom-Ylänne (2010) looked at how students' and teachers' conceptions of teaching differed. Teachers who thought of teaching as transmitting knowledge tended to adopt a teacher-centred approach. In this scenario, teaching tended to be content-heavy and resulted in surface learning. Furthermore, they found that students did not recognise their own role in the learning process, seeing learning as a teacher-centred process. This is in direct contrast to the idea of constructivism, where students' knowledge is built up through their own experiences (Applefield, Huber, and Moallem 2000), and so requiring their own skills and independent learning. This approach to knowledge construction is often referred-to as 'deep' learning (Entwhistle and Peterson 2004). Deep learning, by gaining an overall appreciation of a subject ('seeking meaning') rather than learning facts and strategies for a test, has long been recognised as the most powerful learning approach (Biggs and Tang 2011). In contrast, surface learning (which focuses on factual recall rather than developing understanding, 'reproducing content') is limited in breadth, potency and duration (Entwhistle and Peterson 2004). Chin and Brown (2000) showed that deep learning approaches in school children facilitated them to be more spontaneous and inquiring, providing more complex answers to questions. Such individuals are more likely to be effective as independent learners.

Lumsden, McBryde-Wilding, and Rose (2010) discuss the role of the university in developing students who are independent learners and have a deep knowledge of their subject. There is now a significant body of literature on the transition to university in terms of preparedness in relation to skills and differences in learning – see for example Jones (2011) and Jansen and van der Meer (2012). However, these studies do not address the basic conceptual understanding of the students, which is important because first year university courses are designed based on assumptions about this. The current study was run as a pilot with five UK universities, testing first year bioscience students in their first week at university, to assess their knowledge of basic biological concepts. Throughout this paper the term 'lecturer' is applied to anyone teaching in higher education, while the term 'teacher' refers to those teaching in schools or other pre-university environments.

Materials and methods

First year undergraduate bioscience students (n = 594) from five research-intensive UK universities (three Russell Group, two 1994 Group (since disbanded)) were tested at the start of the academic year, prior to any main subject teaching, for their ability to remember key pieces of knowledge from their pre-university teaching. Students were informed of the existence of the test prior to sitting, but not of its content or subject focus. It was therefore unlikely that students would have revised for the test before taking it. All participating students were given 50 minutes to answer 38 multiple-choice questions (MCQs), where they were given four possible answers, as well as the option to choose 'don't know'. Students were provided with a 'don't know' option because it was important to help remove the guessing element from MCQs: this would have had no value to the current study. The questions were selected by the authors from a variety of Cambridge Assessment A and AS-level papers from between 1993 and 2011. Questions were selected to ensure a range of challenge (following the cognitive model procedure detailed by Crisp and Grayson 2012), as well as broad coverage of A-level core syllabi. Most examination boards do not currently include MCQs in their A-level papers, so this provided most students with a different style of questioning to that which they experienced pre-university, and so provided a relatively similar – and therefore fair – experience for all participants. Questions were split into four categories: cells, genetics, biochemistry and physiology, each of which are core to all A-level syllabi. The 'item facility' for each question (the proportion of students answering the question correctly) was calculated to compare individual questions or subject areas against other demographics. The students were asked their gender, age, A-level biology (or equivalent) exam board, the grade they achieved and the year they took the examination. Examination boards here are designated with letters W to Z; there were also categories for 'other' and 'don't know'.

A group of students (n = 97) from one of the participating universities who had taken the MCQ test at the beginning of the academic year were asked to rank the questions in terms of demand. They were given 20 seconds to look at each question and decide where to place it on a scale of 1 to 10 (where 1 = easy). It is important to note the difference between 'difficulty' and 'demand'. *Difficulty* is the empirical measurement (i.e. captured by the item facility statistics) after a test has been taken, while *demand* is to do with perception, as related to the underpinning content being tested or the nature of the task, for example, and is more subjective (Crisp and Grayson 2012).

The protocols were approved by the local ethical committees of the participating universities. The students were notified in advance of the project and informed that participation was entirely voluntary. All answer papers were anonymous. Data were combined for all participating universities and *t*-tests, correlations and analysis of variance were applied where appropriate.

Results

Of the 594 students participating in this study, 40.2% were male and 58.7% female; 1% did not say. In terms of age, 0.5% were under 18, 92.3% were between 18 and 20 and 4.5% were older than 20. These gender and age distributions reflect the overall cohorts of the participating universities. Students were asked which examination board they studied with for A-level biology; the results of this distribution are not shown because the results could identify the boards, since they reflected national patterns.

