Thinking about Thinking: The Relationship between Confidence, Attainment and Metacognition in Computer Science

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Abstract: Thinking about thinking, or metacognition as it is better known, is something that cannot be easily taught but rather is developed and practised by an individual. It can be beneficial because students make connections between their learning experiences, discover their own learning preferences and can improve their understanding of interconnection between concepts that the current HE system of modularisation tends to undermine. It is a skill that an individual develops and practices over time based on a wide range of experiences and learning opportunities. We hope to develop teaching approaches that help to improve students' awareness of their own metacognitive processes and learning strategies and by extension, their confidence in applying their previous experiences and knowledge to unfamiliar tasks and problems they encounter during their degree. This paper outlines a preliminary study that explores the impact of confidence on student attainment. The study involved reviewing three stages of student experience - (i) The level of experience and confidence of students when entering the first year of the degree, (ii) their attainment at the end of first year and (iii) their level of confidence before and after coursework submission in the second year of their degree. Our results show that there may be a direct relationship between confidence levels and student attainment. Our results show there is some link between metacognition and confidence, with further exploration we can identify this link further and create metacognitive learning strategies.

1 INTRODUCTION

On entering university, most students have a wealth of knowledge and skills that are not purely academic and have developed from their more general life experiences. The learning from these experiences can be used to improve or enhance their academic performance but often students find it difficult to see their relevance or potential to add value and so they fail to transfer what they have learned to their university studies. These skills can be relevant to their learning in Higher Education (HE) but often students find it difficult to see the connection and transfer that learning to their HE studies. Flavell (Flavell, 1976) first introduced the term metacognition and defined it as being "one's knowledge about one's cognitive processes or anything related to them". Research in the area of metacognition explores the idea that those who have metacognitive abilities tend to be better learners and have an awareness of their cognitive processes (Mani and Mazumder, 2013) and thus tend to be better learners.

As teachers, we want to ensure that each of our students make the most of their learning opportunities in HE and to perform to the best of their ability. However, this is something that has become challenging in recent years due to the growth in student numbers. To ensure that each student gets the opportunity to explore and develop equally we need to develop tools and curricula that enable them to take greater control of their own learning when we are not around to support them, eventually leading to them becoming the self-directed learners that we would like them to be at the end of their degree programme. This paper reports on a preliminary study that explored to what extent stage 2 students could see the theoretical and practical connections between 4 different modules on their undergraduate computer science programme and their confidence in completing the new module assignments based on this awareness. Our initial findings confirm that some students could see the connections between modules and that those students who could, had greater confidence and performed better in the subsequent assignment.

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2 RESEARCH QUESTIONS

We used two research questions to explore the idea that students who consciously use their metacognitive abilities to transfer their learning from one task to another are more effective learners and are more confident in their ability to learn:

1. Can students see the relationship between modules which develop similar skills between the first and second year of their degree?
2. Do those who are most confident in their ability to learn perform better in their coursework?

3 BACKGROUND

3.1 The Effect of Confidence on HE Learning

There is a strong link in transitioning to HE and confidence. Lowe et al (Lowe and Cook, 2003) investigated the question "are students prepared for higher education?" and found that 35% of the students surveyed, felt they had chosen the wrong course and 13% were unsure whether they should actually be at university. This raises the question whether the student had a lack of confidence in their own ability or whether there were external pressures that made them choose their course. After two months, the students were surveyed again and it was found that students had a greater confidence in their choice and it increased to 57%. More interestingly, the number of students who felt they shouldn't be at University increased to 19%. Lowe et al (Lowe and Cook, 2003) do note in their investigation that a substantial minority (20%) perceived themselves to be lacking more in confidence then they had expected. This shows for the majority of students that confidence increased after 2 months of being at University.

Previous experiences are strongly linked to confidence and there is extensive literature that shows experiences within general CS concept and programming greatly improve a student's confidence (Alvarado et al., 2014; Hagan and Markham, 2000; Bergin and Reilly, 2005) in university-level computer science. Alvarado et al (Alvarado et al., 2014) identify that most first year HE courses are designed to mitigate prior experiences. By designing a course that mitigates prior learning experiences, all students start off on a level playing field in terms of knowledge and the gap is closed in pre-requisite knowledge needed to cope well in their degree. This raises the questions whether the student can use their cognitive processes to identify the relationship between their previous experience and what they are doing.

