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Modelling the impact of study behaviours on academic performance to inform the design of a persuasive system

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ABSTRACT

Information technology is deeply ingrained in most aspects of everyday life and can be designed to influence users to behave in a certain way. Influencing students to improve their study behaviour would be a useful application of this technology. As a preamble to the design of a persuasive system for learning, we collected data to identify the study behaviours of students and recent alumni. We then developed two models to measure which behaviours have the most significant impact on learning performance. Current students reported more foundational behaviours whereas alumni demonstrated more higher-order thinking traits.

1. Introduction

People often behave in suboptimal and non-rational ways [38]. To address this problem, many researchers have investigated the potential of information technology (IT) to persuade individuals to improve their behaviours in various ways and contexts [13]. Due to the growing computational power of IT, and its continued spread throughout business and society, this technology offers great potential for such work. The process of using computer systems to persuade has been referred to as "Captology" (Computers As Persuasive Technology) or, more generally, "persuasive technology" or "persuasive systems" [13].

Persuasive technology can be applied to education, specifically to address poor study behaviour. For example, many students seek to improve their grades by developing study plans so they can keep up to date with their work, yet they may struggle to maintain their schedule; this is where persuasive technology might be of assistance. As with general behaviour, study behaviour can be complex to measure because it is composed of many elements and influenced by many factors [27].

The goal of this research is to identify the most significant study strategies and behaviours that enhance academic performance, which can then be used to inform the design of persuasive systems to improve student learning that is automated and scalable. Understanding the learning environment and the behaviours exhibited within it by students is an important first step in planning the design of system features as *consistency* with the user's view is key to developing a persuasive systems design. That is, a persuasive system should generally align with users' behavioural expectations. We devised the following research question to obtain a picture of the current landscape of student behaviour in relation to learning performance:

- Which study behaviours have the greatest impact on academic performance?

To answer this question, we first review the existing literature on behaviour and persuasive design and then discuss instruments designed to measure study strategies and learning motivation. Next, we present the results of a survey of students about their study experiences, from which we then develop several models that explain which behaviours and strategies have the most significant impact on learning performance.

2. Background

2.1. Behaviour change

As persuasive systems are aimed at influencing behaviour, it is important to understand the main theories related to behaviour change. One such model is the Transtheoretical Model for behavioural change, also known as the Stages of Change model. The premise of this model is that the process of behaviour change can be broken down into the following discrete stages:

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(1) pre-contemplation, (2) contemplation, (3) preparation, (4) action, (5) maintenance, and (6) termination [30]. In the first stage, the individual has no desire to change until they reach stage 2, in which they are actively considering a change. In stages 3 and 4, the individual has decided to adopt a new behaviour by planning how to enact the change and then performing the new behaviour. Stage 5 involves the individual continuing the new behaviour, despite the temptation to relapse into the old one. Finally, in stage 6, the individual has completely let go of the undesirable old behaviour and adopted the new behaviour. Transition through the stages is traditionally time-based, with each stage usually lasting approximately six months.

The idea of behaviour change as broken down into time-based stages has been questioned. Considering that human behaviour is often irrational and unpredictable, it is difficult to accept that behaviour is a definite linear process with a permanent end result. The idea of permanent termination of an undesired behaviour is also disputed as people often terminate an undesirable behaviour only to relapse after a long period of time [37]. The SNAP model was devised to better address the reality of human behaviour and overcome the limitations of the Stages of Change model [38]. SNAP is an acronym for "Staying the old behaviour", "New behaviour engagement", "Attempting to change" and "Planning to change". This model views behaviour as a never-ending series of states, such that one can progress through any of the four states at any time and in any direction.

Although the Stages of Change and SNAP theories describe how behaviour functions as a process, they do not prescribe how to change behaviour. This is a clear distinction between persuasive design theories and behavioural theories. Furthermore, it is important to note that, although different, these two types of theories do not compete with one another, but are complementary. Models such as SNAP may help to better understand and utilise persuasive design. For example, it is implied that once you have persuaded an individual, that behaviour will become permanent. Yet persuasive system design may not lead to permanent adoption of a behaviour, but instead continual triggers (as per the SNAP concept of states of behaviour) will be needed to ensure long-term behaviour change.

2.2. Persuasive systems

The process whereby technology can be designed to influence human behaviour can be defined as following three main phases: (1) understanding the key issues behind persuasive technology, (2) analysing the persuasion context, and (3) designing the system qualities. Collectively, this process defines the Persuasive Systems Design (PSD) framework [26]. The first phase is based on aligning the system the seven key postulates that underpin the design of persuasive systems:

1. Information technology is never neutral.
2. People like their views about the world to be organised and consistent.
3. Direct and indirect routes are key persuasion strategies.
4. Persuasion is often incremental.
5. Persuasion through persuasive systems should always be open.
6. Persuasive systems should aim at unobtrusiveness.
7. Persuasive systems should aim at being both useful and easy to use.

In contrast to earlier decades, the impact of computing technology can no longer be seen as neutral. Technology is now far more ingrained in our everyday lives, which is why it can be so persuasive. Unlike traditional methods of persuasion such as billboard advertising, many people use technology to complete everyday tasks, such as learning at an educational institution. This makes the application of a persuasive system a suitable choice to help improve student learning performance. The second postulate is of particular importance to the present research, as it explains that persuasive systems need to align with users' views. This is why it is vital to identify the key study strategies and behaviours of students, as the persuasive system will need to conform to this requirement.

Outlining the *intent* of the persuasion, the *event* in which it occurs and the *strategy* by which it is carried out is the core of the second phase of persuasive systems design. In this phase it is important to define who is performing the persuasion and who is being subjected to it. In this research, the persuaders are the teaching staff and the students are those being persuaded to improve their learning behaviour.

Finally, the system features are designed in accordance with the previous two phases. There are four categories in which potential features can be classified: primary task, dialogue, credibility and social support. Primary task support is the user's main purpose for using the system and therefore anything that makes this easier will likely encourage the user to perform that action. Dialogue support is concerned with creating a likeable human–computer interface. Credibility support ensures that users trust the system by making it clear why the system is credible. Finally, social support leverages the motivation of seeing others performing behaviours in a system in order to encourage others to also adopt those behaviours.