The majority of students gained an A grade in A-level biology (Table 1) and there was a small but significant correlation (Pearson correlation coefficient = 0.230; p = 0.000 one-tailed) between A-level grade and mean test score when combining all exam boards. The mean score (± SD) for the test across all students was 15.75 ± 5.15, equivalent to 41.4%, ranging from 0/38 to 30/38. Male students scored significantly higher (16.4 relative to 15.4, p = 0.017) than female students.

Variation between examination boards was explored (Table 2 and Figure 1). There was very little difference in A-level grade distribution between the boards, but there were differences between examination boards in the mean test scores (one-way ANOVA $p <$ 0.005). Two of the boards (W and Y) show correlations (Pearson) between A-level grades and test score (Table 2). The questions were split into four subject categories and the facility (proportion of students getting the questions right) was investigated with respect to each exam board (Figure 1). There was variation between examination boards in terms of the number of questions in each subject group that students answered correctly, although examination board W had the least variation between question subjects.

The proportion of students answering each question correctly ('item facility') ranged from 0.05 to 0.88. During the test design, the questions had been ranked by subject

Table 1. Comparison of student A-level grade with mean test score

Grade at A-level biology	% pupils achieving the grade	Mean score on test ± S.D.
A*	9.04	18.8 ± 4.86
A	49.41	17.1 ± 4.70
B	37.91	15.7 ± 4.32
C	3.40	14.0 ± 3.84
D	0.23	11.0

Percentage of pupils gaining each mark classification at biology A2 level in comparison to their test score. Data shown only for students taking A2 level examinations. Data from equivalent examinations (e.g. baccalaureate, access course) are not included.

Table 2. Comparison of student mean test score between A-level examination boards

Examination board	Mean A level grade[1] ± SD	Mean test score ± SD	Correlation between A level grade[1] and test score	P value
W	4.68 ± 0.66	17.24 ± 4.25	0.292	0.000*
X	4.63 ± 0.71	13.84 ± 4.86	0.106	0.210
Y	4.61 ± 0.68	16.51 ± 4.15	0.235	0.001*
Z	4.68 ± 0.72	19.30 ± 5.89	0.264	0.118
Don't know/ other	4.59 ± 0.87	13.18 ± 6.03	0.185	0.083

Note: Mean A-level grade (numeric) and test score, split by exam board, and the correlations between them.
[1]A level grades have been converted to a numerical score (A* = 6 points, A = 5 points, B = 4 points, C = 3 points, D = 2 points, E = 1 point).

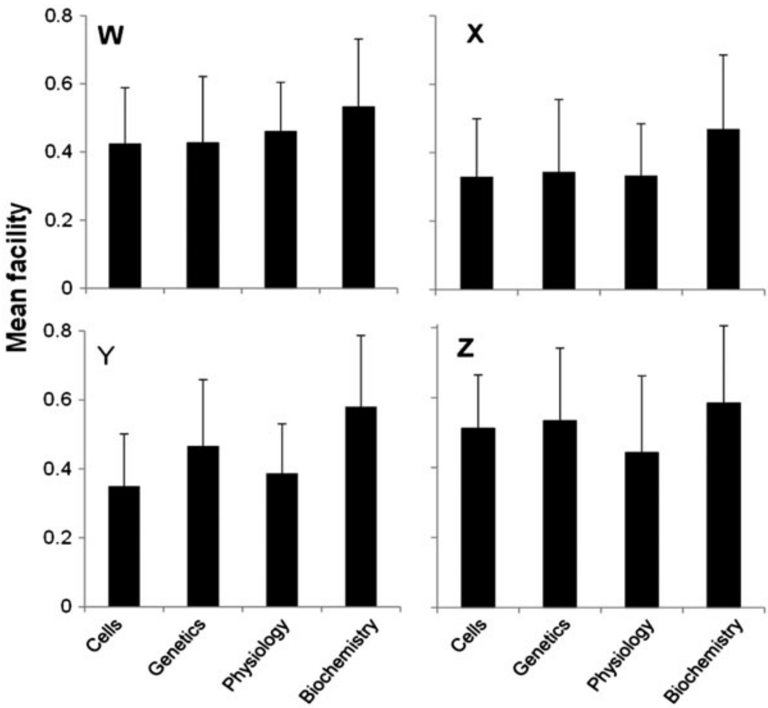

Figure 1. Mean facility (proportion answering questions correctly) split by subject and examination board (W-Z). Error bars show standard deviation

experts on perceived demand. Subsequently, some students in this study also ranked questions according to perceived academic demand. There was no relationship between mean facility and mean perceived demand ($R^2 = 0.0025$), and while the relationship between the two independent ratings of demand (student and expert) shows some agreement, it is not absolute. For example, the question with the lowest facility of 0.05 (which happened to be on plant physiology) was designated as easy by the exam board, and

