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Technology Integrated with Metacognitive Regulation Approach as Natural Formula for Connecting Mastery and Effective Learning in Mathematics

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ABSTRACT--*This study aims to look at the effectiveness of mathematical learning through a metacognitive regulation approach with the technology integrated through modules, kits and interactive activities. Metacognitive regulation skills are students' ability to manage their learning by planning, monitoring and evaluating. The combination of technology has created the motivation and impetus for meaningful learning. The objective of this study was to look at the impact of using the Meta-Seller Tutoring module and mathematics learning kit on the metacognitive regulation skills and mastery of student mathematics concepts. Based on quantitative approach using experimental design, the present study involved 159 students from three secondary schools. The results show that the use of modules combined with technology and metacognitive regulation strategies has the greatest impact on the metacognitive regulation skills and students' mastery of mathematics concepts in shaping effective learning. The implications indicate that, teachers need to increase their knowledge of the latest pedagogy and improve their teaching design skills based on current technologies and trends. The parties need to look at approaches in the current curriculum to be more technology-friendly as well as apply learning strategies based on metacognitive skills that are seen as the best platform for improving students' thinking skills.*

Keywords-- *Metacognitive regulation; Metacognitive regulation approach; Students' mastery; Mathematics learning; Technology integrated*

I. INTRODUCTION

Mathematics learning not only provides the basics of mathematics but also needs to be integrated with the various skills and competencies (Philippe, 2018). True mathematics learning is related to the ability to adapt and apply all mathematical concepts learned (NCTM, 2000). This ability is related to mathematics competency. According to Palmer & Johannson (2018), mathematical competencies involves a wide range of skills including the ability to formulate problem-solving skills, apply concepts, build relationships, be able to choose appropriate mathematical methods, follow reasoning processes and can use mathematical knowledge in the field of discussion. Therefore, a good mastery of mathematics concepts is fundamental to mathematics competency and is also a key factor in ensuring success in mathematics education.

According to Tony Karnain et al (2014), Ibrahim & Iksan (2017) and Abdullah, Rahman & Hamzah (2017), the level of mathematics mastery among students is still low and a hindrance in achieving mathematics education

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goals. Musso, Kyudt, Cascallar & Dochy (2012) and Phi (2017) have argued that among the issues contributing to weak learning in mathematics teaching is, does not well develop students' metacognitive regulation skill during the learning. The ability and skill of metacognitive regulation greatly influence the learning process of mathematics (Amin & Sukestiyarno, 2015; Abdul Qohar & Utari Sumarmo, 2013). Metacognitive regulation is the highest component of metacognitive skills in addition to metacognitive knowledge (awareness) and metacognitive experience (Tarricone, 2011; Du Toit & Du Toit, 2013; Crawford, 2018). Beginning with metacognitive knowledge and experience, students will then develop cognitive skills to plan thinking activities and actions to achieve their learning goals and successes (Crawford, 2018). If students can plan, monitor and evaluate their cognitive actions while learning or solving mathematics problems, then they will be able to master the mathematics concepts (Daher, Anabousy & Jabarin, 2018).

Tarricone (2011) argues that metacognitive regulation is a secondary cluster of metacognitive and is the driving force and catalyst for metacognitive knowledge in mathematical problem-solving. This metacognitive regulation is also the result of the interaction between self-regulation and students' metacognitive knowledge (Tarricone, 2011). Therefore, it is very important to develop a mathematics learning approach that can train and develop metacognitive regulation skills. Accordingly, Phi (2017) and Crish (2015) state that teachers need to emphasize students' thinking and exploration of their knowledge through an active and interactive learning approach to achieve the success of the mathematics curriculum. Choosing inappropriate activities can hinder interaction and block for metacognitive regulation occur (Smith & Mancy, 2018). Therefore, there is a need for this study to look at the effectiveness of a technology-integrated with the metacognitive regulation approach towards students' mastery of mathematics concepts. The researcher took the initiative to develop the module by applying an approach through a metacognitive regulation strategy combined with the elements of technology to produce an interactive kit activity as an intervention to the mastery of student in mathematics concepts. Furthermore, a study of the effectiveness of the use of such modules should be carried out to gain insight and impact on mathematics learning.