To be effective, persuasive systems should target a single behaviour, as targeting any more may obfuscate the persuasive message [14]. System features should then be designed around this target behaviour. However, this paper is focused on phase 2. Although identifying the current state of behaviours is not directly part of the established PSD framework, it is a crucial step as it provides deeper insights into typical student (or user) behaviour in order to design features in phase 3.

Table 1
MSLQ scales and subscales.

Learning Strategies Scales		Motivation Scales	
Scale	Subscale	Scale	Subscale
Value	Intrinsic Goal Orientation	*Cognitive and Metacognitive*	Rehearsal
	Extrinsic Goal Orientation		Elaboration
	Task Value		Organisation
Expectancy	Control of Learning Beliefs		Critical Thinking
	Self-efficacy		Metacognitive Self-regulation
Affective	Test Anxiety	*Resource Management*	Time and Study Environment
			Effort Regulation
			Peer Learning
			Help Seeking

Reproduced from Pintrich [27].

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2.3. Study strategies and behaviour

Given that the broader goal of this research is to influence behaviour so as to improve academic performance, it is important to understand the typical study behaviours of students. Learning encompasses many different skills and abilities and so there are many study behaviours that either have a positive or negative impact on learning performance. Previous research has thus sought to identify and categorise many of the types of study behaviours and strategies students typically adopt [12]. Two scales resulting from this previous work are the LASSI (Learning And Study Strategies Index) and the MSLQ (Motivated Strategies for Learning Questionnaire). The LASSI instrument consists of 80 items categorised under the following scales: *skill, will* and *self-regulation*. These scales are then further divided into subscales. The MSLQ consists of 81 items broadly categorised as part of either the *motivation* or *learning strategies* scales [27]. Those scales are then divided into two further levels of subscales (refer to Table 1 for a full breakdown of the scales and subscales of the MSLQ. Definitions of each scale can be found in Appendix A). Both instruments serve a similar purpose, which is to assess the learning strategies employed by students.

Although both questionnaires measure similar concepts and have been shown to be reliable [24,28], an advantage of the MSLQ over LASSI is that there is no implied internal model that must be used to interpret results. The scales are also designed to be modular so as to allow a researcher to develop a model structure to fit the needs of a particular study [27]. This ability to customise the MSLQ makes it an appropriate choice for use in the present study, as our research is of an exploratory nature and therefore requires greater freedom in interpreting the data collected.

As a result of the MSLQ's modular design, previous studies have attempted to analyse the latent structure of the MSLQ and provide a framework for investigators to use. One such study attempted to validate the MSLQ by performing confirmatory factor analysis on the general model presented by the MSLQ, with that being the motivation and learning strategies scales, and all of the subscales. The model was refined, resulting in a model with a three-factor structure, including: *expectancy*,*value* and *resource management* (see Fig. 1). Other studies have simply used a subset of the lower-level subscales available, in order to develop a relationship model (as shown in Fig. 2). These examples demonstrate the versatility and adaptability of the MSLQ. Although the purpose of our study is to identify specific behaviours for persuasive system design, we will also be analysing the broader scales in which the items belong. This enables us to identify the broader factors that lead to higher performance among students, which can be used in later research

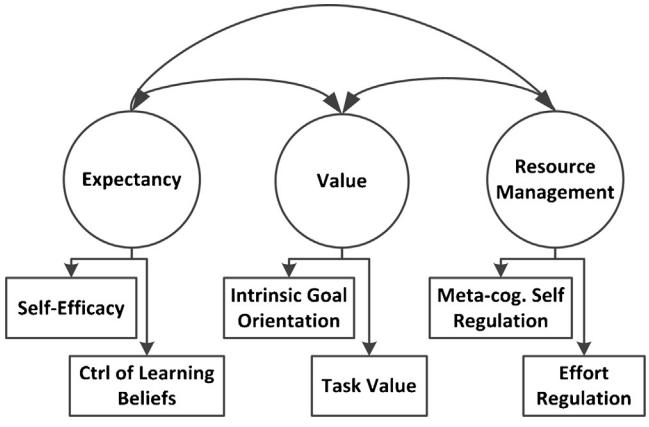

Fig. 1. MSLQ three-factor model.
Reproduced from Hilpert et al. [16].

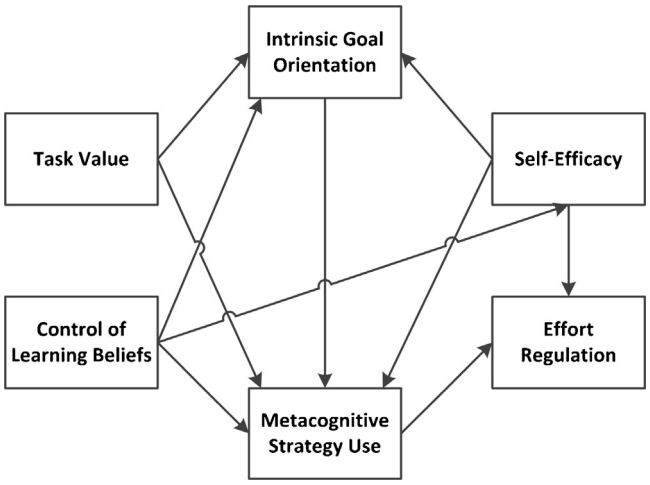

Fig. 2. MSLQ subscale model.
Reproduced from Sungur [36].

to identify the type of educational environment that is conducive to high performance, and therefore be more likely to be successful in applying the principles of persuasion to instil good study behaviours in students. The models depicted in the figures below provide a baseline against which we can later compare our results.

Furthermore, we can strengthen the link between study behaviour scales and pedagogy by observing how they relate to Bloom's taxonomy for learning [5], which has informed the design of learning objectives that lead to higher-order levels of thinking in students [9]. It is possible to break down learning into several stages, ranging from absolute and basic types of learning proficiency to more abstract types. Ideally, an individual would follow an educational path that includes (1) acquiring knowledge, (2) comprehending what the information means, (3) applying knowledge in practice, (4) being able to use knowledge to analyse problems, (5) combining different aspects of knowledge to synthesise new knowledge, and (6) being able to evaluate information. These six steps define the high-level categories of Bloom's original taxonomy for developing learning objectives [5]. The taxonomy's purpose is to enable instructors to devise learning objectives in accordance with this scale in order to encourage students to adopt higher levels of thinking. Since its inception, the taxonomy has since been revised to include: (1) remember, (2) understand, (3) apply, (4) analyse, (5) evaluate and (6) create [1]. The original taxonomy suggested that progression through each stage was ideally linear, whereas the revised model allows for flexibility while progressing from application to analysing, evaluating or creating. This difference is illustrated in Figs. 3 and 4.

