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Keywords

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Keywords

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Introduction

The learning styles of university students enrolled on nursing and midwifery courses have been quantified (Cavanagh, Hogan, & Ramgopal 1995; Cowman 1998; Mansouri, Soltani, Rahemi, Nasab, Ayatollahi & Nekooeian 2006; James, D'Amore & Thomas 2011; D'Amore, James & Mitchell 2012); however, other science disciplines, such as engineering and chemistry (Case & Gunstone 2003; Lastusaari & Murtonen 2013; Zeegers 2001), are less extensively studied. As approaches to study and learning either enhance or undermine educational outcomes, it is important for educators to be knowledgeable about the approaches their students use. For example, Cowman (1998) and others (Mansouri, Soltani, Rahemi, Nasab, Ayatollahi & Nekooeian 2006) found that adopting strategic or deep approaches to study was associated with better educational outcomes in undergraduate nurses, and a similar finding has been reported in first-year medical students (Mattick, Dennis & Bligh, 2004). A deep or strategic approach to study, coupled with activities that increase students' interest in the subject, may lead to improved academic outcomes. Furthermore, educators who focus on the assessment of recalled factual knowledge may endorse a surface approach to study and learning in students, whereas those who undertake the assessment of understanding may encourage a deeper approach (Marton & Säljö 1976a).

Instruments to Measure Learning Styles

The assessment of students' approaches to study has led to the development of a number of instruments (Tait & Entwistle 1996; Kolb 1981). These include the Approaches and Study Skills Inventory for Students (ASSIST – Tait, Entwistle & McCune 1997), the Visual, Aural, Read/Write, Kinaesthetic learning-styles inventory (VARK – Fleming & Mills 1992; Alkhasawneh, Mrayyan, Docherty, Alashram & Yousef 2008; Leite, Svinicki & Shi 2010), the Motivated Strategies for Learning Questionnaire (MSLQ – Zeegers 2001) and the Inventory of Learning Styles in Higher Education (ILS – Vermunt, 1994; Vermunt, 1998). Each of these inventories is based on some conceptualisation of learning that can be represented in a theoretical model of learning styles. These models of learning styles are multidimensional, in that they identify a dimension along which some measure pertaining to the individual learner can be located. Dimensions may relate to personality, information processing, learning and/or studying strategies and/or instructional preferences. For example, the sensory modalities (visual, aural, read-write and kinaesthetic) that a student prefers to use when internalising information is the focus of the VARK inventory. Some students prefer to use one sensory modality when internalising information (uni-modal); however, most people prefer to use two, three or all four modalities (multi-modal). The Learning Styles Questionnaire is purported to measure a person's relative strengths in four information-processing aspects of learning style: activist, reflector, theorist and pragmatist (Sadler-Smith 1997). The Inventory of Learning Styles in Higher Education (ILS) was developed to inductively explore students' learning strategies at university (Vermunt 1998), and to capture descriptions of cognitive, affective and metacognitive learning activities.

The Approaches and Study Skills Inventory for Students (ASSIST) identifies a student's characteristic orientation to studying as either "deep", "surface", "strategic", "lack of direction" or "academic self-confidence", all of which logically contribute to concretely differing learning outcomes. The ASSIST was developed using ideas originally proposed by Marton & Säljö (1976a, 1976b) and others (Biggs 1987), combining knowledge about learning styles with descriptions of a strategic approach to studying. A deep approach to study is characterised by a student's desire to understand, learn with meaning and recognise underlying principles and connections among related principles. The deep approach is linked with a conception of learning as “transforming”, and also with a preference for teaching that encourages and challenges understanding; these processes link closely with both the intention to seek meaning and interest in ideas. A strategic approach to study is accompanied by students’ close attention to details such as the structure of the content as laid out in the text, adherence to an instructor’s guidelines for studying and expected test format. Students who show a strategic approach can discern and use the aspects of a learning environment that will support their way of studying. Linkages between approach and motive are clear-cut within the strategic approach, where achievement motivation is strongly associated with both organised studying and time management. A surface approach to study often involves students’ memorising information and doing only what is necessary to succeed on an upcoming assessment. Students with a surface approach prefer teaching that directs learning towards assessment requirements even if this leads to a lack of both understanding and purpose. We suggest this style is the least beneficial for chemistry students because it leads to remembering content in isolation from its application.

