Assessing the Metacognitive Awareness among Foundation in Engineering Students

Betsy Lee Guat Poh, Kasturi Muthoosamy, Chiang Choon Lai, Ooi Chel Gee

Abstract

The transition phase is a critical moment to students who have completed their secondary school education and are proceeding to pre-university education in Malaysia. The long duration of exposure to rote-learning and examination oriented education systems at school has somehow shaped these students' perceptions about teaching and learning. Thus, this paper aims to examine the quality of first year students' experiences in constructing their knowledge and skills throughout the Foundation in Engineering (FIE) programme. This experience refers to metacognitive awareness, namely students' learning experience from one mode of thinking to the other to construct meaningful knowledge and skills. The researchers used the Metacognitive Awareness Inventory (MAI) (Schraw and Dennison, 1994) as a rating tool to trace the students' baseline in metacognition and access their successive levels of metacognitive awareness throughout their first semester in the FIE program. The students showed improvements in a number of metacognitive sub-processes. The findings provided the details of the quality of the program's efficacy and served as a benchmark for future development of effectiveness of teaching and learning approaches.

Keywords: metacognition; metacognitive awareness; teaching and learning; academic achievements; MAI.

Introduction

The term "metacognition" was coined by John Flavell (1979) to described the state of consciousness of one's own thinking and learning processes (Kayashima *et al*., 2004). Learners exhibiting metacognition are acutely aware of the knowledge content in their mental resources and possess the ability to control and monitor these cognitive activities to perform higher-order thinking skills (Ozsoya & Ataman, 2009; Pennequin *et al.*, 2010). Thus, two essential components play a dominant role in the control of metacognition i.e. metacognitive knowledge and metacognitive skills (Hollingworth & McLoughlin, 2001). Metacognitive knowledge refers to what one recognizes about his or her own potential in processing information, about knowing the features of a task and also allocating appropriate strategies that can be applied to successfully accomplish a task (Flavell, 1987; cited in Hollingworth & McLoughlin, 2001). Metacognitive skills refer to the ability to use metacognitive knowledge effectively (Ozsoya & Ataman, 2009). Metacognitive activities help to control and monitor one's own cognitive system and functioning process. Self-regulation exercises commit one to demonstrate high order executive skills such as prediction, planning, monitoring and evaluation (Ozsoya & Ataman, 2009; Schneider & Artelt, 2010).

Engineers by definition are real life problem solvers, critical thinkers and innovators. It is expected from the engineers to develop solutions for various application problems. In other words, they are self-regulated learners and possess the ability to think metacognitively. The path to become an engineer regardless of specialization primarily relies on engineering education. Thus, the development of engineering students' thinking abilities highly depends on the teaching and learning process and the contextual learning environment during their academic years. This includes the exposure of students to various engineering concepts and hands-on experience to develop their technical skills. In other word, metacognitive skill is an integral part of the knowledge development that engineering students should cultivate and master as early as possible starting from the Foundation in Engineering (FIE).

Problem Statement

The transition period from school to university is a critical moment to upgrade students' ability to university students' status. Students' performance at the primary and secondary school level in Malaysia is constantly assessed by grade levels achieved in their examinations. In the process, they fail to develop an inquisitive mind and analytical skills as most of their time is spent attending tuition classes, extra classes, and examination workshops to better prepare them for the upcoming examinations. As a result, these students retain a rote learning mindset and studying pattern when they enter the university. These are the common issues observed in first year students at other institutions as well (Bowles et. al., 2011; Briggs, Clark & Hall, 2012). In order to provide the academic preparation of the first year entry in the FIE programme, the Foundation Engineering School has begun to review the performance of its programme to ensure that it provides students with top notch engineering education. Thus, this study aims to assess the FIE students' baseline and follow-up levels of metacognitive awareness throughout the program.

Literature Review

The importance of metacognitive awareness in teaching and learning has been widely acknowledged (Hurme & Jarvela, 2001; Ozsoya & Ataman, 2009; Schneider & Artelt, 2010; Stillman & Mevarech, 2010). Nevertheless, metacognition is an inner awareness rather than an observable behavior which is crucial to measure such ability. Several explorations have been carried out by researchers to discover appropriate instruments to measure the metacognitive ability. Schraw and Dennison (1994) developed the 52 item Metacognitive Awareness Inventory (MAI) to measure adults' metacognitive awareness. The findings indicated that MAI provides a reliable initial test of metacognitive awareness among older students. Kazemi and Ghoraishi (2012) measured university students' metacognitive awareness in mathematical problem solving by using two methods i.e., protocol analysis and self-questionnaire. A total of 64 university students were asked to write their total mental process during problem solving and subsequently they responded to a metacognitive inventory that rated their metacognitive abilities. The results showed that both methods were applicable for measuring metacognitive awareness.