Denny et al (Denny et al., 2010) conducted an experiment which asked students to predict their performance in an introductory programming course. Quizzes were held at the start of lectures to assess their understanding of the material. Denny et al (Denny et al., 2010) found that male students were more confident than female students, which coincides with current computer science education literature. (Beyer et al., 2003; McDowell et al., 2006; Sankar et al., 2015). Denny et al (Denny et al., 2010) study also shows that female students achieved a slightly higher (+2.6%) exam mark overall. Some students are also overconfident in their abilities and this has been found in many studies (Gluga et al., 2012; Pinto et al., 2017) which show that students find it hard to understand why they are over-confident or even to detect that they are being over-confident. In most of these studies the authors found that over-confidence was detected too late for students to mitigate as they had already completed their summative assessments. This raises the question of whether previous experiences creates overconfidence as students think they did well previously so they are going to do well in the future. By developing a student's cognitive knowledge they can understand the relevance of an experience(Garner, 1987).

3.2 The Role of Metacognition within Higher Education

Metacognition has two aspects, knowledge of cognition and regulation of cognition (Schraw, 1998). Knowledge of cognition refers to the knowledge that an individual has about their own cognition and regulation of cognition is the set of activities that can help an individual control their learning. Garner (Garner, 1987) writes that those who are said to be good learners are said to have a better understanding of their cognitive knowledge. The use of metacognition will be a way of helping students to improve their learning. Metacognition involves students having a deeper understanding of their own cognitive processes (Flavell, 1976). By helping students understand and improve their cognitive processes, they will be able to have a better understanding of their own learning. By developing a deeper understanding of self-study and learning transfer, students will be able to see the relation between modules and should minimise the effects of

modularisation.

4 METHODS

4.1 Participants and Setting

To explore the links between metacognition, confidence and student attainment, we reviewed the marks and experience of 224 students in their second year of study (three-year degree programme). We looked at their exam and coursework results for the first year of study and their overall grade average and also their initial results from one of their first modules in Year 2 - Operating Systems. After reviewing the data only 221 students were included in the final review as some students did not sit the Operating Systems exam due to personal circumstances. We then monitored a sub-set of the original population during the Operating Systems module (29). These students volunteered to give details on their level of confidence before completing coursework and afterwards, before receiving marks. All participants in this study gave consent for their results to be monitored and tracked over the course of the programme. The first year modules (exam:coursework) used were Programming 1 (50:50), Programming 2 (60:40) and the Computer Architecture (50:50) module.

The operating systems module has a weighting of 80% exam to 20% coursework. For this study we chose to look at the coursework element as typically students score very low in the coursework element. The coursework element of the module has 2 assignments and we chose to specifically analyse the first assignment as it focuses on the core introductory theories of the module. The first assignment has 2 parts to the coursework in which part 2 can only be completed by completing part 1.

4.2 Confidence Level Measures

We gathered student confidence levels through a questionnaire. We used a modified Likert scale to get the confidence levels on individual questions. The students could choose from the following: strongly agree; agree; unsure and disagree. The questionnaire was given out before the students attempted the coursework and after the students had submitted the coursework. The second questionnaire was distributed only to those who had completed the first part of the experiment.

Table 1 shows the questions asked to students when assessing their level of confidence. The questionnaire had 3 parts to it; the coursework as a whole, part one of the coursework and part two of the coursework. The questions in table 4 show what was asked for the coursework as a whole and only slight changes were made in the tense of the question.

Table 1: Questions asked to assess their confidence.

(1) I feel confident that I understand what the specification is asking me to do
(2) I know what the material from the module I need to know before attempting the coursework
(3) I will do well in this piece of/part of the coursework
(4) I believe this coursework/part will help me with preparing for my exams
(5) This coursework will test my understanding of the material

5 FINDINGS AND DISCUSSION

5.1 CS1 Results against CS2 Module

When analysing first year results, we wanted to see the correlation between modules. We used Pearson's correlation co-efficient to see the relation between Programming 1 (CSC1021), Programming 2 (CSC1022), Computer Architecture (CSC1024) and Operating Systems (CSC2025). The modules that we had chosen to analyse had links in skills with one another. In CSC1022, you needed to use the knowledge and skills developed in CSC1021. CSC1024 was analysed as CSC2025 requires knowledge gained in the programming modules as well as CSC1024.