The ASSIST can be used to help identify students at risk through ineffective study strategies (Tait & Entwistle 1996; Webster 2002). This version of the instrument provides a clearly laid out profile of the learning approaches of each student identified via the administration of a self-report questionnaire. Reflection and discussion of a student’s profile and answers to specific items may raise awareness of their own learning styles. While students are often vaguely aware of their own “style” in comparison to those of others, illumination of specific differences may let them enhance their study approaches to optimise their learning. The ASSIST instrument measures students’ characteristic study approaches, which logically have implications for the achievement of learning outcomes, rather than students’ preferred mode(s) of presentation of the content (as does, for example, the VARK inventory). Therefore, in this study, the ASSIST was selected as the instrument to identify students’ preferred learning style, and in turn to identify students who may benefit from help with refining their learning habits.

Methods

Setting

At this university, the subject of chemistry is delivered at first-year level as SCCHE1011 (Chemistry 1) and SCCHE1012 (Chemistry 2) in the first and second semesters respectively. SCCHE1011 is a compulsory prerequisite for SCCHE1012. At first-year level both of these subjects are a key component (core subject) to succeed in certain programs (for example, Biomedicine and Food and Nutrition), whilst only SCCHE1011 is required for other programs such as Geology and Metallurgy. Students who have passed SCCHE1011 may elect to do SCCHE1012 if it is not a core subject in their chosen named pathway. In a typical year about 140-150 students enroll in SCCHE1011, which falls to about 70-80 for SCCHE1012 in the second semester. SCCHE1011 contains two one-hour lectures (on two separate days) weekly and a two-hour tutorial or practical on alternative weeks. Assessment is based on tutorial attendance and participation (weighting at 10%), completion of assigned online learning assessments (weighting 15%), laboratory practical (weighting 25%) and a final three-hour examination (weighting 50%).

Instrument

With appropriate institutional ethics approval, the ASSIST instrument was given to the first-year SCCHE1011 undergraduate students, who had been recruited to complete the survey during the second-last week (week 11) of their first semester of study in 2014. The ASSIST has 52 items (Appendix 1) that are related to three approaches (deep, strategic and surface) to studying and learning. All items were scored on a five-point Likert scale where 5 = agree, 4 = agree somewhat, 3 = unsure, 2 = disagree somewhat and 1 = disagree. For each respondent, the score for the items comprising each of the learning-style scales were totalled, and the mean score for each scale was calculated for each respondent. The learning style “deep” was made up of 16 questions originally composed of four sub-divisions: seeking meaning, relating ideas, use of evidence and interest in ideas. The learning style “surface” was made up of 16 questions originally composed of four sub-divisions: lack of purpose, unrelated memorising, syllabus-focused and fear of failure. The learning style “strategic” was made up of 20 items originally comprised of five sub-divisions: organised studying, time management, alertness to assessment demand, achieving and monitoring effectiveness.

Statistical Analysis

All statistical analysis was carried out using IBM SPSS Statistics 22 software. The internal consistency of questions forming each learning style was calculated using Cronbach’s alpha. For each respondent, the mean score for each learning style was calculated; the results were compared with a one-way analysis of variance, followed by a post-hoc t-test. Gender comparisons were made between the learning styles using Students un-paired t-tests. The students were separated into their named majors (BSc Biomedicine, BSc Food and Nutrition, BSc Geology, BSc Science, and unnamed BSc pathways such as health science, metallurgy, education and psychology).