Self-questionnaire is the most extensively used method to measure metacognition, whereby it allows the participants themselves to rate their metacognitive skills without a researcher's interference. Young and Fry (2008) assessed Schraw and Dennison's MAI to ascertain how the metacognitive rating associates to single tests and cumulative GPA as well as end-course grades for college students within one semester. The findings revealed a significant positive correlation between the MAI and overall academic performance. However, they were amazed to discover the insignificant correlation between the MAI scores and a single test of a course. According to their report, single test performance might be influenced by the affective behaviors of students over a particular course. In another study, Kesici,Erdogan, and Özteke., (2011) examined differences in metacognitive awareness strategies in prediction of high school students' mathematics and geometry course achievements. Schraw and Dennison's MAI (1994) was also adapted in the study and discovered that declarative knowledge is a significant predictor of mathematics course achievement while evaluation and procedural knowledge of metacognitive awareness strategies are significant predictors of geometry course achievement. Ciascai and Lavinia (2011) employed the Junior Metacognitive Awareness Inventory to scrutinize the potential gender differences in metacognitive abilities among a group of eighth grade pupils. Their statistical analysis indicated that the boys and girls adapted differently in their metacognitive knowledge and skills in the learning process.

However, subsequent research reports inconclusive findings regarding the differences in metacognition according to pupils' gender. Abdolhossini (2012) reported the effects of cognitive and meta-cognitive methods of teaching mathematics subject for high school students. The results showed that cognitive and meta-cognitive methods of teaching had positive effects on educational progress of male and female students. Nevertheless, no positive relation was observed between the boys' and girls' average grades. Ayazgok and Aslan (2014) examined science and mathematics university students' reflective thinking skills and level of metacognitive awareness according to age, gender and the level of class and found that there was no significant difference according to gender regarding metacognitive awareness or reflective thinking. Thus, there are a variety of challenges related to metacognition investigation. For instance, Bersley and Spero (2014) compared three groups of college students who received different instruction methods of the same course material. They revealed that the group receiving direct infusion of critical thinking increased the students' knowledge of what they knew and did not know. In other word, the students' metacognitive awareness was stimulated through the act of intervening. Hoorfar and Taleb (2015) studied the correlation between mathematics anxiety and metacognitive knowledge for 323 seventh grade female students. Results showed that mathematics anxiety was negatively correlated with metacognitive knowledge. On the other hand, Bayat and Meamar (2016) investigated to what extend algebra problem solving performance, metacognitive strategies and cognitive strategies served as predictors of mathematics achievement in a public university in Malaysia. The findings revealed asignificant contribution of algebra problem solving performance and overall metacognition in mathematics achievement.

Thus, the purpose of this study is to trace the students' baseline in metacognition and access their successive levels of metacognitive awareness throughout their first semester in the FIE programme. In addition to this,, the researcher would like to measure to what extent the metacognitive awareness served as a determining factor to students' overall academic performance.

Methodology

In this study, a quantitative method was used. The quantitative data helped to tracestudents' baseline in metacognition and access their successive levels of metacognitive awareness throughout their second semester in the FIE programme. The researchers also examine to what extent the MAI scores served as a determining factor to students' overall academic performance.

Participants

173 surveys were distributed to the FIE students, out of which 75 were disqualified and 98 valid surveys were analyzed. About 23.5% of the survey participants were female and the rest were male (Figure 1). This is the usual female to male ratio in any engineering department. Although gender is sometimes perceived to be a factor in the outcome of the MAI scorea prior report (Abdolhossini, 2012; Ayazgok & Aslan, 2014) revealed insignificant gender differences on metacognition abilities, thus in this present study the gender factor has been disregarded.

The programme consists of three semesters and the study was conducted when the participants were in their second semester. There were six modules offered in Semester 2 i.e., Calculus 1, Mathematical Techniques, Computer Method, Electricity and Magnetism A, Thermal Science A and Study Skills. Study Skills was delivered as a project-based subject where the students worked in groups to organize a charity event such as a marathon, blood donation drive, concert and others. The aim of this module was to develop report writing skills and soft skills in order to prepare them for undergraduate studies and for future careers.