II. MATHEMATICS LEARNING: IMPROVE MASTERY AND BEING EFFECTIVE LEARNING THROUGH METACOGNITIVE REGULATION APPROACH

In learning mathematics, students need to act on the way they think, by designing, monitoring and evaluating their level of understanding (Van der Stel, Veenman, Deelen & Haenen, 2010). Therefore, for students to master concepts and form effective learning, they need to be exposed to learning approaches that can lead to metacognitive skills, namely through metacognitive learning strategies (Du Toit & Kotze, 2009; Smith & Mancy, 2018). Metacognitive learning strategies are those that can practice thinking and analytical skills (Simth & Mancy, 2018; Hasbullah, 2015). According to Menz & Cindy Xin (2016), metacognitive strategies will shape students' learning medium through the impulse to manage, organize, evaluate and build confidence in their learning as only the student himself understands his learning needs and goals based on current situations and content. This situation is described by Zumbrunn, Tadlock & Roberts (2011) as a process of metacognitive regulation where students manage their activities and thinking processes, control their behaviour and put their emotions into learning. Cheng

(2011) also explains that metacognitive regulation drives students to act to set learning goals, plan, choose strategies, constantly monitor the learning process and to reflect on learning independently.

According to Wood (2017) and Adnan & Arsad (2018), students' metacognitive regulation skills can be enhanced through an active learning medium of collaboration, interaction, discussion and role-play, which can motivate students to come up with ideas and engage in positive learning, and, can tolerate and learn in groups. Students' goals or needs for interacting, discussing and giving ideas can be a catalyst for ongoing metacognitive regulation where students ask questions, compare their thinking, determine solutions, guide, and evaluate their mastery. According to Schraw & Moshman (1995), when the motivation develops the ability to manage thoughts and ideas, the metacognitive regulation increasing accordingly, as an aspect of the skill that leads students to master the lesson.

It can be concluded that a very effective metacognitive strategy is through the skills of metacognitive regulation. Therefore, studies on learning activities that enhance metacognitive regulation skills need to be conducted to become mediators that may influence the mastery of mathematics concepts. In studies conducted by Cera, Mancini & Antonietti (2013) and Stephanou & Mpiontini (2017) have shown that there is a positive relationship between metacognitive regulation, grade and achievement. Studies conducted by Su, Ricci & Mnatsakanian (2016), Hasbullah (2015), Palennari, Taiyeb & Siti Saenab (2018) Van der Stel, Veenman, Deelen & Haenen (2010), Nongtodu & Bhutia (2017), Tony Karnain et al (2014) and Leidinger & Perels (2012) have shown that metacognitive learning strategies have relationships and influence student performance and achievement. However, it does not explain what and how the strategy is implemented. The researchers also suggested the need for a more specific strategy on the components of metacognitive regulation for mathematics learning intervention. Therefore, the researchers develop teaching modules based on metacognitive regulation approaches and strategies to meet the interactive activities along with concepts of active learning that are complemented by the learning elements of technology-integrated learning kits.

2.1 Meta-Seller Tutoring (MST) Module and Learning Kit

This teaching module contains two main sections, the first is knowledge sharing on metacognitive strategies to teachers and second is guidance on implementing Meta-Seller Tutoring (MST) activities as learning approaches. The main focus of the module is to introduce learning activities that are conceptually interactive games designed based on entrepreneurial-oriented learning and, buying and selling activities enhanced with peer tutoring activities to optimize student interaction. The MST activities will be conducted in accordance with the normal learning time allocation and will be assisted by a set of kit containing a sample of money, sample of a product, graphic-scientific calculators and sales notes. This activity was developed using the model of metacognitive strategy, Anderson Model (2002), ASK Peer Tutoring Model Fitch & Semb (1993) and supported by 4Ps McCarthy Model (1960) (Bakar & Ismail, 2020). Implementation of MST activities is based on four sub-activities and can be used for any topic in mathematics to creating optimum interaction and collaborative learning. The integration of technology in producing learning kit can make learning more active, motivated and interactive.