Results

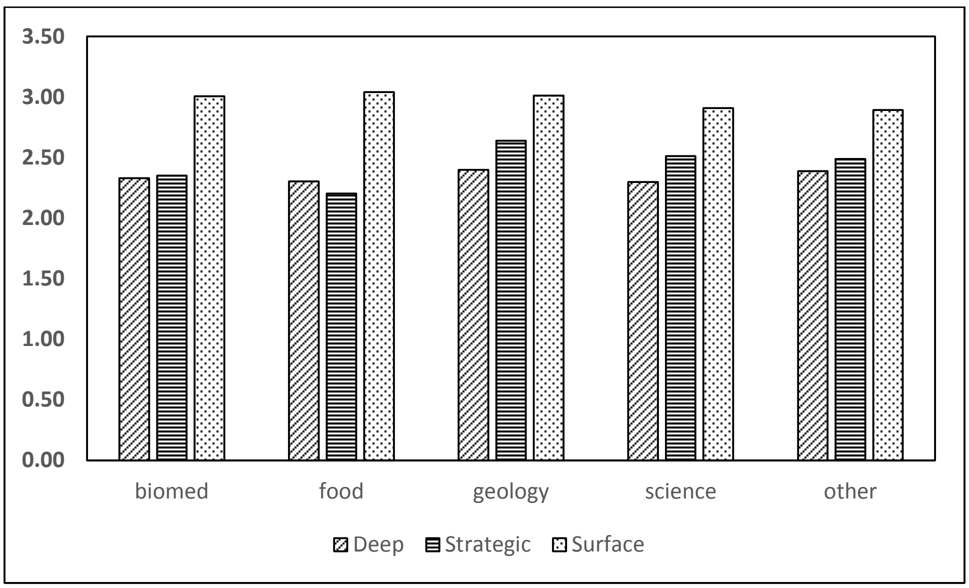
Completed ASSIST forms were returned by 103 students (85% response): 30 students on the BSc Biomedicine pathway, 15 students on the BSc Food and Nutrition pathway, 22 students on the BSc Geology pathway, 18 students on the BSc Science pathway and 18 students on unnamed BSc pathways. There were 44 female respondents and 59 male respondents. As shown in Table 1, the dominant learning style adopted by the students was the surface approach, with a mean score (SD) of 2.94 (0.54).

Table 1: Total and mean scores for the three learning styles identified by the ASSIST learning-styles inventory. Cronbach’s alpha scores, which indicate the internal validity of the items within the scale, are also shown for each scale. * $P<0.01$ (t-test following one-way ANOVA) compared to both strategic and deep. Each subscale within the ASSIST instrument demonstrated good internal consistency.

	Deep	Strategic	Surface
Mean total score (number of items)	37.08 (16 items)	48.98 (20 items)	47.10 (16 items)
Mean	2.32	2.45	2.94*
SD	.51	.61	.54
Cronbach’s alpha	.83	.89	.76

In the current study we used Cronbach's alpha as the statistical measure of internal consistency for each scale, and we assumed that each scale item was equally weighted and consisted of items that contributed only to that particular scale (i.e. each item was unidimensional). We did not examine each item using item-response theory (e.g. RASCH analysis); we considered that this was not necessary given the previous validation of the internal scale structure of the ASSIST instrument (Tait & Entwistle 1996; Webster 2002).

The learning styles adopted by students on different named BSc pathways are shown in Figure 1 (upper). There was a consistent preference for the surface style in all groups, with lower scores recorded for the deep and strategic styles. The deep style was adopted least in the biomedicine, geology, science and other degree pathways, whereas the strategic style was adopted least in the food group. Gender differences were also examined (Figure 1, lower): there was a significantly higher mean score for the strategic style in males compared to females, with no gender-based differences in either the deep or surface styles.