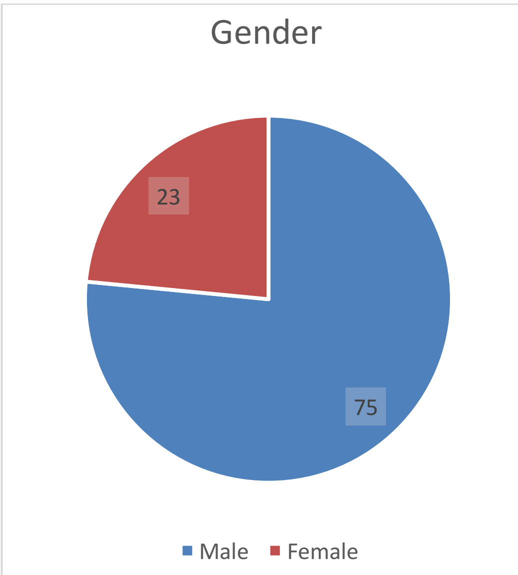

Figure 1. Gender Composition

Instruments

Schraw and Dennison's MAI (1994) was used in this study. In the MAI inventory, there are 17 items related to Knowledge of Cognition (declarative knowledge, procedural knowledge, conditional knowledge) and 35 items related to the Regulation of Cognition (planning, monitoring, evaluation, debugging strategies and information management strategies). The 52 items were measured by a 5-point Likert scale ranging from "strongly disagree" to "strongly agree." A list of abbreviations describing the metacognitive components of Knowledge of Cognition and Regulation of Cognition is exhibited in Table 1 while Figure 2 shows the composition of questions in percentage for each metacognitive component.

Table 1. List of abbreviations representing the metacognitive components of MAI

Abbreviation	Meaning
IMS	Information Management Strategies
DK	Declarative Knowledge
M	Monitoring
P	Planning
E	Evaluation
PK	Procedural Knowledge
CK	Conditional Knowledge
DS	Debugging Strategies

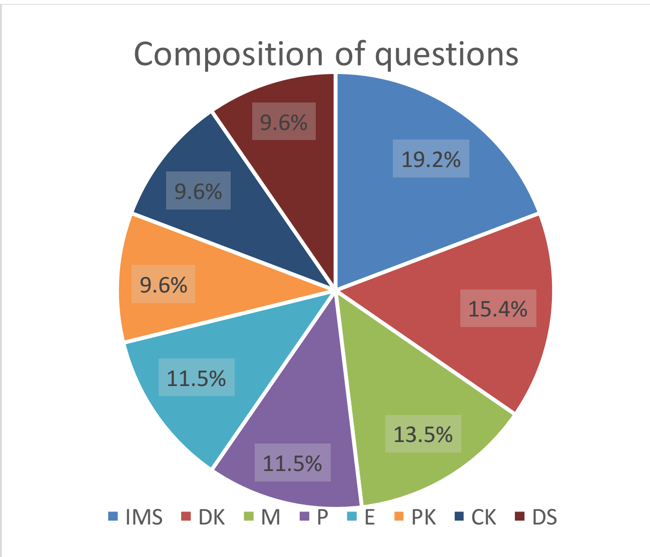

Figure 2. The percentage of items for each metacognitive component

Procedure

The participants were given the survey on the 1st, 6th and 10th week of semester two. An introduction about the study was presented to the students before the first survey was conducted. The participants were informed about the confidentiality of their responses and their participation was on a voluntary basis. During the second survey, the results of the first survey were reported to the participants and were explained briefly about their baseline in metacognitive skills. At the final survey, the students were given a brief statement about their metacognitive progression based on the second survey's results before they filled in the questionnaire.

Data Analysis

The quantitative data were analyzed using SPSS 15.0 to measure the descriptive status and distribution of the data set. In order to examine the significance of metacognitive awareness as an influential factor on students' academic performances, Spearman's Rho non-parametric correlation analysis was carried out.

Results and Discussions

Overall, there was a gradual increase in positive responses from Survey 1 up to Survey 3 (Figure 3), with a significant decrease in the Strongly Disagree sector.