Table 2: Correlation between Student results.

	CSC1021	CSC1022	CSC1024	CSC2025
CSC1021	1	.738	.625	.426
CSC1022	.738	1	.656	.420
CSC1024	.625	.656	1	.568
CSC2025	.426	.420	.568	1

Table 2 shows the results from Pearson's correlation. Values closest to 1 show a strong relation and values closest to 0 show no relation. When analysing the results, we used the following guide by Evans (Evans, 1995) to determine the strength of the correlation: 0.00 - 0.19: very weak, 0.20 - 0.39: weak, 0.40 - 0.59: moderate, 0.60 - 0.79: strong and 0.80 - 1.00: very strong.

When looking at the relation between CSC1021 and CSC1022 results (0.738), we can see there is a strong relation in the results gained by students. In order to do well in CSC1022, you need to understand the concepts that are taught in CSC1021. When looking at the correlation between CSC1022 and

CSC2025, we can see that there is a moderate relation (0.420). The programming language used in CSC1022 is Java, which is a object-orientated programming language. In CSC2025 the students are not taught the programming language C, they are expected to use their knowledge gained in CSC1022 to learn the language for themselves. This could explain the moderate relation between the modules as students cannot use their metacognitive skills to adapt to a procedural language like C. When looking at CSC1024, there is an increase in correlation (0.568) but the strength of the relation is equal to other modules.

Using Evans' (Evans, 1995) guide we were able to determine the strength of correlation between the students results in CS1 and CS2. We found that there was a strong correlation in results in the first year modules between one another but when comparing the correlation to the second year operating systems module, there was only a weak/moderate correlation. This, at first, looks like doubt is being cast on our second research question but when you consider that the majority of students improved on their result in CS1 modules. CSC1022 is considered to be the most important module on our programme, as it is the only core module. Students who fail a core module (¡40%) are not allowed to progress to CS2.

The improvement between CS1 and CS2 results is a positive step in showing that metacognitive processes are taking place.

5.2 Confidence in CS2

We gave each part of the modified Likert scale a value: Strongly agree: 2, Agree: 1, Unsure: 0, Disagree: -1 and Strongly disagree: -2.

This meant that when looking at a student's confidence, we were able to give them a value associated with a specific part of the coursework and the coursework as a whole, for both, before attempting the coursework and after submitting the coursework. We were also able to create a category for the level of confidence based on the value returned: -10 to -5: Very Weak Confidence, -4 to 0: Weak Confidence, 1 to 3: Some Confidence, 4 to 7: Strong Confidence and 8 to 10: Very Strong Confidence. Using a categorical scale allowed us to see if the confidence of a student changed between part 1 and 2. It is worth noting at this stage that no student expressed strongly disagree to any question.

First we analysed the confidence of students in part one of the coursework. We found that the majority of students (62.1%) can be identified to have a strong confidence and the next substantial result was nearly a quarter of the students(24.1%) who were confident. When looking at the categories which would show a lack of confidence (very weak confidence), there were no students who were identified. Students with very strong confidence were a small minority (10.4%) along with a smaller minority (3.4%) for those who had a weak confidence in their ability.

Table 3: Confidence measures both before attempting and submitting the coursework.

	Before attempting				After submitting			
	1	2	Whole	Total	1	2	Whole	Total
1	5	-1	3	7	8	7	9	24
2	5	1	1	7	4	3	4	11
3	5	-3	3	5	5	-3	3	5
4	8	6	8	22	9	10	9	28
5	4	4	3	11	4	4	3	11
6	5	4	3	12	5	4	3	12
7	3	-1	-1	1	6	5	6	17
8	10	9	10	29	9	10	10	29
9	1	1	3	5	1	1	3	5
10	5	3	4	12	6	4	3	13
11	2	3	3	8	8	-2	4	10
12	2	3	2	7	2	0	0	2
13	7	6	7	20	4	5	5	14
14	5	5	4	14	5	5	4	14
15	4	2	1	7	6	-1	1	6
16	4	1	1	6	10	5	6	21
17	0	-2	0	-2	0	-2	0	-2
18	4	4	2	10	4	4	2	10
19	4	0	2	6	4	0	2	6
20	5	3	4	12	4	-1	3	6
21	6	5	4	15	4	2	4	10
22	3	3	1	7	4	-2	1	3
23	6	1	4	11	1	1	2	4
24	3	1	-1	3	-1	-1	0	-2
25	6	6	7	19	2	4	4	10
26	2	2	2	6	2	0	2	4
27	4	0	4	8	4	0	4	8
28	5	3	7	15	3	2	2	7
29	9	9	7	25	6	4	3	13