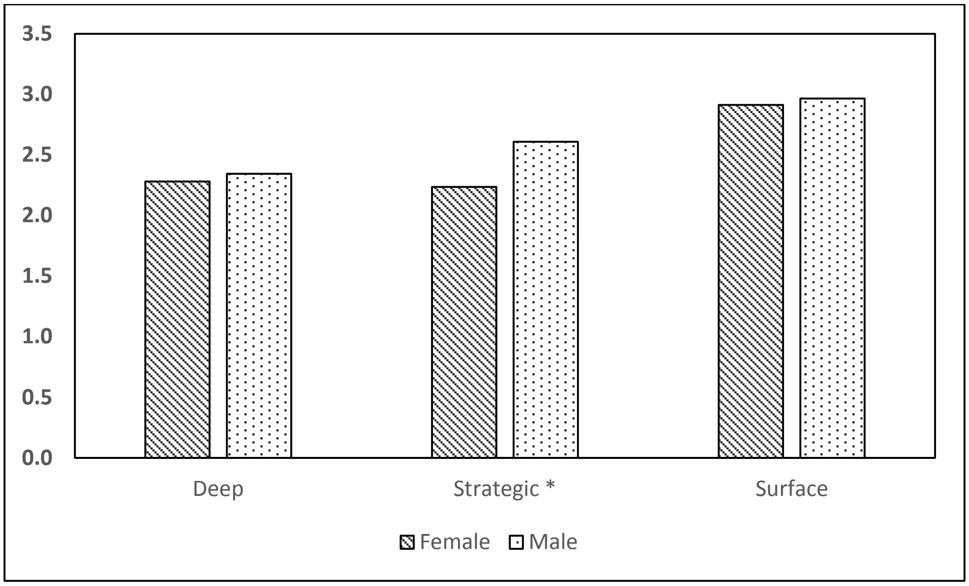


Figure 1: Mean score for the learning styles, determined using the ASSIST learning-styles inventory, in undergraduate students studying an introductory chemistry subject. Upper figure indicates the mean scores for each style (deep, strategic and surface) for students on named degree pathways. The lower figure indicates the breakdown of learning styles by gender. *P<0.05, unpaired samples Students t-test.

Discussion

In the current study, the ASSIST was used to identify the preferred learning style adopted by undergraduates studying introductory chemistry. Uniquely, these students were not majoring in chemistry, but were required to pass this subject to continue on named undergraduate pathways in, for example, biomedicine, and geology and food science. The data indicates that the preferred learning style was the surface style; was consistent for all named degree pathways. The surface approach to study often involves students' memorising information and doing only what is necessary to succeed on an upcoming assessment. Students with a surface approach to learning prefer teaching that transmits information and directs learning towards assessment requirements. Also, the surface-approach learner may construct syllabus boundaries, thus compartmentalising knowledge. We suggest this style is the least beneficial for students studying chemistry because it leads to remembering content in isolation from its applicability to practice. Also, the underlying principles of chemistry may be overwhelming for a first-year undergraduate adopting a surface approach, and we suggest that synthesis of this material with other knowledge is required to understand the more complex interactions required in a student's future applications of chemistry. Based on Bloom's Taxonomy, surface learning requires lower-order cognitive skills such as memory recall and the ability to describe subject material (Crowe, Dirks & Wenderoth 2008); this is consistent with the surface learning style and the preferred approach of the undergraduates studied here.

The adoption of the surface approach may not necessarily indicate a lack of interest in chemistry, but that the content was perceived as being peripheral to the students' interests. This can be a problem when students with a diverse range of career aspirations are required to study common content in large, first-year introductory subjects. In our research, students studying this undergraduate chemistry subject had not chosen a named degree in chemistry, and saw passing the subject as a hurdle they must overcome to progress into their next year of study; this may partly explain their adoption of the surface approach to study. Performance in assessment continues to represent a pivotal role in students' conceptions of learning science, although test-oriented teaching and learning may favour students who adopt a strategic learning style (Breckler, Joun & Ngo 2009; Dobson 2010). However, understanding chemistry requires students to meaningfully retain facts and competently use them in complicated situations; therefore, a strategic approach to learning chemistry, which focuses on test scores, may achieve only limited success. In contrast, in an inquiry-instruction environment – for example, process-orientated guided-inquiry (Brown 2010; Vanags, Pammer & Brinker 2013) – the focus is more on the learning process, and student achievement does not rely solely on performance in tests (Lin, Liang & Tsai 2012). The origins of Process Oriented Guided Inquiry Learning (POGIL) in chemistry education dates back to the mid-1990s. This teaching method uses a learning cycle of exploration, concept invention and application to guide students' construction of new knowledge and encourage a deep understanding of material while developing higher-order thinking skills (Hinde & Kovac 2001; Farrell, Moog & Spencer 1999; Schroeder & Greenbowe 2008). POGIL is a student-centred strategy: students work in small groups, with individual roles to ensure that all students are fully engaged in the learning process. The method develops process skills such as critical thinking, problem-solving and communication through cooperation and reflection (Hanson & Wolfskill 1998; Spencer 2006, 2009).