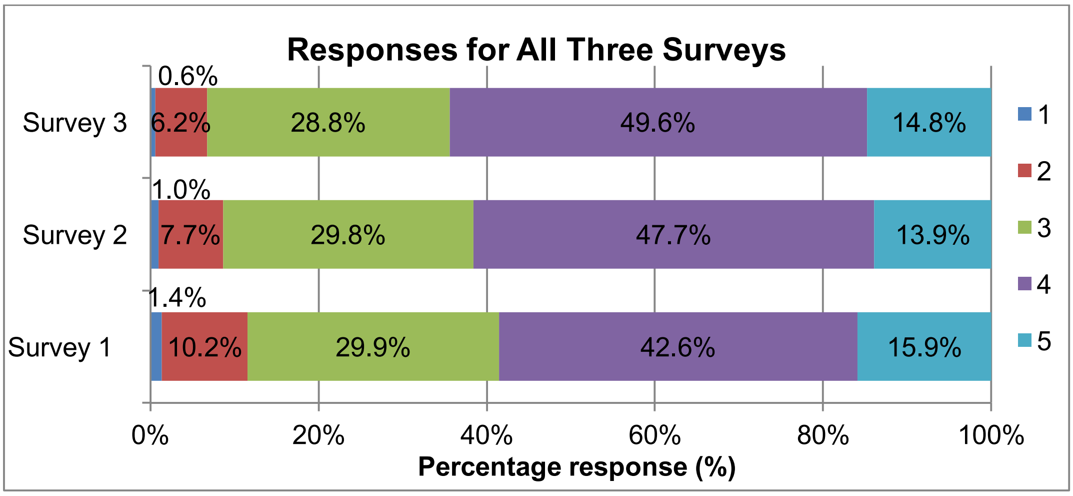

Figure 3. The distribution of the agreement and disagreement scales for the three conducted surveys

Note: 1=Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strongly Agree.

Though no intervention was carried out in this study, the positive response is perceived to be due to students' persistent exposure to and awareness of the various skills in learning. The students were briefed about all the skills involved in metacognition during the three surveys. For instance, when Survey 2 was conducted, the students were given feedback on the overall MAI score in Survey 1 before they answered a series of questions reflecting their metacognitive awareness. Similarly, prior to Survey 3, feedback on Survey 2 was given with extensive explanation regarding the students' strengths and weaknesses. This could have initiated the students to recognize and reflect on their metacognative abilities and explore unattained metacognitive skills throughout the whole semester.

The in-depth study focusing on the Knowledge of Cognition and Regulation of Cognitionfor both sectors showed a gradual increase in the mean score over the three surveys conducted as shown in Table 2. As aforementioned, with three surveys conducted within a short duration (one semester), the students were constantly reminded of the learning skills available for them to explore and enhance their learning experience. This could have played a role with the positive outcome on both sectors of Knowledge and Regulation of Cognition. Metacognition is a self-awareness ability, and students are often not conscious about their knowledge and skillsin the learning process (Kazemi & Ghoraishi, 2012).

Table 2. Mean and standard deviation of the MAI score

	Mean and standard deviation		
	Survey 1	**Survey 2**	**Survey 3**
Overall MAI score	3.62 ± 0.350	3.66 ± 0.322	3.72 ± 0.340
Knowledge of Cognition	3.56 ± 0.827	3.64 ± 0.753	3.68 ± 0.702
Regulation of Cognition	3.64 ± 0.822	3.67 ± 0.757	3.74 ± 0.713

Responses Difference between the Surveys

Figure 4 compares the score for all eight components categorized in the MAI based on Agree, Neutral and Disagree divisions. Initially, the students revealed their strong awareness, especially in their regulation abilities and their strength in debugging skills, which exhibited the highest. However, the ten weeks of teaching and learning sessions exposed the students to a variety of activities that added to their metacognitive knowledge and experiences. InKnowledge of Cognition, the level of agreement on the subdivisions, such as declarative knowledge and conditional knowledge showed a continuous increase. However, the students' opinion about their procedure knowledge decreased slightly after the second survey.