Table 3. Mean demand and item facility between four subject groupings in the test

	Demand ± SD	Facility ± SD
Cells	4.00 ± 1.26	0.37 ± 0.18
Genetics	4.12 ± 0.59	0.42 ± 0.21
Physiology	4.25 ± 0.95	0.39 ± 0.23
Biochemistry	4.30 ± 0.86	0.51 ± 0.23

Note: The relationship between facility and students' perceptions of demand for each category of questions.

given a demand value of 2.42 by the students. Cell biology questions were ranked by students as having the least demand and yet were answered with the lowest facility of all categories (Table 3). For students of all examination boards, biochemistry questions were the most successfully answered; however, students ranked biochemistry questions as the hardest (Table 3). This may reflect students' level of confidence that they understood the question correctly. Students were given the option to state that they did not know the answer to a question and there was a correlation between the demand of the question and the proportion of students stating that they did not know the answer (Figure 2).

Questions were asked relating to the period of time between students leaving school and starting university. Students were asked whether they had done any biology-related work, biology-related reading or other biology-related activity between their A-levels and starting university. When looking at this in relation to their test scores it was found that there was no difference (p = 0.0556) in test score between the students who did any of these activities and those who did not. When looking at the length of time between taking A-level biology and doing the MCQ test an inverse relationship was found, where the longer the length of time since A-level, the lower the test score (Figure 3).

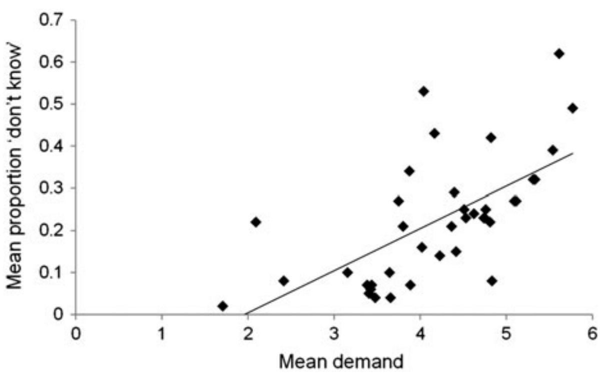

Figure 2. Relationship for each question, between mean number of students opting to say they 'don't know' the answer, and the mean demand of the question where students (n = 97) ranked each question on a scale 0–10, where 10 was the most demanding. Equation of the line: $y = 0.1003x - 0.1963$, $R^2 = 0.4034$

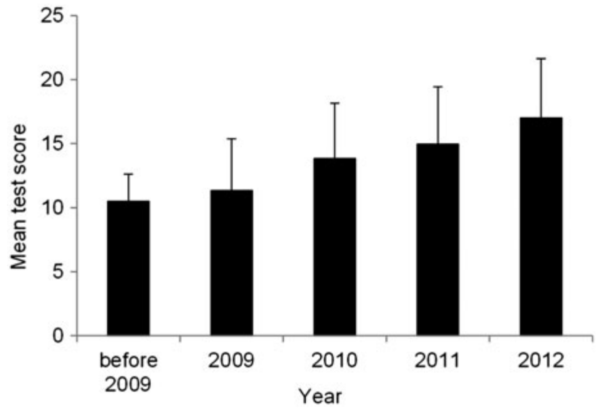

Figure 3. Mean test score for students depending on which year they took their A2 exams. Error bars show standard deviation

Discussion

This study identifies a low retention of knowledge from A-level (and equivalent) biology programs as students enter higher education. Students in this study had a mean score of just over 40% when answering questions on information learned in A-level biology classes. Students also tended to answer questions less well the longer they had spent between taking their examination and beginning university, suggesting that the ability to retain knowledge over time is a key factor in this study. A limit to the retention of information may have significant impact on a student's knowledge base when they begin their degree course. As there is also a correlation between knowledge retention and A-level grade, this is of particular concern to students with lower grades in biology A-level, who may be starting their degree course with a restricted knowledge base, and therefore be at a disadvantage from the outset.

