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Thinking Process of Students with High-Mathematics Ability (A Study on QSR NVivo 11-Assisted Data Analysis)

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Abstract

Students' thinking process in solving mathematical problems is ever an interesting issue to be discussed. Since problem-solving thinking process is remarkably essential, the present study discusses thinking process from various points of views. A qualitative method was applied in this research by taking three research subjects of students with high-order thinking skills. Data were taken using mathematical problem-solving tests and interviews, which were used as method triangulation to determine data credibility. Data presentation and analysis were carried out using QSR Nvivo 11 software and research reliability was done using Kappa test. The research results demonstrate that all three subjects were able to solve mathematical problems on Pythagoras concept properly. There were diverse ways used by each subject to solve problems, but the differences did not affect the solutions since the three subjects had the same concepts at problem understanding level. Mathematical problem-solving thinking processes of all subjects included assimilation and accommodation. Assimilation was accomplished when subjects understood and ascertained the accuracy of the results by reviewing the problem-solving steps. Meanwhile, in accommodation process, subjects were able to plan comprehensive problem-solving and apply the plans to describe the problems comprehensively.

Keywords: Thinking Process, Problem-Solving, QSR NVivo.

INTRODUCTION

Problem-solving activity is a vital activity in learning at elementary, secondary, and high education levels. At both elementary and secondary levels, the graduate standard of competencies mentions that one of mathematics learning objectives is solving problems which include skills to understand problems, plan mathematical models, solve models, and interpret the obtained solutions. Problem-solving learning is to help students develop their thinking skills, solve problems, and develop intelligence [1]. Detailed that problems emerge if there appears a gap between today's situation and future's situation or between today's condition and expected objective. In mathematics learning, problems usually take the forms of mathematical questions which have to be responded [2]. Dealing with this, Vos & De Graaff [3] mentioned that a question remains an individual problem if he does not have certain rule/regulation which he can immediately use to find the solution for the question. In mathematics learning, mathematical questions are divided into two, explicitly exercises that are provided to make students more skillful to apply the concepts they have learned and problems which oblige them to analyze and synthesize what has been previously learned. In order to solve problems, students have to master learned materials, including knowing, understanding, and skilfully using certain concepts and theorems [4]. Moreover, students also have to be able to correlate and apply what they have in new situation appropriately.

Thinking process is an activity occurring in human's brain. Information and data that come into the brain are processed, and thus, what has been in it require an adaptation and even a change, is a so-called adaptation. Adaptation to a new scheme is accomplished through assimilation or accommodation, depending on the type of information that enter mental structure [5]. Piaget said that assimilation and accommodation processes will continue until the balance is achieved [6]. Assimilation is an individual process in adapting and organizing himself with new environment so that his understanding will develop. Meanwhile, accommodation happens when students cannot assimilate new experience with the scheme they have. Teachers must develop a learning environment that can increase students' beliefs and problem-solving abilities [7]. Understanding students' thinking process to solve problems is greatly essential for a teacher. By understanding students' thinking process, a teacher can trace the position and type of students' mistakes. Their inaccuracies can serve as sources of information for their learning and understanding. It is also important that teacher can design learning that is mostly appropriate for students' thinking process. Consequently, a realization of students' thinking process to solve mathematical problems needs further research.

Junior high school students at grade IX have received material on Pythagoras Theorem. There are numerous mathematical problem-solving requiring Pythagoras Theorem. When solving problems related to Pythagoras Theorem, students can apply one of the steps proposed by Polya [8]. When understanding problems, they have to be able to identify what they have identified and what the questions require them to do and whether what has been identified are sufficient to respond to the question. Afterwards, for planning problem-solving, they have to find the relationship among identified data, find the relationship among data and question, determine other prerequisite materials that can be used to find a solution, use all information available in the question, and design a plan to solve the problem by thinking about similar problems. The next step is applying the plan, examining the steps thoroughly, and ensuring that every step is correct. The last step is reviewing through repeating the problem-solving by examining the drawbacks of solution (like improper steps) and being able to apply the solution to other problem. In providing a solution for a problem, junior high school students at grade IX apply thinking process (assimilation or accommodation) in their mind until they find the answer. Related to the results of a preliminary study, the researchers are interested to conduct further investigation on thinking process of students with high-order mathematics skills to solve Pythagoras problems with the help of QSR NVivo 11-assisted data analysis.