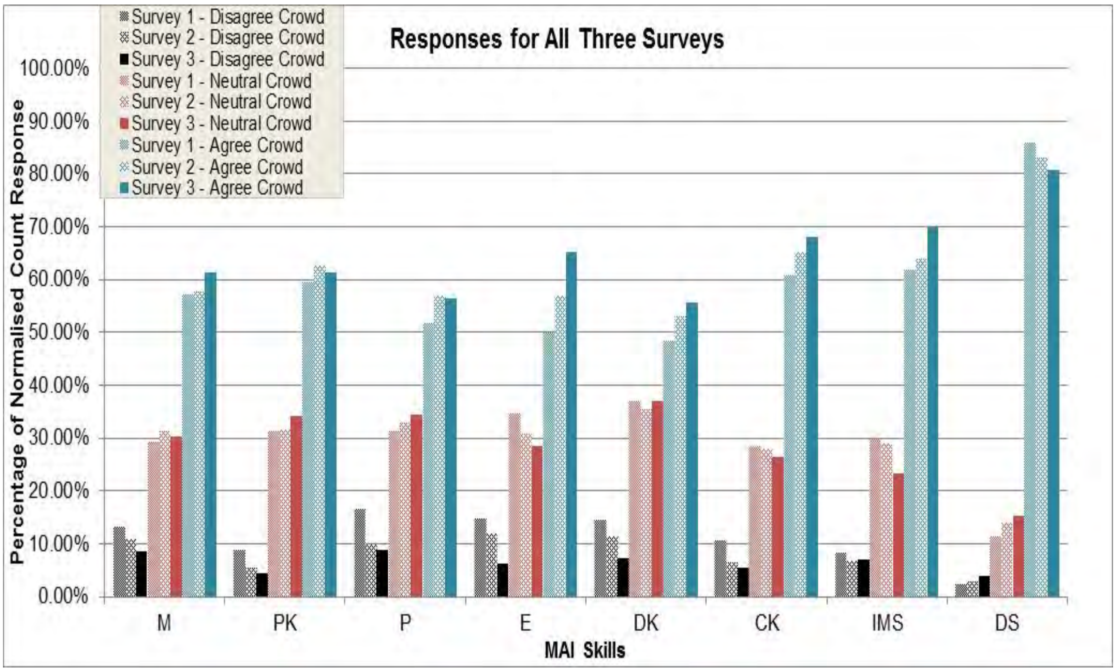

Figure 4**.** The breakdown of the responses of participants on the eight MAI skills based on three types of crowds (Agree, Neutral, and Disagree)

Regarding metacognitive experiences (Regulation of Cognition), the students showed greater abilities in management, evaluation and information management strategies. However, students' awareness about their debugging skills decreased over the three surveys.

The discouraging response for debugging skills could be due to the fact that initially (during Survey 1) the students were unfamiliar with the content and depth of knowledge required from each module as well as the lecturer's expectations. However, as the weeks of teaching and learning passed, the students began to realize the demands and challenges from each module and thus the low response in debugging skills. This would be especially felt in modules that require theoretical knowledge and applications (problem solving skills), such as Calculus 1 and Thermal Science A. Anxiety and low confidence has been found to be directly related to negative metacognition (Hoorfar & Taleb, 2015).

When responses between surveys were compared, more than 5% difference in the evaluation skills were observed between Survey 1 and 2 (Figure 5). In other word, the students showed higher positive responses when it comes to items such as "*I know how well I did once I finish a test,*" "*I summarized what I've learned after I finish,*" and "*I ask myself how well I accomplish my goals once I'm finished.*" On the other hand, the students' disagreement responses in terms of planning skills exhibited a difference of more than 5% between the two surveys.

Some students presented a lesser negative attitude toward planning when they responded in Survey 2. They seemed confident when they answered the items such as "*I pace myself while learning in order to have enough time,, I think about what I really need to learn before I begin a task," "I set specific goals before I begin a task," "I ask myself questions about the material before I begin," "I read instruction carefully before I begin a task," and "I organize my time to best accomplish my goals."*

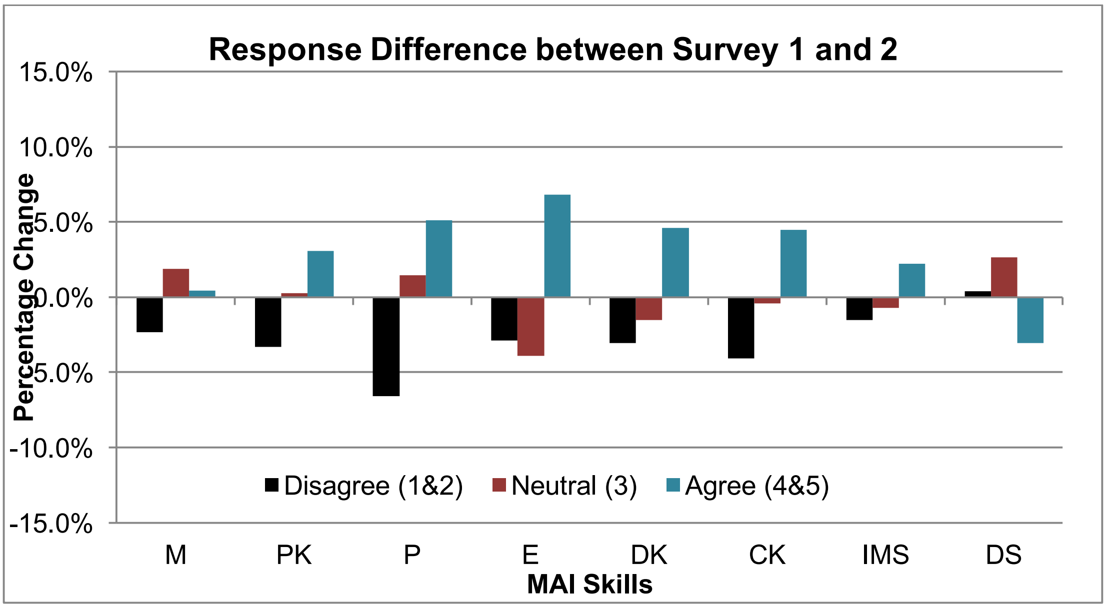

Figure 5. Differences in students' responses between Survey 1 and Survey 2

The students showed a decreased response in the debugging strategy after five weeks of teaching and learning sessions. The students seemed to be hesitant about their debugging strength when they responded to items such as "*I change strategies when I fail to understand,*" "*I re-evaluate my assumptions when I get confused,*" "*I stop and go back over new information that is not clear*" and "*I stop and reread when I get confused.*"

