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Measuring Cognitive Level using Informative Map among Secondary Students: A Quasi-experimental Approach

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ABSTRACT

Spatial thinking is essential because it encourages the human mind to visualise, thus stimulating cognitive thinking which leads to improving higher thinking order (HOTS). Unfortunately, it is found that the geography syllabus taught in secondary school is lacking this vital element. Hence, this study aims to assess the student cognitive level using an informative map module among secondary students in Geography subject. This study was underpinned by the Social Cognitive Theory (SCT). The cognitive level was measured using Bloom Taxonomy cognitive domain from low to high order thinking skills, namely knowledge, comprehension, application and analysis. Data were collected using a one-group pretest-posttest quasi-experimental design. The informative map module has been used as an intervention for the study. Pre-test and post-test questions were distributed before and after the intervention. 31 students of Sekolah Menengah Kebangsaan Arau participated in this study. Data were analysed using a t-test paired analysis. The result reveals the significant difference between cognitive domains among students. The informative map module increases their knowledge, comprehension, application and analysis among students. This study contributes to the empirical evidence of SCT's literature in the context of spatial thinking studies among secondary students in selected geography topics.

Keywords: *Spatial Thinking, GIS maps, Quasi-Experimental, Geography, Secondary School*

1.0 Introduction

1.1 Spatial Thinking

Spatial thinking is an approach in assessing the cognitive level, and it has been focused by several studies (Ghaffari, Jo & Currit, 2018; Utami & Zain, 2018; Verma & Estaville, 2018; Wise, 2018) due to the current advanced geospatial technologies. Bednarz & Lee (2011) suggested that several elements need to be considered in developing spatial thinking, such as direction and position information, map layers and patterns, spatial relationship, three-dimensional (3D) visualisation and map production. All these elements are integrated into geography study through maps, graphs, images, diagrams, models, and visualisations (Bednarz & Bednarz, 2008). There are three elements, such as space, representation tools, and reasoning process are the keys to spatial thinking. Space represents the spatial distance (NRC, 2006). All elements involved in the geography subject can train a student to think spatially, leading to higher-order thinking that state in government policies.

1.2 Geography and Spatial Thinking

Geography is a study of a physical characteristic of the earth, human activity, population distribution, resource, political and economic activities (Webster, 2015). Geography and spatial thinking are interrelated to ensure students understand the spatial patterns and processes in teaching and learning (Bednarz & Bednarz, 2008). In recent years, Geographical Information System (GIS) platforms are used to enhance the student's spatial thinking in both formal and informal education as well as incorporate the geospatial thinking into teacher preparation programs (Chun, 2010; Lateh & Muniandy, 2011; Lee and Bednarz, 2009; Mayalagu, Jaafar & Choy, 2018; Mustapa et al., 2014; Webster, 2015). It can also increase exciting learning in the curriculum using the valuable GIS tool (Webster, 2015). Therefore, higher-order thinking skills (HOTS), as stated in bloom's taxonomy in different levels of human cognition, such as synthesising, examining, interpreting, and assessing knowledge, should be evaluated to test the enhancement of skills through geospatial technologies. It is essential for geographers when dealing with a complex issue and critical analysis (Rankin, 2016).

1.3 Cognitive Level Assessment through Spatial Thinking Skill

Although it is vital to improving the spatial thinking skill by evaluating the HOTS, unfortunately, assessing the spatial thinking skill in different aspects

such as spatial perception, orientation, visualisation, and mental rotation is not easy (Charcharos, Tomai & Kokla, 2015). Charcharos, Tomai & Kokla (2015) declared that spatial thinking among young people had been neglected and the various test has been applied to evaluate the spatial thinking, and unfortunately, it is unsuccessful. Furthermore, most of the students' secondary level only studies on map production and lack of skill in determining location around the worlds (Kaya, 2018; Mustapa et al., 2014). Then, Collins (2018) suggested that geospatial technologies can be applied to convert the traditional maps into digital to develop spatial thinking skills. The question asked in this research is what types of elements should be added in conventional maps to be more attractive and improve spatial thinking among students.

Therefore, this study focused on lower secondary students on the current geography learning assessment using an informative map. The informative map made using the GIS technique that includes spatial thinking elements. Furthermore, the student's cognitive level was determined by using the informative map, namely, cognitive, comprehension, application, and analysis. HOTS was known to be achieved if students can acquire the analysis level in the cognitive level. This study is essential to develop higher-order thinking students based on their human cognitive levels. Also, this approach can help the student to solve a problem or give spatial reasoning

2.0 Methodology

2.1 Underpinning Theory

This study is underpinned by Social Cognitive Theory (SCT) by Albert Bandura (Bandura, 2001). SCT explains the interactions of human factors based on personal factors, environment and continuous behaviour in a learning setting. In other words, SCT claims that people learn based on their experiences, the observation of others, as well as the results of those actions. For this study, SCT explains students used their own experience to use the traditional map and interaction maps in their learning. The informative maps offer a different view of presenting the content, hence giving them a new experience.