Table 1: Brief Description of the Implementation of MST Activity

Activity Phases	**Descriptions**

Sub-activity 1: Seller-customer selection	Students are divided into groups of 4 or 5 members Each group discusses and select their seller and customer Students are responsible for their respective roles
Sub-activity 2: Marketing Planning	Teacher distributes the product to each group. Product is lesson contents refer to mathematics questions and tasks The product has a certain price which is actually the level of task according to Bloom's Taxonomy Seller will serve as the head of the discussion to design the marketing and solve the task Members of group solving mathematical problems, conducting operations and calculations cooperatively
Sub-activity 3: Promotion time	The climax phase of learning activities, the sellers from others group will sell, delivering explanations, explaining, attracting attention, or teaching the customers (not in the same group) to understand mathematical concepts and solutions The process is buying and selling activities, refers to the standard of promotional activities in marketing Sellers are applied peer tutoring and reciprocal teaching methods Purchases occur when the customer is satisfied with the explanation and understand the presentations
Sub-activity 4: Bestseller award	Teacher summarized the activities and determine which seller can raise the highest amount of money for the awarded bestseller Students reflect the learning outcomes

In addition, to strengthen the design of learning activities, skill construct is incorporated into MST activities. Among them are collaborative skill, regulation skill and thinking and mathematics problem-solving skill. According to Pantiwati & Husamah (2017) and Taylor (1992), learning environments with activities that expose collaborative skills lead to metacognitive skills. Therefore, as the MST activity is conceptualized as a game to earn the most money through buying and selling activities, students are trained to self-regulate by managing the game and at the same time also manage their learning well, to reach their goals.

III. METHODOLOGY

The objective of this study was to assess the effectiveness and to see the impact of using the Meta-Seller Tutoring (MST) mathematics learning module and kit on students' metacognitive regulation skills and mastery of mathematics concepts. To achieve this objective, several research questions were developed, including:

1. Do the MST module and kit affect students' mastery of mathematics concepts compared to conventional learning?
2. Do the MST module and kit influence students' metacognitive regulation skills?

3. Is there a significant relationship between metacognitive regulation skills and mastery of students' mathematics concepts after implementation of MST learning?

The study involved 159 Form 2 students from three secondary schools in Pasir Gudang district, Johor, Malaysia. Based on the experimental study design, the sample was divided into two groups, namely experimental groups provided treatment using MST modules and kits, while the control group followed conventional learning without treatment sessions. Both groups engaged in mathematics learning by attending the same teacher-learning session and the same topic for a period of 4 weeks. Before the start of the treatment session, both groups had taken a mastery test and answered the metacognitive regulation questionnaire to determine the level of learning and the current level of metacognitive regulation skills (Pre-test). After the end of the treatment session, both groups took a mastery test and responded to the post-test metacognitive regulation questionnaire to see improvements in the treatment session.

In this study, the instrument used consisted of pre and post-test mastery, MST module and kit, and metacognitive regulation questionnaire. For mastery and questionnaire sets, validity is first required to determine the level of consistency and usability of each item. As such, the metacognitive regulation questionnaire was the result of adaptation and translation of the Junior Metacognitive Awareness Inventory, Jr.MAI (Sperling, Howard, Miller & Murphy, 2001) and the Metacognitive Awareness Inventory, MAI (Schraw & Dennison, 1994), researchers conducting language, construct and, psychometric validities. Then, a pilot study involving 42 samples was conducted to obtain a reliability index of the questionnaire. Based on the Cronbach's Model analysis, the alpha values a, recorded for the planning, monitoring and evaluation constructs were 0.770, 0.748, and 0.760 respectively. The alpha value of the total items obtained was 0.892, indicating that the reliability index for the metacognitive regulation questionnaire was high and suitable for use in the actual study.

Using computerized analysis through the Statistical Package for the Social Science, SPSS version 23, data were analyzed based on descriptive and inferential statistics. Percentage, mean and standard deviation were used to see the levels, while comparative and correlation tests were performed for comparison purposes between groups. According to Alico & Guimba (2015), the mean ranges for the 4-levels are as follows: 1.00-1.74 (Low), 1.75-2.49, (Moderate low), 2.50-3.24 (Moderate high) and 3.25-4.00 (High).

IV. RESULTS AND FINDINGS

4.1Analysis of mastery scores for Pre-test and Post-test

The following **Table 2** present the results of the mastery test analysis conducted by participants before and after the treatment session for both groups.