Students report teaching-to-the-test comprising a significant part of their A-level study time (Daly et al. 2012). If teaching is carried out so that students remember information for a test, the loss of the information from memory will be rapid if not reinforced (Herbert and Burt 2001). Daly's study noted that students and teachers recognised the limitations of a teaching-to-the-test approach, while at the same time seeing learning as a process which leads to assessment.

The present study did identify a link between A-level grade and retention of knowledge through the MCQ test, shown by a correlation between A-level grade and test score, but when broken down by examination board this was only the case for two out of the four boards. However, A-level results can be affected by factors external to the actual ability of the student, such as school type and size of sixth form (Sear 1983), as well as the credentials of their teachers (Clotfelter, Ladd, and Vigdor 2010). The present study cannot add the examination board to this list because there are too many caveats to the study, but it does suggest this may be something worthy of further investigation.

Further suggestions of differences between examination boards were picked up in the data relating to question category and students' ability to remember the information, where there was variation between examination boards and the subjects answered best. This might indicate differences in the curricular structures established by the examination boards for the different subjects, in particular how strongly that material is emphasised in the examination board's curriculum. However, it might also be related to the types of questions asked and the approach to the subjects taken by each different board. It might also reflect students' general personal interests, although the present study found that student engagement with biology-related activities between school and university, which might relate to personal interests, had no effect on test score. Semb and Ellis (1994) suggest that retention is affected by the interval between acquiring the knowledge and testing, and also what happens to the student during that interval. While the present study does not provide supporting evidence relating to activities between acquiring knowledge and testing, the present data do show a decrease in retention of knowledge with time. This finding is supported by Roediger and Karpicke (2006) and also by Jones (2011), who suggests that if they are not reinforced by active use in the curriculum, some skills (particularly maths skills) will have atrophied beyond the point of utility by the start of a degree course.

There were elements in the design of the MCQ test which related directly to the requirements of the present study. One of the problems with MCQs is the element of guessing on the part of the student. In this study it was important to avoid this, because the study needed to know whether students genuinely did not know the answer. Having a 'don't know' option should have removed the issue of guessing. It was found that students were more inclined to answer 'don't know' to questions as demand increased. In addition, it was important in this study to use a type of question which would not favour one examination board over the others. The main boards do not currently use MCQs in their standard A-level papers, and so it was felt that most of the students would find this an equally unfamiliar method of assessment. Informal comments from some of the students taking the test were that they had not experienced MCQs in A-level examinations. Using an unfamiliar type of test will also have helped in testing knowledge of the subject, rather than recalling items learnt for specific types of examination question.

When looking at the rating of demand and difficulty of the questions it was found that there was no relationship, but this is not unusual because it is very difficult to determine question difficulty when developing questions for first use (Crisp and Grayson 2012). Pollitt and Ahmed (2001) have identified a process by which students approach questions including phases of reading and searching memory, and this can be used to try to establish the relative difficulty of a question. However, while one question that was determined as easy by the examination board and of low demand by the students, only 5% got the question right. The question was on plant physiology; this may reflect schools' possible reluctance to teach plant biology (Hershey 1992), students' lack of interest in plants (Schussler and Olzak 2008), the type of plant material covered in biology curricula or a lack of correspondence between the curriculum detail and its assessment.

Virtanen and Lindblom-Ylänne (2010) found that lecturers and students at university have different perceptions about what teaching involves. Students' perceptions of university teaching have been found to relate strongly to their pre-university experiences (Jones et al. 2009). Virtanen and Lindblom-Ylänne (2010) suggest that the gap between teachers' and students' perceptions of teaching is so wide that learning will be restricted if measures are not put in place to develop deep learning strategies. DeHaan (2005) suggests that science teaching in higher education is based more on intuition and habit rather than on pedagogical research. Teaching needs to be informed by research in order to increase its effectiveness, but many teachers are resistant to this (DeHaan 2005). DeHaan argues the need to engage in more learning-centred courses. The results of this study suggest that the beginning of this process is the need to appreciate students' retention of knowledge from their pre-university experiences. The student-centred approach required for deeper learning cannot start without first understanding what the student knows.