A possible way to foster a deep approach in students in this subject would be to provide tutorial support that focused on the separate disciplines, or illustrate the lecture content with appropriate examples from the disciplines. Thus, while the content would remain introductory chemistry, applied examples from geology, food science and biomedical science could be used to encourage deeper learning. Attendance at tutorials was not compulsory; however, attendance did contribute to the summative assessment. During the tutorial sessions, students practised chemistry-based calculations and attempted to solve problems associated with the topic being covered at the time. These problems included (but were not restricted to) those in the recommended textbook. We suggest that both interest and engagement would be increased if these learning opportunities were discipline-specific, and we further suggest that if a students' interest was increased, this would possibly lead to the adoption of a deep learning strategy. For example, students in this introductory chemistry subject who were studying for the named degree BSc Biomedicine could be given specific chemistry problems typical of a pathology report; they could then identify metabolic pathways contributing to abnormal values on the report, or identify likely chemical processes that contributed to the presence of a metabolite in a blood or urine sample. In contrast, the same investigative approach to chemistry in tutorials could involve the analysis of a contaminated soil sample (BSc Ecology), or the identification of additives (e.g. stabilisers) in imported milk powder, and the potential effect of such additives on subsequent chemical processes in food production (BSc Food and Nutrition).

Within the chemistry subject, active learning (which included laboratory practical sessions) provided an opportunity for students to develop the critical-thinking and problem-solving skills necessary to meet higher-order cognitive learning outcomes (Smith, Stewart, Shields, Hayes-Klosteridis, Robinson & Yuan 2005). A further development of these sessions could adopt the POGIL teaching methods, as success with these methods has been shown in the chemistry curriculum (Farrell, Moog & Spencer 1999; Hanson & Wolfskill 1998). The educational staff delivering the subject tried to support students' use of deep rather than surface approaches to learning (Hall, Ramsay & Raven 2004; Nelson-Laird, Shoup, Kuh & Schwarz 2008), as it was assumed that the development of higher-order cognitive skills promoted greater understanding and extended knowledge retention. The techniques used by the teaching staff were consistent with similar introductory undergraduate science courses at this university, using a combination of didactic lectures, interactive tutorials, laboratory practical classes and prescribed reading for independent study. While the focus of staff was predominantly teaching the appropriate content, the awareness of student learning as the primary objective was now becoming more established for this subject. For example, the identification of the students' preferred learning styles was pre-emptive in initiating a more reflective evaluation of current practice, with the focus shifting from content delivery to student learning. It is possible that student levels of interest and engagement and their attitude to study all contributed to the adoption of a surface learning style; our future research will quantify these attributes and attempt to identify links between these and the learning styles of undergraduate students of chemistry. A future research project is to quantify engagement in chemistry students not majoring in chemistry, and correlate it with academic achievement. In the current study, our only measure of student learning was scores on the assessment tasks – we could not correlate the ASSIST responses with the student's academic scores, as the ASSIST was anonymous. Again, a future research project will identify which learning style is more likely to lead to academic success in undergraduate chemistry students following named degree pathways who are not majoring in chemistry.

Identifying students who prefer a surface learning style at an early stage in the undergraduate education journey is an important step in effectively targeting educational resources aimed at enhancing students' learning habits. Emphasising how the content of a subject (particularly more foundational courses such as introductory chemistry) relates to professional practice may help promote deep and strategic approaches to learning. Such understanding might easily and inexpensively be promoted by having postgraduate students or advocates from industry highlight the benefits of persisting with chemistry. Didactic lectures traditionally provided to large student groups in first-year curricula could be supported with more-engaging, interactive small-group discussions led by peers and student tutors. However, this resource-intensive approach potentially has considerable implications for both physical and human resources. It could be introduced gradually; for example, initially with only one or two lecture sessions replaced in the first instance. This approach has an advantage in that each introduction of a novel teaching method could be evaluated, thus contributing to the evolution of the course.

Gender differences were also examined, and there was a significantly higher mean score for the strategic learning style in males compared to females (Figure 1), with no gender-based differences in either the deep or the surface learning styles. However, in this study there were only 44 female and 59 male participants, and the gender distribution on the named pathways was not consistent. For example, on the BSc Geology pathway there were 18 male and four female, whereas on the BSc Food and Nutrition pathway there were six male and nine female participants. Therefore the statistical difference between males and females for the strategic learning style needs to be viewed with caution as it may not reflect a relevant difference. We do not suggest that it is more likely for a male student in chemistry to use a strategic learning style, nor are we suggesting that a female chemistry student is more likely to adopt a surface and/or deep learning style in preference to a strategic style. However, it is worth reporting this finding as it identifies a future avenue of research in which subject characteristics (e.g. gender, ethnicity, age and educational background) are taken into account.