Table 2: Analysis of Mastery Scores by Level and Group

Mastery Test	**Indicator**	**Control group, n=79**		**Experiment group, n=80**	
	Achievement Analysis	Mean	SD	Mean	SD
Pre Test	Marks	58.84	15.576	56.10	18.802
	Grade	2.52	0.766	2.25	0.948

	Interpretation	Moderate-High		Moderate Low	
Post Test	Achievement Analysis	Mean	SD	Mean	SD
	Marks	61.56	15.013	65.93	19.937
	Grade	2.53	0.713	2.73	0.900
	Interpretation	Moderate-High		Moderate-High	

Based on the results obtained, both groups showed improvement in the mastery test, however, the experimental group recorded a greater improvement with the mean score changing from 56.10 to 65.93 compared with the mean control group only increasing from 58.84 to 61.56. The interpretation of achievement levels for the control group remained at a moderately high level while the experimental group changed from moderate low level to moderate-high.

4.2Analysis of metacognitive regulation scores for pre-test and post-test

For metacognitive regulation questionnaire data, the analysis was also based on descriptive statistics for both pre and post-test and based on the group.

Table 3: Analysis of Pre-test Metacognitive Regulation Scores by Subcomponent and Based on Group

Subcomponents	**Control group, n=79**			**Experiment group, n=80**		
	Mean	SD	Interpretation	Mean	SD	Interpretation
Planning	2.66	0.818	Moderate-High	2.64	0.796	Moderate-High
Monitoring	2.81	0.831	Moderate-High	2.63	0.828	Moderate-High
Evaluation	2.64	0.865	Moderate-High	2.60	0.847	Moderate-High
Overall Score	**2.72**	**0.834**	**Moderate-High**	**2.63**	**0.821**	**Moderate-High**

Table 4: Analysis of Post-test Metacognitive Regulation Scores by Subcomponent and Based on Group

Subcomponents	**Control group, n=79**			**Experiment group, n=80**		
	Mean	SD	Interpretation	Mean	SD	Interpretation
Planning	2.73	0.767	Moderate-High	2.86	0.762	Moderate-High
Monitoring	2.83	0.803	Moderate-High	2.90	0.813	Moderate-High
Evaluation	2.66	0.779	Moderate-High	2.74	0.807	Moderate-High
Overall Score	**2.76**	**0.785**	**Moderate-High**	**2.85**	**0.794**	**Moderate-High**

The findings in **Table 3** and **Table 4** indicate that the interpretation of the level of metacognitive regulation skills for pre and post-test was at a moderate level for both groups of students. The analysis for each subcomponent also recorded mean values in the range of 2.60 to 2.90 and could be interpreted at moderate levels. The mean of the total control group score showed an increase from 2.72 (pre-test) to 2.76 (post-test), but the improvement for the experimental group recorded a greater value of 2.63 (pre-test) to 2.85 (post-test).

4.3Comparative analysis of mastery scores and metacognitive regulation scores for pre-test and post-test

For in-depth study, inferential statistic tests were performed to obtain comparisons of mastery and metacognitive regulation scores by test, group and intergroup using non-parametric tests, namely Wilcoxon and Mann Whitney tests. The tables below are the findings.

Table 5: Comparison of Pre-test and Post-test Metacognitive Regulation Scores by Group

Indicator		Mean Rank	Sum of Rank	Z	Asymp Sig. (2-tailed)
Control group	Pre-test	21.28	489.50	-0.850[a]	0.395
	Post-test	20.64	371.50		
Experiment group	Pre-test	21.00	252.00	-3.162[b]	0.002*
	Post-test	23.06	738.00		

**p<0.05, [a]=based on positive rank; [b]=based on negative rank*

The results showed that there was a significant difference between the metacognitive regulation scores of the pre-test and post-test groups with p = 0.002 values smaller than the significance level of 0.05. Whereas the metacognitive regulation scores for the pre-test and post-test control groups did not show significant differences.

Table 6: Comparison of Pre-test and Post-test Metacognitive Regulation Scores between Group

Indicator		Mean Rank	Sum of Rank	Z	Asymp Sig. (2-tailed)
Pre-test	Control group	84.86	6704.00	-1.629	0.103
	Experiment group	75.20	6016.00		
Post-test	Control group	72.36	5716.50	-2.469	0.014*
	Experiment group	87.54	7003.50		

**p<0.05*

Table 6 shows that there was no significant difference in pre-test metacognitive regulation scores between groups, but there was a significant difference (p = 0.014, <0.05) for metacognitive regulation scores in post-test between groups.