The ability to encourage deep learning approaches in school is vulnerable to political drivers, such as league tables based on proportions of students achieving a threshold grade. Such pressures will inevitably lead to students being taught-to-the-test rather than developing deep learning approaches. Effective deep learning requires the curriculum to be designed appropriately (Entwhistle and Peterson 2004), requiring contextualised scaffolding, identifying that scaffolding clearly to the student and activities that promote questioning and inquiry (Chin and Brown 2000). Lecturers can make the change to a student-centred teaching strategy to allow students the chance to develop a deep learning approach, but this requires knowledge of the amount and type of information students have retained from their previous learning environment (Figure 4). In line with Virtanen and Lindblom-Ylänne's (2010) findings, the present study reinforces the message that the transition to university needs to be handled carefully to help students develop a student-centred approach to learning early on in their time at university. It is challenging for students to adopt deep learning if they are not already experienced in its use, as students' approaches to learning are influenced by their experience in the classroom (Diseth et al. 2006). It is therefore perhaps unreasonable to expect undergraduate students to adapt immediately to a deep learning approach if they were not used to such an approach in their prior learning or have not previously had cause to find a surface-learning approach to be limiting. Fee, Greenan, and Wall (2009) highlight the importance of teachers supporting students' transition to higher education, and note that the significance of knowledge in the pre-university learning environment should be emphasised. Lumsden, McBryde-Wilding, and Rose (2010) highlighted the difference between students' previous experiences and lecturers' expectations. The authors also discuss the need to understand the culture the students come from – in particular its target and performance-led aspects and the university system's need to understand this – but more important is the need to understand what students retain from this environment and what guidelines they need to be given to adapt to the different learning environment they are entering into in HE. In Lumsden, McBryde-Wilding, and Rose's (2010) paper they outline a model titled 'transitional bridging', where student support begins with their educational history. What is

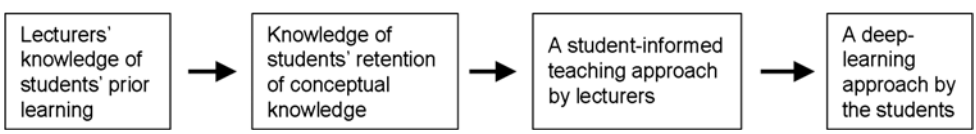

Figure 4. Suggested model of how knowledge of students' prior learning feeds into the development of a deep learning approach

missing from this model is what students retain from their educational history (Figure 4) and whether any of this aligns with the expectations of them in a degree course.

Knowledge retention is intricately linked to skills, because in higher education, more so than in pre-university education, the student cannot rely solely on a surface learning approach to gain the knowledge base from which to answer examination questions well. However, Jansen and van der Meer (2012) found that schools which concentrated on skills to better prepare their students for higher education produced students with less of a subject knowledge base. In the early stages of higher education, those who learn well and achieve are found to be those who remember information (VanderStoep, Fagerlin, and Feenstra 2000). However, this approach is ultimately likely to be limiting in more advanced stages of the degree. This may be a reflection of the difference in demands of school and university. Memorisation of material tends to happen when students do not understand what is being taught (Lujan and DiCarlo 2006) or do not appreciate the importance of deep learning and the broader significance of education beyond attaining examination grades. At school it is possible to engage in pure memorisation of information to pass examinations, although not necessarily to achieve the highest grades; however, the volume and demand of examinations in higher education means that a surface-learning strategy of memorisation will limit success.

Studies have been carried out to look at how retention of information might be improved. Basic memory of information has been linked to the way in which information is taught – for example, memory of information given through anecdotes or demonstrations (VanderStoep, Fagerlin, and Feenstra 2000). With results from the present study, this would need to be examined in terms of a longer-term retention of the students' knowledge base, since students going through the current education system based on a very surface-based approach, show a very low retention of knowledge as they enter university. However, perhaps knowledge *per se* need not be the primary focus of education. Semb and Ellis (1994) reviewed many studies on retention and found that where specific knowledge was lost, analytical ability on the same subject matter improved, and also that where knowledge was lost, comprehension improved, provided that the scaffolding to support this learning was sufficient.

This study has highlighted that there is a problem with regard to the retention of knowledge from pre-university studies as students enter biological sciences courses in higher education. With current proposals to make A-levels more relevant to higher education, students' ability to retain key concepts must be a key requirement for further investigation. In addition, university courses need to be more closely aligned with the levels of conceptual knowledge with which their students arrive, in order to employ a deeper, student-centred approach to teaching.

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