2.2 Context of the Study

This study aims to assess whether the use of the informative map increases the cognitive level among geography students. The cognitive level was tested using test scores based on pre-test and post-test questions. The cognitive levels are classified as knowledge, comprehension, application, and analysis developed

based on the standard school level as approved by the geography teacher in the respected school. The test score was compared at the end of the sessions.

2.3 Participants of this study

The selection of study area is Sekolah Menengah Kebangsaan Arau, placed at Jalan Besar Arau, Perlis. The area was chosen due to the easy access that closes to the Universiti Teknologi MARA, Perlis branch. Furthermore, the geography teacher of SMK Arau can give full commitment to assist the test among the students. The sample size of respondents consists of 31 students.

2.4 Development of Informative Map

The informative map was enhanced from the existing geography textbook was developed using the Geographical Information System (GIS) technique. The GIS platform is used to integrate all spatial layers such as rainfall, country boundary, temperature and climate, and finally, the map was generated as output in WGS84. All the spatial elements, such as symbol, colour, density, and pattern, were adopted in the proposed informative map. The spatial element used to create the map was taken from a study by NRC (2006), where it is the concept of space that makes a distinctive form of thinking of spatial thinking.

The topic chosen for knowledge assessment is climate diversity and its influence on Asia's human activities. The topic selection is due to the suitability of the content, which is related to geography elements in developing spatial thinking skills such as comparison, pattern and distribution aspects.

2.5 Design and Validity

This study employed a quasi-experimental, non-randomised, two groups with pre-test and post-test design. Firstly, students attended geography learning using traditional maps. The cognitive levels were controlled using the test specification table. The validity issues have been carefully observed and employed based on a suggestion made by Creswell & Guetterman (2019) on participation, procedure and treatment.

2.6 Methods of data analysis

The informative map was given to the student for them to identify the diversity of climate in Asia (knowledge domain). Then, the student must explain

the characteristic of climate based on zones of climate (comprehension domain). Finally, the student's understanding of how to differentiate the climates influenced human activity (analysis domain) was also assessed. All the student's understanding was assessed and analysed using Statistical Package for the Social Sciences (SPSS) using a paired t-test.

3.0 Result

3.1 Informative Geography Maps with Spatial Elements

The informative maps were developed with elements of spatial that includes symbol, colour and pattern. The content used in developing the informative maps is based on form two geography textbook with the selected topic of climate diversity and its influence on Asia's human activities. The map was produced by adding an element of cartography mapping. Only use a colour element to differentiate the types of climate. In the textbook, the existing maps show a climate presented by different colours and lack of information (Figure 1).

Civil Engineering Design project is a studio orientated course where students are guided in performing design of structural elements of a reinforced concrete building and a steel structure, by integrating the knowledge gained from previous courses. This course requires students to pass two courses i.e. structure analysis and concrete and steel design in lower semester. Students will be given 1-hour lecture and 4 hours studio within a week in order to complete a task. The maximum number of students in a group is 4 persons and the assessment is based on individual progress work.

At the beginning of the semester, students will be briefed on the lesson plan for 14 week activities together with the tasks that should be completed within the time frame. For the first ten (10) weeks, students need to complete all tasks relating to reinforced concrete structure, consisting of analysis of loading, and preparing design calculation for slab, beam, column, footing, and staircase. All work checking must be performed using Eurocode 2 and design work is validated using software known as ESTEEM. Meanwhile, the remaining 4 weeks is to prepare design for steel structure that covers beam, column, and connections. Design checking should be done according to Eurocode 3. The assessment will be monitored on weekly basis depending on the tasks that have been assigned in each week.

Figure 1: Climate Map (MOE, 2017)

Therefore, to develop student critical thinking on geography and interact student interest on learning related to position and direction spatially, rainfall distribution map was converted into more informative by using different colour tones and specific legends on the temperature and rainfall volume for world map as shown in Figures 2a. The elements of colours will help students' memories and stimulate their critical thinking skills by identifying the area which receiving high and low rainfall volume and climate of Asia. The colour also is representing the range of Asian temperature. Figure 2b presents the rainfall density using diamond shape in different size scale.