It is expected that the behaviours will align with the different levels of Bloom's taxonomy. In designing future persuasive systems, the aim would thus be to encourage students to improve their behaviour in accordance with the higher levels of Bloom's taxonomy.

3. Methodology

To identify the study behaviours and strategies that have the greatest impact on academic performance, an online survey targeting current students and alumni was conducted. The questions for the survey were sourced from the MSLQ instrument with some modification. This section outlines the details of those modifications as well as the statistical approach used to determine the most important study behaviours.

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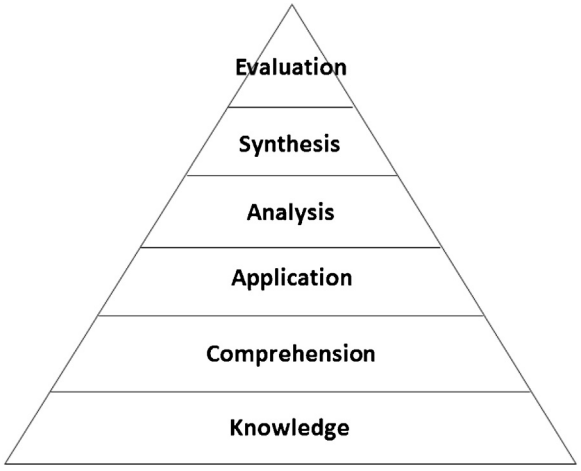

Fig. 3. Bloom's original taxonomy.
Reproduced from Anderson and Sosniak [2].

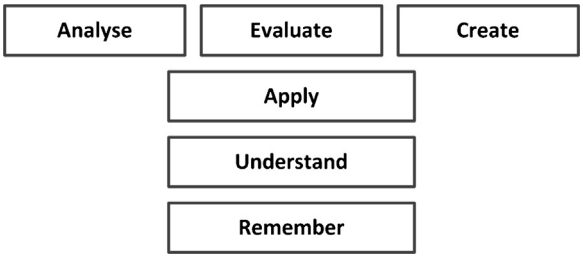

Fig. 4. Bloom's revised taxonomy.

3.1. Instrument design

The survey instrument consisted of two main sections. The first section enquired about the respondents' demographic details, namely: (1) age, (2) sex, (3) degrees undertaken, (4) current student status, (5) and predominant academic load. The second section featured the entire MSLQ questionnaire with some minor modifications.

Modifications were made to the MSLQ instrument, as there were two main issues with using it in its original form. First, the MSLQ questions were designed to be answered in relation to a single class. That is, the questions were to be answered about one specific class the student is undertaking. Second, the survey did not enquire about academic achievement. This was due to the MSLQ's original intent to be administered in a single class, in which case the details of students' academic performance would be readily available to instructors. Data on students' past academic grades was not available for analysis in our research, given our broader scope of university degrees in general.

To address the first issue, the wording of some questions was altered to be more general. This has been shown to be an appropriate process in some previous research which has demonstrated that generalising the questions still results in instrument validity [33]. An example of some of the questions that were altered is shown in Table 2. Care was taken not to alter their original meaning and purpose.

To address the lack of questions regarding academic performance, the following two new questions were added to the survey instrument:

1. How would you describe your academic performance as a student?
2. How often did you receive high grades (of over 80%) for assignments, exams or subjects overall?

The questions cover different dimensions of academic performance. The first question concerns a student's self-perception of their performance. The intention is to use the study behaviours from the MSLQ to identify those that lead to students believing they are good performers. The second question is intended to identify a more concrete measurement of performance. The percentage level was set in accordance with Mastery Learning theory which suggests that receiving a grade of above 80% indicates real understanding [4]. Respondents were instructed to answer using a 5-point Likert scale, with options ranging from "very much disagree" to "very much agree" for the MSLQ items, excluding the two performance questions. Self-perceived performance ranged from "very poor" to "very good" and responses for the second question above ranged from "never" to "all of the time". No restrictions were placed on the geographic location of respondents, thus offering greater flexibility in enquiring about performance given the differences in grading systems around the world.

3.2. Survey distribution

In order to maximise exposure, the web-based survey was distributed through the use of links on our personal Facebook and LinkedIn accounts for a duration of eight weeks. The general approach was to post an announcement with a message instructing potential respondents to fill in the survey and asking them to share the link in their friendship networks. This was done to encourage a 'snowball effect'. Facebook was selected as it is a popular choice for online social networking for undergraduate students. LinkedIn was selected as there is an active community of alumni that regularly communicate with their former instructors at university, hence increasing the odds of obtaining alumni respondents. That is not to suggest that Facebook will only provide undergraduate respondents and LinkedIn will only provide alumni respondents, but rather, that it may be more likely to do so. The purpose of targeting both students and alumni was to identify whether the immediate goal of graduating has an impact on what current students perceive their learning behaviour to be as compared to alumni who responded to this survey retrospectively.

3.3. Data modelling process

The collected data was analysed by testing each of the original MSLQ questions on both of the academic performance questions we devised. The software that was used for this process is SPSS as it contains a feature known as Automatic Linear Modelling [34]

Table 2
Example of MSLQ question generalisation.

Original Question	Modified Question (generalised)
Getting a good grade in this class is the most satisfying thing for me right now	Getting a good grade is the most satisfying thing for me
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn	I prefer course material that arouses my curiosity, even if it is difficult to learn

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which assists with narrowing down the most important study behaviours on academic performance.

3.3.1. Step 1: automatic linear modelling (ALM)

Performing exploratory linear modeling can be a time-consuming process, particularly when there are many items that can potentially be used. In this scenario, ALM helps the researcher to test many individual linear models quickly, and provides a ranked list of variables and their impact factors. To perform this test, we selected the academic performance item as the dependent variable, and all of the MSLQ items as independent variables. The software then tested every possible combination and produced a list of the variables with the largest impact. The software provided an accuracy measurement in the form of the adjusted r^2 value, expressed as a percentage. The top ten variables that resulted from this process were then used in the following step.