Table 7: Comparison of Pre-test and Post-test Mastery Scores by Group

Indicator		Mean Rank	Sum of Rank	Z	Asymp Sig. (2-tailed)
Control group	Pre-test	38.00	1292	-1.238[b]	0.216
	Post-test	40.66	1789		
Experiment group	Pre-test	30.67	828	-3.676[b]	0.000*

	Post-test	44.85	2332		

**p<0.05, [b]=based on negative rank*

The analysis results in **Table 7** show that there was a significant difference between the pre-test and post-test experiment group scores of p = 0.000, whereas there was no significant difference between the pre-test and post-test control group with the record p-value is greater than the significant level, 0.216.

Table 8: Comparison of Pre-test and Post-test Mastery Scores between Group

Indicator		Mean Rank	Sum of Rank	Z	Asymp Sig. (2-tailed)
Pre-test	Control group	85.31	6739.50	-1.446	0.148
	Experiment group	74.76	5980.50		
Post-test	Control group	73.06	5772.00	-1.889	0.059
	Experiment group	86.85	6948.00		

**p<0.05*

Furthermore, **Table 8** shows the analysis of pre-test and post-test comparisons between groups. The results showed that there was no significant difference between pre-test and post-test mastery scores between groups, but post-test between groups showed a p-value is 0.059, approaching to the significant level of 0.05.

4.4Correlation Analysis *of mastery scores and metacognitive regulation scores*

To examine the relationship between mastery scores and metacognitive regulation scores, Spearman correlation tests were performed. The results are as in Table 10 below.

Table 9: Correlation Analysis of Metacognitive Regulation Scores and Mastery Scores for Pre-test, Post-test, Overalls, and based on Group

Indicator		Overall	Control group	Experiment group
Pre-test	Correlation coefficient	0.102	0.124	0.070
	Sig. (2-tailed)	0.200	0.275	0.538
Post-test	Correlation coefficient	0.280**	0.198	0.301**
	Sig. (2-tailed)	0.000	0.080	0.007

*** Correlation is significant at the 0.01 level (2-tailed)*

According to **Table 9**, there is a positive relationship between mastery scores and metacognitive regulation scores. However, in detail, the results for the relationship of mastery score and the metacognitive regulation score of the experimental group in the post-test showed a significant correlation with a sufficient correlation where the correlation coefficient r, was 0.301 at p = 0.007 below the significance level 0.01. Each recorded a weak correlation for the overall pre-test, overall post-test, pre-test and post-test control groups and, pre-test experimental groups.

However, it still showed significant correlations for overall post-test between mastery scores and metacognitive regulation scores (r = 0.280; p = 0.000).

V. DISCUSSION

This study is aimed at assessing the effectiveness of the development of modules, kits and activities based on metacognitive regulation strategies with a combination of several technology elements in creating active and meaningful learning. Previous studies have reported that using metacognitive strategies can improve student achievement as implemented by Shaw (2008), Asmuni (2011), Suriyon, Inprasitha & Sangaroon (2013), Du Toit & Kotze (2009) and Palennari, Taiyeb & Siti Saenab (2018). Therefore, based on the need to address the problem of weak mastery of mathematics concept which is seen as fundamental in mathematics education, activities through the game application based on entrepreneurship simulation, buying and selling activities, are developed as mathematics learning activities. The injection of technology elements by providing flexible kits with some of the latest technology tools such as scientific calculators, money samples and more interactive sales notes is expected to encourage active student engagement, interest and better emotional impact. According to Borba et al (2016) and Mat Sina, Talib & Norishaha (2013), highly engaging and appropriate technology material can stimulate students' motivation and interest in learning. Studies by Clarebout et al (2013), Gurbin (2015), Eyyam & Yaratan (2014) and Sherman (2014), have shown that students' motivation and interest are enhanced through learning using interactive materials and tools.