These research findings are the initial stage of a project to improve the student experience studying the applied sciences at this regional university. The identification of students' learning styles allows a baseline to indicate the current status. This baseline in turn allows an opportunity to quantify the impact of future curriculum changes on the learning styles of students in undergraduate chemistry courses. Further research on both student attitudes to the study of chemistry (Berg 2005; Bauer 2008) and engagement (Handelsman, Briggs, Sullivan & Towler 2005) with the subject, coupled with the assessment of students' preferences for a style of learning, is ongoing.

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Appendix 1: Approaches and Study Skills Inventory for Students (ASSIST)

1. I manage to find conditions for studying which allow me to get on with my work easily.
2. When working on an assignment, I'm keeping in mind how best to impress the marker.
3. Often I find myself wondering whether the work I am doing here is really worthwhile.

4. I usually set out to understand for myself the meaning of what we have to learn.
5. I organise my study time carefully to make the best use of it.
6. I find I have to concentrate on just memorising a good deal of what I have to learn.
7. I go over the work I've done carefully to check the reasoning and that it makes sense.
8. Often I feel I'm drowning in the sheer amount of material we have to cope with.
9. I look at the evidence carefully and try to reach my own conclusion about what I'm studying.
10. It is important to me to feel that I'm doing as well as I really can on the courses here.
11. I try to relate ideas I come across to those in other topics or other courses whenever possible.
12. I tend to read very little beyond what is actually required to pass.
13. Regularly I find myself thinking about ideas from lectures when I'm doing other things.
14. I think I'm quite systematic and organised when it comes to revising for exams.
15. I look carefully at tutors' comments on course work to see how to get higher marks next time.
16. There's not much of the work here that I find interesting or relevant.
17. When I'm reading an article or book, I try to find out for myself exactly what the author means.
18. I'm pretty good at getting down to work whenever I need to.
19. Much of what I'm studying makes little sense: it's like unrelated bits and pieces.
20. I think about what I want to get out of this course to keep my studying well focused.
21. When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.
22. I often worry about whether I'll ever be able to cope with the work properly.
23. Often I find myself questioning things I hear in lectures or read in books.
24. I feel that I'm getting on well, and this helps me put more effort into the work.
25. I concentrate on learning just those bits of information I have to know to pass.
26. I find that studying academic topics can be quite exciting at times.
27. I'm good at following up some of the reading suggested by lecturers or tutors.
28. I keep in mind who is going to mark an assignment and what they're likely to be looking for.
29. When I look back, I sometimes wonder why I ever decided to come here.
30. When I am reading I stop from time to time to reflect on what I am trying to learn from it.
31. I work steadily through the term or semester, rather than leave it all until the last minute.
32. I'm not really sure what's important in lectures, so I try to get down all I can.
33. Ideas in course books or articles often set me off on long chains of thought of my own.
34. Before starting work on an assignment or exam question, I think first how best to tackle it.
35. I often seem to panic if I get behind with my work.
36. When I read, I examine the details carefully to see how they fit in with what's being said.
37. I put a lot of effort into studying because I'm determined to do well.
38. I gear my studying closely to just what seems to be required for assignments and exams.
39. Some of the ideas I come across on the course I find really gripping.
40. I usually plan out my week's work in advance, either on paper or in my head.
41. I keep an eye open for what lecturers seem to think is important and concentrate on that.
42. I'm not really interested in this course, but I have to take it for other reasons.
43. Before tackling a problem or assignment, I first try to work out what lies behind it.
44. I generally make good use of my time during the day.
45. I often have trouble in making sense of the things I have to remember.
46. I like to play around with ideas of my own even if they don't get me very far.
47. When I have finished a piece of work, I check it through to see if it really meets the requirements.
48. Often I lie awake worrying about work I think I won't be able to do.
49. It is important for me to be able to follow the argument, or to see the reason behind things.
50. I don't find it at all difficult to motivate myself.
51. I like to be told precisely what to do in essays or other assignments.

52. I sometimes get "hooked" on academic topics and feel I would like to keep on studying them.