Why QSR NVivo 11-assisted data analysis? Limitations experienced by researchers in a qualitative study when analyzing data finally ended up with a bright spot of the presence of computer-based analysis tool. This is in line with Zamawe [9] in recent times the use of electronics to analyze data applies only to quantitative research, but now has begun to develop Computer Assisted Qualitative Data Analysis Software (CAQDAS) that can be used to analyze qualitative data. Corresponding to that opinion, Basak [10] argued that the use of CAQDAS software in academic research will improve research productivity. This is because the use of CAQDAS software in qualitative data analysis significantly assists researchers in importing data, coding the text, retrieving data, reviewing data, combining words in the coding pattern and exporting data in various presentation forms. The most effective CAQDAS software in qualitative data analysis is NVivo [11]. It is also strengthened opinion that the latest software used in qualitative data analysis include: Atlas.Ti, N4 Classic, N5, NVivo, and Winmax [10]. However, it is only NVivo providing complete and ideal tools in qualitative data analysis. A Software is categorized as CAQDAS if it can search, link items, encode, query, annotate, and map research data. In choosing CAQDAS election, Babbie [12] recommended NVivo because it is quite popular among overseas researchers. This is underlined by Walsh [13] who said that NVivo is a software that works like folders in qualitative manual data analysis techniques. In addition, the folder is much smarter. Thus, researchers who are accustomed to using manual methods in qualitative data analysis will be familiar with this software.

RESEARCH METODOLOGY

The present research belongs to descriptive, qualitative study. The researchers directly collected the data for the research and therefore, the main instruments were the researchers and the first additional instrument was a problem-solving test and interview guideline. This instrument was used to gather written data on thinking processes of students' with high-mathematics ability (three subject with code HNFL, AR and DP). Interviews were recorded using a video recorder and used as documents of activities that were later analyzed using QSR NVivo 11 software. All data obtained from various sources, including interview, an observation that was written in field work report, picture, photograph, and so on [14] were analyzed. Bandur [15] declared that qualitative research data are numerous and from various sources. They were taken using various data collecting techniques and were analyzed using QSR NVivo 11 software.

One of the fundamental things to be taken into account by each qualitative researcher is how to measure the accuracy and consistency of qualitative research. In order to measure the reliability, the researcher used Coding Comparison Query feature in QSR NVivo 11 software. This feature was applied to compare coding performed by two users or two groups of users. It provided two ways for measuring qualitative research reliability, namely by examining agreement level between users through percentage agreement calculation or by measuring inter-users reliability through Kappa coefficient. QSR NVivo 11 software calculated Kappa coefficient and percentage agreement individually for each node combination and data source, and therefore, the calculation of average score of Kappa coefficient or percentage agreement was required in several sources or nodes to reflect comprehensive qualitative research reliability. If we want to do so for one node in some data sources, or for some data sources and nodes, we need to consider the weight of various data sources with a different calculation. There are two types of weighing methods, explicitly similar weighing for all data sources and different weighing for all data sources, based on the size. In this research, the calculation of Kappa coefficient and agreement percentage used the same weighing for all data sources. Further, the average Kappa coefficient was interpreted using the following guidelines [16-17].

Table 1. The Guidelines of Kappa Coefficient

Kappa Value	Interpretation
Less than 0.40	*Poor Agreement*
0.40 – 0.75	*Fair to Good Agreement*
More than 0.75	*Excellent Agreement*

RESULTS AND DISCUSSION

To find out whether a student used assimilation or accommodation to solve the mathematical problem, indicators of assimilation and accommodation thinking process were provided. Table 2 clearly demonstrates the indicators.