After the third survey, the students' responses in planning showed minimal differences i.e., less than 1% between the Survey 2 and 3 (Figure 6). However, many students focused on their strengths and weakness in their regulation skills, especially on monitoring, evaluation and information management skills. There were some students that felt their strength in evaluation improved over the ten weeks of teaching and learning sessions.

At the same time, some students were more aware of their information management skills and monitoring skills when they responded to the items such as "*I ask myself periodically if I am meeting my goals,*" '*I consider several alternatives to a problem before I answer,*" "*I slow down when I encounter important information*" and "*I consciously focus my attention on important information.*". Nevertheless, there was a tremendous drop in the students' confidence with the debugging strategy.

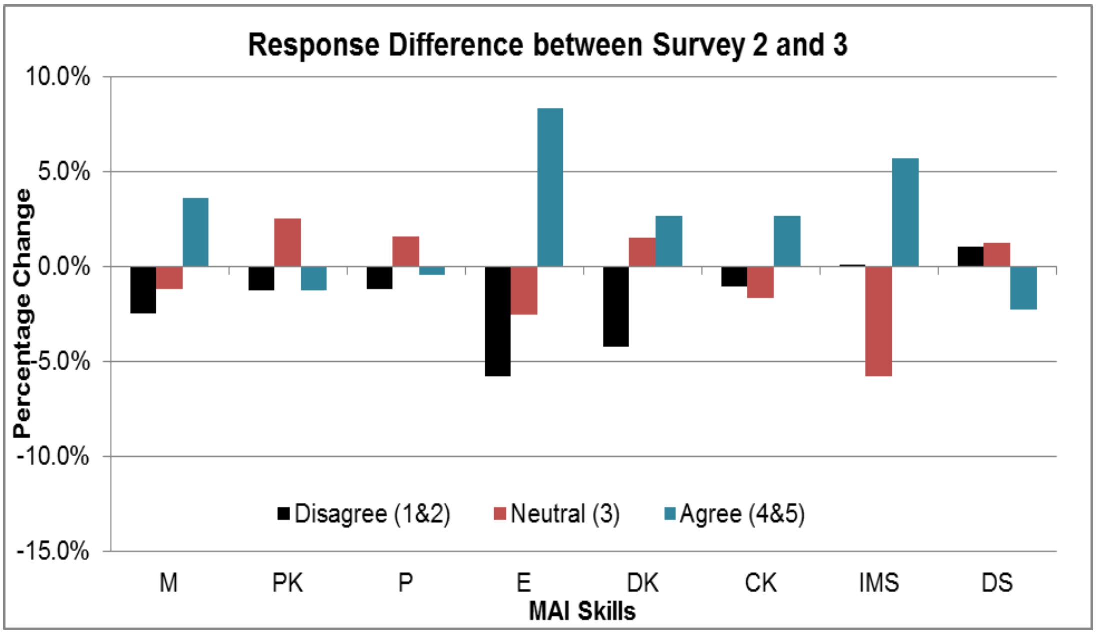

Figure 6. Differences in students' responses between Survey 2 and Survey 3

Obvious positive responses were seen for all the eight MAI components except debugging strategy (Figure 7) over the ten weeks of teaching and learning sessions. As there are six modules taught for the semester, there is a wide spectrum of learning skills experienced by the students. For instance, the Study Skills module, which is project-based, requires the students to organize a charity event focusing on management proficiency and related skills such as monitoring, planning and evaluation.