3.3.2. Step 2: multiple linear regression (MLR)

The resulting variables from the ALM were used in the construction of several MLR models. The significance of each of the variables was assessed and any that did not fall below 0.05 significance were excluded and the MLR was performed once again with the reduced set of variables. This continued until all remaining variables were significant and within the acceptable Durban-Watson value range of between 1 and 3 [11]. It was expected that the final models would have between three and five variables that were significant.

4. Results and discussion

The survey was distributed and analysed as per the process described in Section 3.3.

4.1. Data analysis

The ALM feature of SPSS provides an option to automatically prepare the data for analysis, which we elected to use. The process involves date and time adjustment, measurement level adjustment, outlier handling, missing value handling and supervised merging. There were 84 respondents to the survey, out of which were captured 67 complete usable samples. The data was representative of younger-aged students (both current student and alumni), with respondents typically aged between 18 and 29, and gender was evenly distributed – which aligned with the demographic we wanted to target. Table 3 details the descriptive statistics of the usable dataset.

The data collected appeared to be biased towards higher-performing students and alumni as 75% self-reported as being either *good* or *very good* students (see Fig. 5). Of the total, 56% of the respondents reported that they *often* received a grade of over 80% (see Fig. 6). Although this "good student" bias was an unexpected occurrence and we were expecting a wider range of responses, it is

Table 3
Descriptive statistics.

Characteristics	Count	Percentage	Characteristics	Count	Percentage
Gender			*Mode of Study*		
Male	34	50.75%	Full-time	62	92.54%
Female	33	49.25%	Part-time	5	7.46%
Age group			*Status*		
18–29	60	89.55%	Current Student	28	41.79%
30–39	6	8.95%	Alumni	39	58.21%
40–49	0	0%			
50–59	1	1.50%			
60 and over	0	0%			

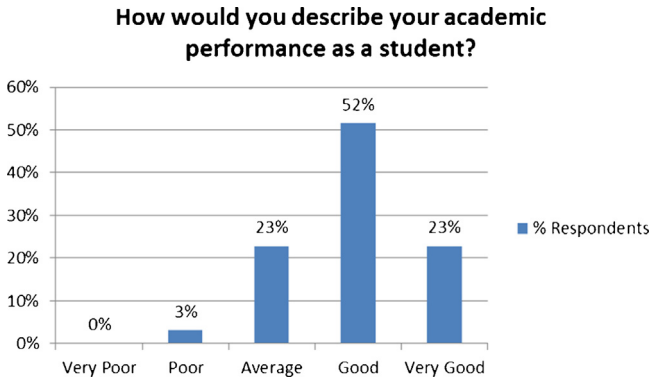

Fig. 5. Self-reported description of academic performance.

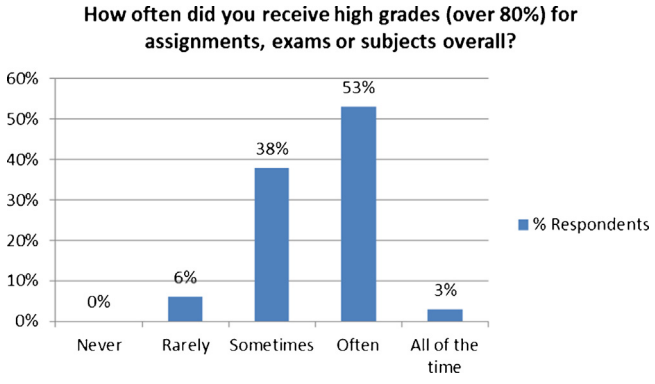

Fig. 6. Self-reported rate of achieving results of over 80%.

plausible that good students would be more likely to respond to a survey enquiring about their learning performance as opposed to lower-performing students. Regardless, the data is still valuable to this study as the purpose is to model the behaviours that result in higher performance.

4.2. Results and findings

More thorough data analysis resulted in two academic performance models being constructed, which were successfully modelled using the MSLQ items as independent variables. This section discusses these models in greater detail. For each model, we first present the behaviours that were uncovered for the entire sample. We then present a breakdown of the behaviours that were uncovered by running the same process on two subsets of the data: current students and alumni. We present these as sub-model "A", which had a sample of 28 current students; and sub-model "B", which had a sample of 39 alumni. Finally, we analyse the scale to which each study behaviour belongs in order to discuss the behaviours in terms of Bloom's taxonomy of learning.

4.2.1. Model 1: self-perceived level of academic performance

The model regarding students' self-perceived performance was successfully built and, as can be observed in Table 4, the accuracy of

Table 4
Reliability results for each model.

	ALM Accuracy	Durbin-Watson	r^2
Overall model	67.7%	2.28	0.41
Current students sub-model	90.2%	2.02	0.83
Alumni sub-model	79.2%	2.40	0.51

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the models was deemed acceptable as they explained, at a minimum, 67% of the variance, and, at a maximum, 90.2%. The Durbin-Watson values were all within acceptable ranges of 1 and 3 (see Section 4.2).

Given that each model satisfied the reliability criteria, a discussion of the resulting items is presented below.

Equation (1) Current students and alumni combined

$$f(x) = (0.18)x_1 + (-0.21)x_2 + (-0.28)x_3 + 4.39$$

where: f(x) = How would you describe your academic performance as a student?; x_1 = When I study for a class I pull together information from different sources, such as lectures, readings and course materials*; x_2 = I often get so lazy or bored when I study for a class that I quit before I finish what I planned to do**; x_3 = When a subject's work is difficult, I either give up or only study the easy parts** (Note: * $p < 0.05$, ** $p < 0.01$).

Instructors have long advocated seeking multiple sources of information when studying [18] and so the inclusion of *study behaviour 1* (x_1)in the overall model indicates that students are aware of the benefits of this approach when gathering information, in order to improve their learning. Respondents who reported that they did this more often also reported that they believed themselves to be good students. This may suggest that higher-performing students have a stronger desire for knowledge acquisition, as they are routinely seeking information from a wide variety of sources. However, it may also be due to the wealth of information available on the internet in that students may have become used to being able to seek multiple sources of information. For example, many students may use multiple social networking sites including Facebook and Twitter to source information about their friends' activities.