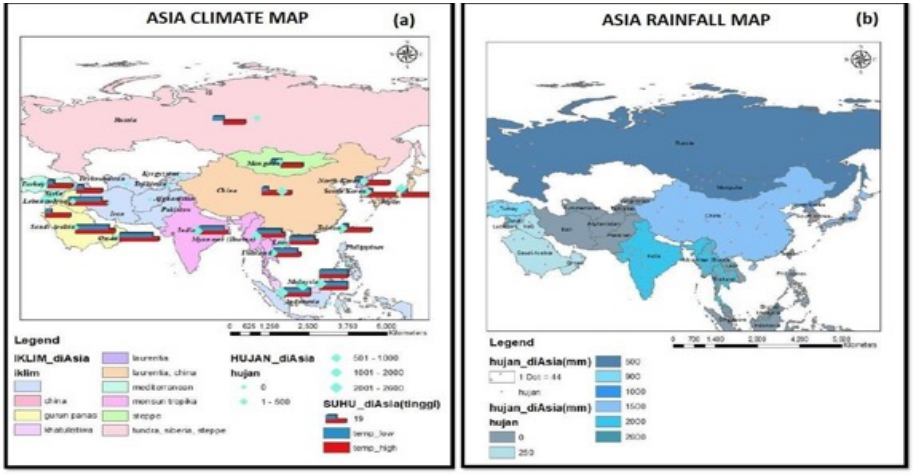

Figure 2: Map of Asia (a) Climate and (b) Rainfall Distribution

3.2 Cognitive Level Assessment

We analysed the effect of an informative map on the cognitive levels using paired t-test. The same level of difficulty questions was given to students before introducing the interaction map sessions and after the exposure to the informative map session. The result indicates a significant difference between pre-test and post-test for the overall assessment ($t = 2.879$, $p < 0.05$), where the mean value for post-test results is higher than the mean value for pre-test results. The result confirms that teaching geography through the spatial approach using an informative map allows students to understand the content better as compared to the traditional technique.

Moreover, the results about the differences between cognitive level among students also show a significant difference for knowledge ($t = 7.448$, $p < 0.001$) and analysis ($t = 3.950$, $p < 0.001$) cognitive level among students where the mean value for post-test are higher as compared to the mean value for the pre-test. However, this study does not provide enough evidence to support the significant difference between pre-test and post-test for comprehension and application level.
Previous scholars highlighted that most of the students' secondary level only studies on map production, hence influences the cognitive levels of their learning outcomes for the related subject such as geography (Kaya, 2018; Mustapa et al., 2014). For this study, there is a difference in cognitive level for knowledge and analysis among students, where the results show a difference of knowledge and analysis of the cognitive level with the exposure of the informative map in their learning for geography subject. Students understand the spatial layers such as rainfall, country boundary, temperature and climate based on the country a lot better as compared to the traditional map. The spatial elements such as symbol, color, density, and pattern help to enhance their visual learning.

Similarly, when students understand the map, it is easier for them to achieve the analysis level of the cognitive because their understanding of the spatial layers help them to think at the analysis level, such as to suggest the economic activities suitable based on the information of the spatial layers like rainfall, country boundary, temperature and climate. For example, agriculture activities are suitable in the rainfall area; however, not all crops are suitable for this area. Hence, this study confirms the suggestion by Collins (2018) that geospatial technologies and traditional maps should be implemented to develop spatial thinking skills. Moreover, the spatial elements like symbol, colour, density, and pattern elements added in the informative maps are attractive and improve students' spatial thinking.

4.0 Conclusions

This study explains the theory of SCT by using spatial thinking through the informative map in the geography subject among lower secondary students. Students learned through their own experience with the informative map. From there, students interacted with the instructors, who facilitated them to use the map. At the same time, students discussed among their friends in class to improve their understanding. The informative map's learning experience triggered the interactions with students as individuals, the different learning environment, and the learning continues with the discussion with their peers.

This study suggested that spatial elements in the interaction map-able help promote students' cognitive levels. The significant difference in overall results and the cognitive knowledge level shows that this map improves students' learning ability. Moreover, a significant difference reported for the analysis level, indicating that students achieve the HOTS through the map. The insignificant results for comprehension and application suggested the improvement need to be made when designing the assessments. For future studies, we recommend that the questions used a test specifications table to control the development of the assessments, but the similarity of the questions needs to be reviewed. Overall, we can conclude that spatial thinking can improve the cognitive level among students in the context of geography in secondary schools. More studies need to be conducted to explore how this informative map is better used to support the relevant topics in the subject.

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