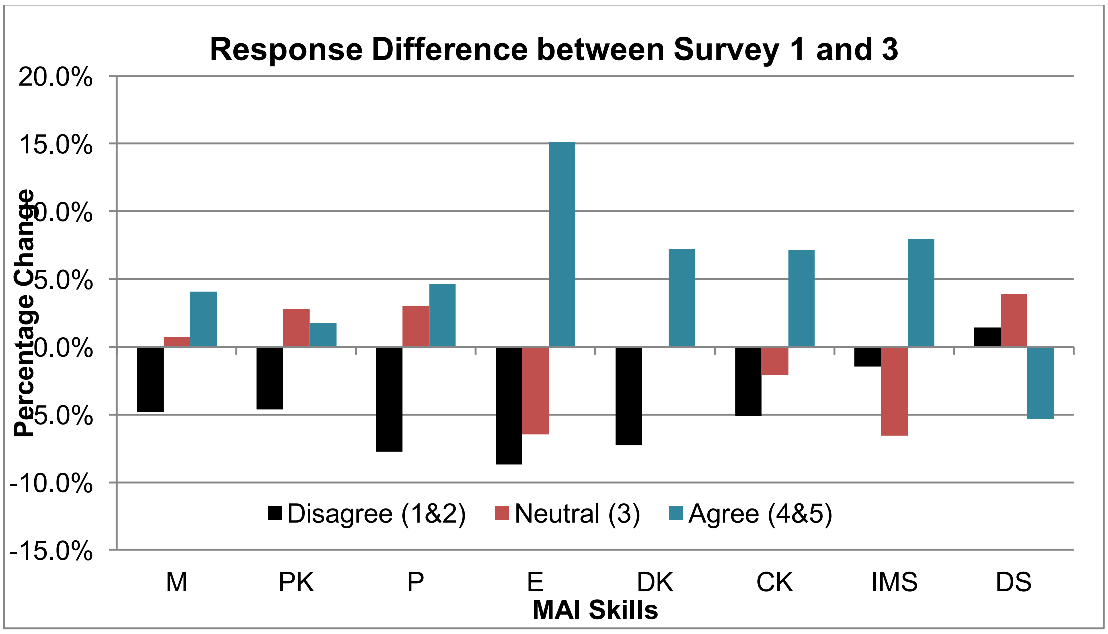

Figure 7. Differences in students' responses between Survey 1 and Survey 3

MAI Score and Overall Academic Achievement

A Spearman's correlation was conducted to determine the relationship between overall academic achievement and the MAI subscales. The MAI scores were based on survey 3 where the students have completed their Semester 2 teaching and learning sessions. Findings from the analysis are summarized in Table 3.

Table 3. Correlations between MAI components' scores and overall academic achievement

			Exam Result	Mean M	Mean PK	Mean P	Mean E	Mean DK	Mean CK	Mean IMS	Mean DS
Spearman's rho	Exam Result	Correlation Coefficient	1.000	-.185	-.037	-.203*	-.054	-.013	.141	-.163	-.066
		Sig. (2-tailed)	.	.068	.717	.045	.595	.896	.167	.109	.520
		N	98	98	98	98	98	98	98	98	98

*. Correlation is significant at the 0.05 level (2-tailed).

According to the findings of the study, there was no significant correlation between overall academic achievement and all MAI components. However, there appears to be a weak correlation between planning and overall academic achievement $r = -0.203$, $p < 0.05$. This could be mainly due to the fact that this study serves only as an awareness program rather than an intervention to the existing teaching and learning delivery system. In addition, the survey was conducted based on all six modules in the semester, whereas a more focused survey on a particular module might provide a significant correlation between MAI score and academic achievement. As previously reported, interventions or direct infusion and continual reinforcement are necessary to improve the metacognitive skills among students, especially for mathematics subjects and subjects that require problem solving or critical thinking (Kesici *et al*., 2011; Bensley & Spero, 2014). In this case, intervention would be necessary to improve the students' debugging skills along with the other seven MAI skills. In addition, a mixed methodology (protocol analysis and self-questionnaire) would be needed to validate and substantiate the measurements of metacognitive awareness (Kazemi & Ghoraishi, 2012).

Conclusion

Based on the findings, the aim of increasing awareness among FIE students on their metacognitive skills is a useful tool for learning efficiency, critical thinking and problem solving (Kesici *et al*., 2011). There was an obvious improvement in the eight tested metacognitive skills based on preliminary (Survey 1), intermediate (Survey 2) and end of the semester (Survey 3) surveys, with the exception of debugging skills. Nevertheless, there was no relation between the MAI score and the overall academic achievement of the students. Despite this limitation, the current study serves as an awareness program for the students and as preliminary data for the lecturers. As a future study, intervention on a specific module will be carried out with great emphasis on improving the students' debugging skills.

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References

Abdolhossini, A. (2012). The effects of cognitive and meta-cognitive methods of teaching in mathematics. *Procedia - Social and Behavioral Sciences*, *46*, 5894–5899. doi:10.1016/j.sbspro.2012.06.535

Ayazgök, B., & Aslan, H. (2014). The review of academic perception, level of metacognitive awareness and reflective thinking skills of science and mathematic university students. *Procedia-Social and Behavioral Sciences*, *141*, 781-790.