Conversely, there are times when students lose interest in the information they have at hand, as *study behaviour 2* (x_2) represents. Logically, this would be expected to have a fairly strong negative association with students' self-perceptions as good academic performers. Students are now accustomed to interactive and engaging technology and are often distracted by it while studying [32]. However, this primarily explains the "bored" reaction to studying; the "lazy" response may be the result of the level of difficulty of the work. When students find a learning task too difficult, they often procrastinate [31], and are then more likely to terminate their study session before completion. This correlates very closely with *study behaviour 3* (x_3), whereby students who find studying too difficult end up only studying what is easy. *Study behaviour 3* was also found to have a negative impact on self-perceived academic performance. Interestingly, the fact that students still attempt to study even the easy parts suggests that they are aware that studying is a good thing to do to improve grades; however, the difficulty or boredom they experience when studying inhibits their ability to study effectively. Next, we discuss the results of the two sub-models.

Equation (1A) Current students

$$f(x) = (-0.14)x_1 + (0.35)x_2 + (0.22)x_3 + (-0.48)x_4 + 3.88$$

where: f(x) = How would you describe your academic performance as a student?; x_1 = If I get confused taking notes in class, I make sure I sort it out afterwards*; x_2 = I'm certain I can understand the most difficult material presented in the readings for a subject. ***; x_3 = When I take tests I think of the consequences of failing. **; x_4 = I often feel so lazy or bored when I study for a class that I quit before I finish what I planned to do.***

Equation (1B) Alumni

$$f(x) = (-0.25)x_1 + (-0.39)x_2 + (0.41)x_3 + 4.11$$

where: f(x) = How would you describe your academic performance as a student?; x_1 = During class time I often miss important points because I'm thinking of other things*;x_2 = I rarely find time to review my notes or readings before an exam**; x_3 = I try to apply ideas from course readings in other class activities such as lecture and discussion** (Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

Upon first inspection of the two sub-models, interestingly *study behaviour 1* (x_1) in both models is concerned with what is happening during a class. The difference is that current students are identifying the problem with their study behaviour and are simply attempting to solve it, whereas alumni are aware of the problem and understand why it happens. This difference in metacognitive awareness is consistent with the literature which explains how metacognition develops over time [19]. Current students are focused on overcoming their immediate problem so as to continue towards graduation. Alumni tend to have a higher level of maturity and experience and so are able to identify the reason why they might miss important points in class – for example, that they are thinking of other things.

Furthermore, *current student study behaviour 1* had a negative correlation to self-perceived performance despite it providing evidence of self-directed learning, which is a beneficial process for student learning [15]. Clarifying confusion is a good learning strategy and yet this was found to have a negative relationship with self-perceived performance. A potential explanation for this might be that students are interpreting their confusion about a topic to mean that they are not good students, as they may incorrectly assume that good students immediately understand everything that is presented to them. *Student study behaviour 3* (x_3)could also be classified as a form of perceived academic inadequacy in that the student is fearful of failing a test. However, this behaviour was found to be a positive indicator of perceived academic performance. Fear of failure can provide motivation for some types of students in various ways [21], and so it may be that students interpret their fear as justification of the importance of doing well on assessments. Generally, a student's goal is to complete their degree to transition into their career of choice, which can create a level of anxiety as it is a hurdle they must overcome [8]. This could also explain how *Student study behaviour 4* (x_4) as completing what one plans to do is presumably concerned with coursework

Table 5
Model 1 factor summary.

Model 1 How would you describe your academic performance as a student?			
	Factors		
Model Item	Overall	Students	Alumni
x_1	Elaboration	Elaboration	Meta-cognitive Self-Regulation
x_2	Effort Regulation	Self-Efficacy	Time and Study Environment
x_3	Effort Regulation	Test Anxiety	Elaboration
x_4	N/A	Effort Regulation	N/A

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completion. Therefore, by completing tasks in preparation for tests, the student may feel a level of anxiety not due to being ill-prepared, but because of a desire to validate their efforts by completing the test satisfactorily. In contrast, *alumni study behaviour 2* (x_2) and *3* (x_3) demonstrate how alumni are more concerned with the bigger picture of studying – that is, not merely completing coursework and preparing for exams but also applying ideas learned through study. This illustrates a more mature attitude towards study, whereby the purpose is not solely to pass assessments, but also to practically apply their knowledge.

The analysis thus far has focused on the individual study behaviours uncovered by the data analysis. It is also useful to consider the broader factors that these variables belong to in order to give further context to the findings of this research. Table 5 outlines the MSLQ subscales to which each model item belongs. As can be observed, the current student model had the closest relationship with the overall model as both featured *elaboration* and *effort regulation* as significant factors influencing self-perceived performance. The alumni model only shared one factor with the overall model, *elaboration*, which is used to describe strategies such as making summary notes or analogies to commit information to memory [27]. The *elaboration* scale measures the ability to understand information and process it for long-term recollection. Coupled with *effort regulation*, this suggests that both alumni and current students believe that working consistently and being able to organise and recall knowledge are essential skills in being a high-achieving student.

4.2.2. Model 2: results-based measure of academic performance

The results-based measurement of academic performance was also successfully modelled. As per Table 6, it can be observed that ALM accuracy was acceptable, explaining 71.2% of the variance at the lowest and 86.7% at the highest. All three models (combined, students and alumni) also fell within the acceptable range for the Durbin-Watson test.

Next, we discuss the significant items that were selected for each of the models.

Equation (2)

$$f(x) = (0.24)x_1 + (0.30)x_2 + (-0.19)x_3 + (-0.19)x_4 + (0.14)x_5 + 2.16$$

where: f(x) = How often did you receive high grades (of over 80%) for assignments, exams or subjects overall?; x_1 = When I study for a class, I pull together information from different sources, such as lectures, readings, and discussions**; x_2 = I usually study in a place where I can concentrate on my work**; x_3 = I find it hard to stick to a study schedule**; x_4 = It is my own fault if I do not learn the material in a subject*; x_5 = When I study for a subject I write brief summaries of the main ideas from the readings and my class notes* (Note: * $p < 0.05$, ** $p < 0.01$).