This study is an experimental study that involved 159 students and consisted of 80 experiment group students and 79 control group students. The experiment group underwent a 4-week treatment session and the control group followed conventional learning. Overall, the results of the implementation of activities through the MST learning modules and kits have an impact and effect on the learning and mastery of students' mathematics concepts. The results showed that there was a significant difference in the mastery of students' mathematics concepts after MST learning with mean values increasing from 56.10 to 65.93 for and p = 0.000, < 0.05 for experiment groups in pre-test and post-test. This result shows that MST learning can effectively influence students' mathematics concepts. Through MST learning, student mastery can be improved and MST is suitable for intervention in mathematics learning. This result is in line with the findings of Leidinger & Perels (2012) and Hasbullah (2015), studies that used metacognitive strategies in producing effective learning to enhance student achievement. According to Hasbullah (2015) and Nongtodu & Bhutia (2017), metacognitive strategies need to be implemented to enhance student learning outcomes.

Besides, this study also reported that there were significant differences in the metacognitive regulation skills after MST learning. Based on the Mann Whitney and Wilcoxon test analysis, it was found that the respective p values for the post-test comparison of metacognitive regulation between the control and experimental groups, and the comparison of pre-test and post-test metacognitive regulation scores for the experiment group, were 0.014 and 0.002 respectively, is less than a significance level of 0.05. This result answered the second research question, is MST learning has influenced students' metacognitive regulation skills? This means that the development of learning activity with the concept of entrepreneurship, buying and selling activities can provide training and enhance aspects of student metacognitive regulation and thus be effective in enhancing student achievement. In line with the findings of Makantal (2012), Shanklin & Ehlen (2017) and Palmer & Johannson (2018), they also show that entrepreneurial activities can enhance students' thinking skills and impact student achievement. The results of this study provide the implication that entrepreneurship, buying and selling activities in learning can be innovated into teachers instruction, in line with technologies developments, this instructional design can be further enhanced. As suggested by Bakar & Ismail (2019), so that teachers are constantly updating their teaching approach to the current technology. However, the overall level of metacognitive regulation skills remains at a moderate level for both control and experimental groups. These results are in line with the results obtained by Asmuni (2011), Idris, Abdullah & Sembak (2015) and Abdullah, Rahman & Hamzah (2017) which show that the level of metacognitive skills is also at a moderate level.

In this regard, the results also showed that there was a significant relationship between metacognitive regulation skills and mastery of student mathematics concepts ($p = 0.007, < 0.05$). Based on the correlation index set by Sarwono (2016), correlation coefficients, $r > 0.25$ to 0.50 give enough correlation and r values, in the range > 0 to 0.25 represent very weak correlations. Therefore, the correlation coefficients obtained in this study recorded enough correlation interpretation values for overall post-test relationships and post-test relationships for experiment groups with respective correlation coefficients, r being 0.280 and 0.301. The implications of the study show that MST learning can influence the relationship between metacognitive regulation skills and mastery of student mathematics concepts. These results are in line with the findings of Kazemi, Fadaee & Bayat (2010), Listiani, Wiarta & Darsana (2014), Anwar (2015), Ibrahim & Iksan (2017), Cera, Mancini & Antonietti (2013), Tony Karnain et al (2014), Nongtodu & Bhutia (2017), Cheng (2011), Su, Ricci & Mnatsakanian (2016), Stephanou & Mpiontini (2017), Hassan & Rahman (2017) and Idris, Abdullah & Sembak (2015) show that there is a significant relationship between metacognitive skills and student achievement. However, there are few differences with the results of Hassan & Rahman (2017) that show a strong correlation between achievement and metacognitive aspects. This is due to the limitation of the study, which is that treatment sessions are only given for a relatively short period and use only one topic. As suggested by Darussalam & Hussin (2018), the best experimental study duration is from 1 to 3 months.

VI. CONCLUSION

The results of this study indicate that metacognitive regulation learning strategies can impact students' learning and achievement. In conclusion, this study achieves the objective with positive results. The MST module and learning kit have proven successful in mastering students' mathematics concepts. However, the continuity of the study can be continued to support the findings of this study. Some suggestions for future studies include, for example, furthering the module by adding some activities in line with the metacognitive regulation strategy and developing specific learning models for activity-based learning in metacognitive strategies. Also, studies can be performed to look at the effectiveness of these modules and kits in different dimensions, for example, different subjects, different ages, different levels of education and so on. In-depth research can be done to look at these MSTs from other areas of expertise, such as critical thinking skills, leadership skills, communication skills and so on.

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