Bayat, S., & Meamar, A. (2016). Predicting algebra achievement: Cognitive and meta-cognitive aspects. *Procedia-Social and Behavioral Sciences*, *217*, 169–176. doi:10.1016/j.sbspro.2016.02.054

Bensley, D. A., & Spero, R. A. (2014). Improving critical thinking skills and metacognitive monitoring through direct infusion. *Thinking Skills and Creativity*, *12*, 55-68.

Bowles, A., Dobson, A., Fisher, R., & McPhail, R. (2011). An exploratory investigation into first year student transition to university. In K. Krause, M. Buckridge, C. Grimmer, and S. Purbrick-Illek, (Eds.), *Research and Development in Higher Education: Reshaping Higher Education, 34* (pp. 61 – 71).

Briggs, A. R. J., Clark, J., & Hall, I. (2012). Building bridges: Understanding student transition to university. *Quality in Higher Education*, *18*(1), 3-21.

Brown, A. (1987). Metacogntion, executive control, self-regulation, and other more mysterious mechanisms. In F. Weinert and R. Kluwe (Eds.), *Metacognition, motivation and understanding* (pp. 65-116). Hillsdale, NJ: Erlbaum.

Ciascai, L., & Lavinia, H. (2011). Gender differences in metacognitive skills. A study of the 8th grade pupils in Romania. *Procedia-Social and Behavioral Sciences*, *29*, 396–401. doi:10.1016/j.sbspro.2011.11.255

Hollingworth, R. W., & McLoughlin, C. (2001). Developing science students' metacognitive problem solving skills online, *Australian Journal of Educational Technology*, *17*(1), 50-63.

Hoorfar, H., & Taleb, Z. (2015). Correlation between mathematics anxiety with metacognitive knowledge. *Procedia-Social and Behavioral Sciences*, *182*, 737–741. doi:10.1016/j.sbspro.2015.04.822

Hurme, T. R., & Järvelä, S. (2001). Metacognitive processes in problem solving with CSCL in mathematics. In P. Dillenbourge, A. Eurelings, & K. Hakkarainen (Eds.) Proceedings of the *European perspectives on computer-supported collaborative learning* UORO-CSCL 2001 (pp. 301-307). Maastricht, Neterhlands: University of Maastrict.

Kayashima, M., Inaba, A., & Mizoguchi, R. (2004). What is metacognitive skill? collaborative learning strategy to facilitate development of metacognitive skill. Proceedings from *World Conference on Educational Multimedia, Hypermedia and Telecommunications* (pp. 2660-2665).

Kazemi, F., & Ghoraishi, M. (2012). A comparison between two methods of measurement of meta-cognitive awareness on mathematical problems solving of university students.

Procedia-Social and Behavioral Sciences, *46*(1987), 3807–3811. doi:10.1016/j.sbspro.2012.06.151

Kesici, S., Erdogan, A., & Özteke, H. I. (2011). Are the dimensions of metacognitive awareness differing in prediction of mathematics and geometry achievement? *Procedia-Social and Behavioral Sciences*, *15*, 2658–2662. doi:10.1016/j.sbspro.2011.04.165

Ozsoy, G. & Ataman. A. (2009). The effect of metacognitive strategy training on mathematical problem solving achievement. *International Electronic Journal of Elementary Education*, *1*(2), 67-82.

Pennequin, V., Sorel, O., Nanty, I., & Fontaine, R. (2010). Metacognition and low achievement in mathematics: The effect of training in the use of metacognitive skills to solve mathematical word problems. *Thinking & Reasoning*, *16*(3), 198-220.

Schneider, W., & Artelt, C. (2010). Metacognition and mathematics education. *ZDM*, *42*(2), 149-161.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology*. doi:10.1006/ceps.1994.1033

Sperling, R. A., Howard, B. C., Staley, R., & DuBois, N. (2004). Metacognition and self-regulated learning constructs. *Educational Research and Evaluation*, *10*(2), 117-139.

Stillman, G., & Mevarech, Z. (2010). Metacognition research in mathematics education: From hot topic to mature field. *ZDM*, *42*(2), 145-148.

Young, A., & Fry, J. D. (2008). Metacognitive awareness and academic achievement in medical students. *Journal of the Scholarship of Teaching and Learning*, *8*(2), 1–10. doi:10.3109/0142159X.2010.487711

Zulkiply, N., Kabit, M. R., & Ghani, K. A. (2009). Metacognition: What role does it play in students' academic performance? *International Journal of Learning*, *15*(11).