Seeking multiple sources of information (*study behaviour 1* (x_1)) is common to both models 1 and 2, with each demonstrating that this behaviour has a positive impact on academic performance. Once again, this is logical, as model 2 explains the factors that lead to grades of over 80% and utilising only one source of information would severely limit students' abilities to perform well in an assessment. Furthermore, *study behaviour 5* (x_5) was found to have a strong positive relationship with performance for those students who summarise notes after class and from readings, which has previously been identified as a strategy adopted by high-performing students [6]. Having the ability to distil the vast amount of information available should lead to improved grades as it allows the student to solidify their understanding of a topic. However, this may not lead to gains in performance for students who are unable to stick to a study schedule (*study behaviour 3* (x_3)) as not being able to do so was found to be negatively related to performance. This may be the case as it is potentially related to *study behaviour 2* (x_2), which was found to have a strong positive impact on performance for students who were able to find places conducive to study. Previous work has identified that informal locations can be effective study spaces [17] provided that the surrounding stimuli are neither too distracting nor completely absent. Some students may not be able to identify when and where an appropriate time for them to study is, which thus impacts their ability to follow a regular study schedule.

Study behaviour 4 (x_4) was found to have a negative relationship to performance, which is inconsistent with existing research which reveals that taking responsibility for learning has positive outcomes for learning performance [23]. Previous research has shown that students typically attribute at least half of their learning to personal responsibility [10], and so it would be expected that high-performing students would take responsibility for their learning outcomes. However, if one views this from a different angle, it may be that high-performing students who stick to a schedule and source appropriate material believe that they have exhausted every avenue to achieve their best possible mark. Hence, the key word in this question is "fault"; in that good students do not believe that it is a fault in their effort or ability when they fall short of expectations; but perhaps simply an area that requires further understanding.

Equation (2A) Current students

$$f(x) = (0.21)x_1 + (0.16)x_2 + (0.37)x_3 + (-0.18)x_4 + 1.17$$

where: f(x) = How often did you receive high grades (of over 80%) for assignments, exams or subjects overall?; x_1 = When studying for a subject, I often try to explain the material to a classmate or friend**; x_2 = When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence*; x_3 = When I study, I set goals for myself in order to direct my activities in each study period***; x_4 = During class time I often miss important points because I'm thinking of other things**.

Equation (2B) Alumni

$$f(x) = (-0.33)x_1 + (0.54)x_2 + 2.68$$

where: f(x) = How often did you receive high grades (of over 80%) for assignments, exams or subjects overall?; x_1 = I often find myself questioning things I hear or read in a subject to decide if I find them convincing*; x_2 = I try to apply ideas from course readings in other class activities such as lecture and discussion** (Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

The most noticeable difference between the two models is in the number of significant items identified. The alumni model identified only half as many items as the current students model. Although this might be seen to indicate that the alumni model is too simple to explain all of the important behaviours needed to achieve high grades (of over 80%), when considered in combination, the items in this model form a good description of what a high-achieving student does. That is, they are critical of information that is given to them (*alumni study behaviour 1* (x_1)), and when they are happy with the content, they confidently apply that knowledge in other relevant areas (*alumni study behaviour 2* (x_2)).

Table 6
Reliability results for model 2.

	ALM Accuracy	Durbin-Watson	r^2
Overall model	71.2%	2.22	0.49
Current students sub-model	86.7%	2.04	0.80
Alumni sub-model	74.1%	2.04	0.31

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One aspect in which both models share an MSLQ scale was in *critical thinking*, albeit with opposite effects. Current students reported that they try to decide if there is good supporting evidence for what is presented to them (*current student study behaviour 2* (x_2)) while alumni often question what they read or hear (*alumni study behaviour 1* (x_1)). The difference here is that the alumni behaviour shows a higher level of intellectual confidence, whereas current students are somewhat hesitant to question information, and simply "try to decide if there is good supporting evidence". Critical thinking, particularly for first-year university students, can be weaker as they have yet to gain significant expertise with this skill [35]. Furthermore, because the information in question is being disseminated at a university, to a degree, current students automatically trust and do not question that information. This is interesting in terms of persuasive design, particularly as a system that appears to have authority is more likely to persuade someone [7].

An odd finding to come from the alumni model is that *alumni study behaviour 1* was found to have a negative influence on performance when it is reasonable to expect that it should be positive. An explanation for this could be related to the wording of the question, which asks whether respondents "often" question things to "convince" themselves. Respondents may have answered this negatively as they may not "often" question things, but rather only when required. Once again, as the context for this survey was university study, the level of trust students have towards a university instructor may mean that they do not *often* find themselves needing to question what they hear, which is not to say that they never do so.

Providing some insight into the current student priorities is *current student behaviour 3* (x_3). The findings for this item indicate that students are goal-oriented while they study, which helps them to achieve their academic outcome of grades of over 80%. Goal-setting has been identified as a key determinant of final grades [39]. The lack of this or a similar behaviour in the alumni model indicates that goal-setting may be only a main concern for students whiel they study. However, perhaps alumni simply do not remember using this as their main strategy when they reflect on their time as a student as a whole. Previous research has identified differences in goal-setting for students who are of present and future time-orientation [20], and so it is possible that a similar pattern may be occurring here between respondents of past and current time-orientation.

As per Table 7, the list of variables for the two sub-models was very similar, with both featuring *critical thinking* and *elaboration*. *Elaboration* involves students using strategies that commit information to long-term memory by connecting new information with prior knowledge. The two factors would be expected to appear together for a high-achieving student. However, in the overall model, *critical thinking* was not listed at all. This is partly a result of the relatively small sample size available for creating the sub-models, but it also suggests that, when viewing study behaviour from a broad perspective, *time and study environment* and *control of learning beliefs* are more informative factors given the broader context. That is, finding the right environment and believing that one's effort will result in a positive academic outcome (see Appendix A for further explanation of this factor) are likely to lead to greater academic performance in general. When one examines the critical factors at the individual (or student) level, however, it is the ability to think for oneself and integrate and connect new knowledge with what one has already acquired (the *elaboration* factor) that provides deeper insight. Furthermore, *metacognitive self-regulation* would be expected to be an influential factor for current students as it involves planning, monitoring and regulating learning behaviour, as these are important skills for enhancing performance.

4.3. Findings

Analysis of the overall models for academic performance revealed that there was very little commonality between each of their learning behaviour predictors. Indeed, at the overall level, there was only one instance of two models sharing the same behaviour: *"when I study for a class, I pull together information from different sources, such as lectures, readings, and discussions"*. In terms of the sub-models, only one behaviour was found in multiple models: "*during class time I often miss important points because I'm thinking of other things*". This reinforces the idea that learning is a complex process, and no single behaviour leads to strong academic performance.