In part 2 of the coursework, the results shifted to show that confidence had decreased between part one and two. The most substantial category became 'some confidence' (44.9%), rather than 'strong confidence' (27.6%). Cases in which students showed 'weak confidence' rose (20.7%) and again no students were categorised as having a lack of confidence. In all cases, students were less confident or equally as confident in the second part of the confident to the first part.

Looking at the coursework as a whole the results did not change drastically. Again, the majority of students were categorised as having 'some confidence' (48.3%) in the coursework and a 'strong confidence' (34.5%). The number of students categorised as showing a lack of confidence, again,

was zero.

When completing the questionnaire after submitting the coursework, there was some minor changes to the students level of confidence. Part one of the coursework found similar results to the confidence levels students expressed in before attempting the coursework. The majority of students , again, were categorised as having a 'strong confidence' (55.2%). Interestingly, the number of students categorised as having 'weak confidence' doubled at this stage (6.8%) and the number who had 'very strong confidence' (17.3%) rose. In part two of the questionnaire, again, the results stayed similar to that of before attempting the coursework. There was no clear majority in this section and both 'weak confidence' and 'strong confidence' had an equal (37.9%) share of the results. Those who had 'very strong confidence' (6.8%) remained the same. Confidence on the coursework as whole had minor differences but the number of students who had 'weak confidence' (10.4%) and were 'confident' (48.3%) remained the same. Those who were 'extremely confident' (10.3%) decreased and those who had 'strong confidence' (34.5%) increased.

5.3 Confidence and Operating System Result

The results show that students who achieved a high mark also expressed very strong and strong confidence levels. Some potential outliers could be identified within this study, student 29 expressed they had strong confidence in the coursework but overall in the module they attained 35%. This could be an indication of an outlier or a student who doesn't have cognitive awareness of their learning and have misconceptions of how their previous experience could relate to their current experience.

The student that attained 98% in the module was categorised with very strong confidence and this should be expected in a student who achieved such a high result. What is more worrying is the student who failed the module but expressed strong confidence in their work. This level of confidence could just be for the coursework, rather than the module as a whole. In hindsight, this is something that we should have considered when analysing their confidence in coursework against their result in the module overall.

6 CONCLUSION

The results of our study show that students who have greater levels of metacognitive abilities and experiences are able to transfer their learning better and achieve a higher result. Further research and investigation into how metacognition can be facilitated within HE is needed. We hope to be able to start designing curricula that aids the development of student's metacognitive processes. This curricula will hope to negate the problems caused by modularisation, and improve a student's cognitive development and learning transfer. Computer science is a field that rapidly changes and students leaving HE need to be able to adapt to these rapid changes. Through developing students metacognitive ability and helping them see the connections from one learning experience to another, we can better prepare them for these rapid changes.

7 FUTURE WORK

There are several different routes for future work. In this investigation we looked at confidence levels that students had in coursework. This could be extended to look at exam questions and assess a student's confidence before and after attempting a question. This would be a minor extension of this study, but a more major extension would include assessing the confidence of the student's in modules other than operating systems. If we were to extend this study to programming and computer architecture then we could monitor the student's confidence level as it develops over modules. This investigation focused on the role of confidence with metacognition, future work will look at other cognitive processes within learning, such as learning styles and how they relate with student attainment. Looking at the confidence and metacognitive abilities of pre-entry students to courses and also recent graduates would be an interesting step to this research. With the spin of looking a pre-entry students we could identify any metacognitive practice gained from previous studies. Work with graduate students would allow us to see the skills gained in their studies and the impact those studies have had on their job.

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