When the individual behaviours were analysed from the point of view of their broader factor scales, we observed some overlap with the existing MSLQ models described earlier. In comparison to Hilpert et al.'s [16] model, we found significant individual behaviours that belonged to each of the top-level scales, not simply *expectancy*, *value* and *resource management*. There was also a correlation between the factors we identified and the factors featured in Sungur's [36] model. Factors such as *task value*, *control of learning beliefs*, *metacognitive self-regulation*, *effort regulation* and *self-efficacy* were identified as significant in both studies. In fact, Hilpert et al.'s [16] model also shared the same subscale factors, leading to the conclusion that these are likely to be important factors to consider when designing learning objectives and educational systems. This is given further weight when one considers that this research was designed to identify individual behaviour items first and then overall factors, whereas the related work aimed to model the scale using all of the available MSLQ items, and yet each study found similar significant factors. This also demonstrates the versatility of the MSLQ and that it is capable of reliably measuring learning strategies for multiple purposes.

Table 7
Summary of model 2 factor.

Model 2 How often did you receive high grades (of over 80%) for assignments, exams or subjects overall?			
	Factors		
	Overall	Students	Alumni
x_1	Elaboration	Elaboration	Critical Thinking
x_2	Time and Study Environment	Critical Thinking	Elaboration
x_3	Time and Study Environment	Metacognitive Self-regulation	N/A
x_4	Control of Learning Beliefs	Metacognitive Self-regulation	N/A
x_5	Elaboration	N/A	N/A

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At the variable level of the models, some differences were identified between current students and alumni in the general types of behaviours and strategies found to be significant. Current students were typically engaged in behaviours and strategies that had more of an immediate urgency in terms of their learning, rather than the longer-term view held by alumni. The models also featured several behaviours that reflected feeling "lazy or bored" or being "distracted". This suggests that learning environments should be as engaging as possible, yet not to the point that they are distracting for students. For example, using mobile technology can positively augment the learning environment, but can also distract students from their classroom activities [22].

It was also evident from the results that the learning behaviours of both current students and alumni were at some of the higher levels of Bloom's taxonomy. For instance, *metacognitive self-regulation* and *elaboration* featured in each model, at both the overall level and the sub-model level. This was in addition to what could be considered lower-level Bloom stages of learning such as *time and study environment* and *effort regulation*. The combination of lower- and higher-level learning behaviour factors in our models supports the original interpretation of the taxonomy in that one must graduate from the lower levels to the higher levels and should not attempt higher-level thinking without first mastering the basics [5]. This could be a result of modern university degrees incorporating the taxonomy into their course design and strengthens the argument that this is an ideal approach to producing high-performing academic students.

The behaviours and strategies present in the models and the higher levels of Bloom's taxonomy reached by alumni also demonstrate how good students naturally develop their study behaviours and strategies. This is likely a result of the education systems in which the students have been immersed, including early years through to tertiary learning. We are not aware of any widely used and purposefully designed persuasive system for learning and so these behaviours must be a product of the natural learning environment. The goal of any future persuasive system should be to enhance the transition from current student to alumni, and encourage the higher levels of Bloom's taxonomy for underperforming students. In relation to the persuasive systems design framework, this progression will help better develop the *strategy* of persuasion as it provides the designer with greater insights into student behaviour.

4.4. Implications

This research has implications for educators in that the models shed light on how certain study behaviours lead to changes in performance, as well as their relationship with one another. The alumni models presented in this research represent "successful" students, in that they have already obtained their degree. The study behaviours identified are not necessarily better than others, but the findings do reveal that there is a relationship between undertaking certain behaviours and strategies and successful completion of a degree. By understanding the relationships between behaviours and different areas of performance, instructors will be better able to determine how to develop their curriculum in order to empower students to develop a wide range of study skills. Coupled with a persuasive system to influence these behaviours among students, this knowledge may lead to improvements in student learning outcomes.

The results of this research will also allow designers to carry out the second phase of the PSD model: analysing the persuasion context [25]. The models provide context on the current behaviours of students and an evidence-based foundation from which the intent, event and strategy can be analysed. This can facilitate the design of a better quality persuasive system which will ultimately help students improve their learning behaviour and strategies.

4.5. Limitations

Although we were able to construct reliable models that measure the impact of study behaviours and strategies on academic performance, two limitations of the research were identified. First, the sample size was fairly small. This may have resulted in some study behaviours failing to meet the reliability criteria for inclusion in the models. Second, it was evident that the types of students who responded to the survey were typically "good" students. That is, they were high performing and generally exhibited positive study behaviours, although this was self-reported. This did not hinder the identification of the key study behaviours that enhance performance. However, we were unable to obtain insights into the behaviours that inhibit good study behaviours, which would have been more evident from lower-performing students. Hence, we were required to extrapolate potential behavioural barriers from the "good" student data we collected. Finally, the nature of this research is exploratory, and therefore further data collection and analysis will be required to test the validity and reliability of the models presented.

5. Summary

Technology can be used to support students to improve their study behaviours and strategies. As there are a multitude of behaviours that could potentially benefit student learning, we used a statistical process to identify which study behaviours have the greatest impact on academic performance. Two models were created that covered different dimensions of performance – self-perception and results achieved. We then modelled the data based on current students and alumni and identified a general trend towards behaviours and factors that provide immediate benefits for current students, and higher-order thinking behaviours and factors for alumni. The models outlined in this paper form the basis from which persuasive systems can be designed to improve learning outcomes, as they provide a richer picture of how student learning behaviours naturally develop. Drawing on this knowledge, persuasive systems for education can now aim to influence the natural progression of good students for those students who are underperforming, possibly due to their behavioural deficiencies.

6. Future work

This research provided the background for understanding how higher education students currently behave in terms of study. The next step will be to select a single behaviour that we would like to encourage in students, as per the recommendation of [14]. The individual strategies and behaviours uncovered in this research are not strictly required to be used as the target in a future system. An unrelated behaviour can be selected; however, it will need to align to some degree with the models presented in this research. That is, it should be consistent with what students expect in relation to how they learn and attempt to alter their behaviour where necessary. Negative behaviours that featured in several of the models should also be given more careful consideration in order to avoid encouraging their development in any new persuasive system. An important consideration in any future work on persuasive systems will be to ensure that ethics are carefully evaluated. Although the goal of building a persuasive system for study is to benefit students, designers should ensure that systems are not too invasive and do not interfere too far into the personal lives of students.

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A longer-term study could involve investigating whether acquiring the study behaviours identified in this research have an impact on workplace behaviours and productivity. The logical progression for a student is to graduate from a degree and find employment, and so it may be useful to investigate whether one's learning behaviour as a student correlates with workplace learning behaviour. Such research could be conducted through the lens of lifelong learning to analyse whether establishing good study behaviours translates in some form into the workplace, and the impact this has on productivity. This would be of particular interest to both educators and employers.

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Appendix A.

The following definitions of the MSLQ subscales have been reproduced from Pintrich [27].

Intrinsic goal orientation

Goal orientation refers to the student's perception of the reasons why she is engaging in a learning task. On the MSLQ, goal orientation refers to student's general goals or orientation to the course as a whole. Intrinsic goal orientation concerns the degree to which the student perceives herself to be participating in a task for reasons such as challenge, curiosity, and mastery. Having an intrinsic goal orientation towards an academic task indicates that the student's participation in the task is an end all to itself, rather than participation being a means to an end.

Extrinsic goal orientation

Extrinsic goal orientation complements intrinsic goal orientation, and concerns the degree to which the student perceives herself to be participating in a task for reasons such as grades, rewards, performance, evaluation by others, and competition. When one is high in extrinsic goal orientation, engaging in a learning task is the means to an end. The main concern the student has is related to issues that are not directly related to participating in the task itself (such as grades, rewards, comparing one's performance to that of others). Again, this refers to the general orientation to the course as a whole.

Task value

Task value differs from goal orientation in that task value refers to the student's evaluation of the how interesting, how important, and how useful the talk is ("What do I think of this task?). Goal orientation refers to the reasons why, the student is participating in the task ("Why am I doing this?"). High task value should lead to more involvement in one's learning. On the MSLQ, task value refers to students' perceptions of the course material in terms of interest, importance, and utility

Control of learning beliefs

Control of learning refers to students' beliefs that their efforts to learn will result in positive outcomes. It concerns the belief that outcomes are contingent on one's own effort, in contrast to external factors such as the teacher. If students believe that their efforts to study make a difference in their learning, they should be more likely to study more strategically and effectively. That is, if the student feels that she can control her academic performance, she is more likely to put forth what is needed strategically to effect the desired changes.

Self-efficacy

The items comprising this scale assess two aspects of expectancy: expectancy for success and self-efficacy. Expectancy for success refers to performance expectations, and relates specifically to task performance. Self-efficacy is a self-appraisal of one's ability to master a task. Self-efficacy includes judgments about one's ability to accomplish a task as well as one's confidence in one's skills to perform that task.

Test anxiety

Test anxiety has been found to be negatively related to expectancies as well as academic performance. Test anxiety Li thought to have two components: a worry, or cognitive component, and an emotionality component. The worry component refers to students' negative thoughts that disrupt performance, while the emotionality component refers to affective and physiological arousal aspects of anxiety. Cognitive concern and preoccupation with performance have been found to be the greatest sources of performance decrement. Training in the use of effective learning strategies and test-taking skills should help reduce the degree of anxiety.

Rehearsal

Basic rehearsal strategies involve reciting or naming items from a list to be learned. These strategies are best used for simple tasks and activation of information in working memory rather than acquisition of new information in long-term memory. These strategies are assumed to influence the attention and encoding processes, but they do not appear to help students construct internal connections among the information or integrate the information with prior knowledge.

Organisation

Organization strategies help the learner select appropriate information and also construct connections among the information to be learned. Examples of an organizing strategies are clustering, outlining, and selecting the main idea in reading passages. Organizing is an active, effortful endeavour, and results in the learner being closely involved in the task. This should result in better performance.

Critical thinking

Critical thinking refers to the degree to which students report applying previous knowledge to new situations in order to solve problems, reach decisions, or make critical evaluations with respect to standards of excellence.

Metacognitive self-regulation

Metacognition refers to the awareness, knowledge, and control of cognition. We have focused on the control and self-regulation aspects of metacognition on the MSLQ, not the knowledge aspect. There are three general processes that make up metacognitive self-regulatory activities: planning, monitoring, and regulating.

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Planning activities such as goal setting and task analysis help to activate, or prime, relevant aspects of prior knowledge that make organizing and comprehending the material easier. Monitoring activities include tracking of one's attention as one reads, and self-testing and questioning: these assist the learner in understanding the material and integrating it with prior knowledge. Regulating refers to the fine-tuning and continuous adjustment of one's cognitive activities. Regulating activities are assumed to improve performance by assisting learners in checking and correcting their behaviour as they proceed on a task.

Time and study environment

Besides self-regulation of cognition, students must be able to manage and regulate their time and their study environments. Time management involves scheduling, planning, and managing one's study time. This includes not only setting aside blocks of time to study, but the effective use of that study time, and setting realistic goals. Time management varies in level, from an evening of studying to weekly and monthly scheduling. Study environment management refers to the setting where the student does her class work. Ideally, the learner's study environment should be organised, quiet, and relatively free of visual and auditory distractions.

Effort regulation

Self-regulation also includes students' ability to control their effort and attention in the face of distractions and uninteresting tasks. Effort management is self-management, and reflects a commitment to completing one's study goals, even when there are difficulties or distractions. Effort management is important to academic success because it not only signifies goal commitment, but also regulates the continued use of learning strategies.

Elaboration

Elaboration strategies help students store information into long-term memory by building internal connections between items to be learned. Elaboration strategies include paraphrasing, summarizing, creating analogies, and generative note-taking. These help the learner integrate and connect new information with prior knowledge.

Peer learning

Collaborating with one's peers has been found to have positive effects on achievement. Dialogue with peers can help a learner clarify course material and reach insights one may not have attained on one's own.

Help seeking

Another aspect of the environment that the student must learn to manage is the support of others. This includes both peers and instructors. Good students know when they do not know something and are able to identify someone to provide them with some assistance. There is a large body of research that indicates that peer help, peer tutoring, and individual teacher assistance facilitate student achievement.

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