Table 2: Indicators of Assimilation and Accommodation Thinking Process

Problem-Solving Steps	Problem-Solving Indicators	Indicators of Assimilation and Accommodation Thinking Process
Understanding problem	- Students can determine minimum requirements (what is identified) and specific requirement (what is asked) - Students are able to determine whether the minimum requirements have answered the specific requirements.	- Students are considered using assimilation thinking process if they are able to integrate new information immediately after reading the problem into the scheme which has existed in their mind, and hence, students are able to identify easily and accurately what they have known and what is asked in the question and are able to determine whether what they have known are adequate enough to respond to the question. - Accommodation occurs if students are not able to assimilate new information and knowledge they have. This is so since students' existing scheme is no suitable for new information, and hence, 'conflict' takes part in students' mind.
Planning problem-solving	- Students are able to determine the correlation among existing information available in question. - Students can determine other requirements which have not been identified in the question, like formula or other information; if any. - Students can use all essential information in the question. - Students can plan solution or problem-solving.	- Students are considered using assimilation thinking process if they are able to integrate new information into the existing scheme in their mind immediately, and therefore, they are able to mention other knowledge easily and correctly to find solution, draw the relationship among the existing information based on the scheme they have, and plan solution for the problem based on what they have known. - Accommodation occurs if students are not able to assimilate new information with the knowledge they have already had. For example, students are confused when relating information they have identified so that they need to combine the scheme they have in their mind to determine the correlation when determining other relevant knowledge to solve problems, and hence, they are not able to plan problem-solving immediately based on the existing information.
Applying problem-solving plan	- Students are able to apply all steps appropriately. - Students are skillful to solve algorithm and answer question appropriately.	- Students are considered using assimilation thinking process if they successfully solve the problem based on the planned problem-solving steps and algorithm is properly calculated. - Students are considered using accommodation thinking process if they are not able to assimilate the designed plan and solve the problem using a different way.
Reviewing/Rechecking	- Students are confident with the accuracy of the solution for the problem. - Students are able to determine the relationship among problem-solving applied in other problems.	- Students are considered using assimilation thinking process if they are confident with the accuracy of the results obtained by reviewing the steps applied to solve problem. - Accommodation occurs if students are not able to assimilate new information with the knowledge they have already had, for example, students are not sure of the accuracy of the obtained results and able to make new problem-solving.

Notes. confusion occurs because students have never met similar questions.

There are various ideas related to mathematical problem-solving. One of the opinions came from Gunawan [18] mathematical problem-solving is a process undertaken by students to solve a given problem using their knowledge and understanding. After understanding the meaning of 'mathematical problem solving,' the researcher attempted to explore the phase of mathematical problem-solving performed by research subjects based on Polya's steps. This was accomplished with the help of QSR NVivo 11 software through the Matrix Coding Query feature. This feature is a constant comparative analysis that is essential for qualitative data analysis [19]. With this technique, researchers could present the results of comparative analysis between the sub-category of themes and demographic research data. To conduct this analysis, the researchers made a classification aimed at providing descriptive information about the data source, subject, place, or other case in the study. There are three types of data classifications in NVivo with different functions, including source classifications, case classes, and types of relationship. In this study, researchers used case classifications to arrange cases to be able to compare differences in attitude and/or behavior of research participants based on their demographic data. Figure 1 shows different problem-solving steps performed by all three subjects (code: HNFL, AR and DP) based on Polya's steps.

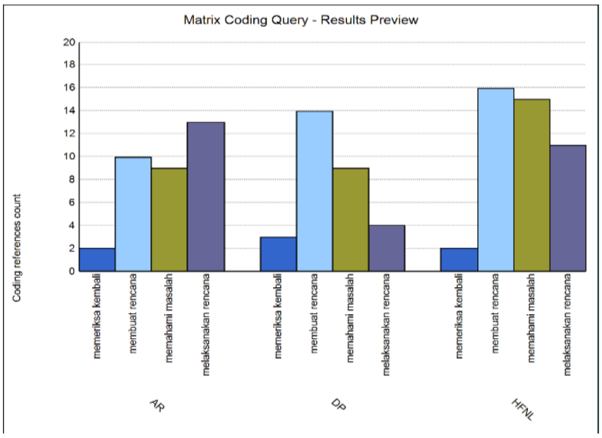

Figure 1: Subjects' Mathematical Problem-Solving (*in Indonesian*)

HNFL's problem-solving skill is visible, compared to AR and DP, who are at the same level of understanding. This condition is also obvious in the troubleshooting planning step, in which HNFL appears to have excellent planning skill compared to the other two subjects. However, DP has better planning skill if compared to AR. Different thing appears in the implementation step of probem-solving. AR has excellent problem-solving skill compared to HNFL and DP. However, HFNL has better problem-solving skill than DP. Other different finding is also indicated in reviewing step. DP examines the answer to the problem in detail, but HFNL and AR did not perform this thoroughly. On the basis of the description, it is obvious that although all subjects possess high-order skills in math, applied different ways to find solution.

Furthermore, the researchers presented a map of problem-solving steps developed by Polya through the project map that is evident in Figure 2. The project map refers to the themes of coding results that can be used to explore and present data connections. The first step proposed by Polya's is understanding the problem. Students identify what information is available in the question, determine the part asked in the question, and consider the adequacy of the information to solve the problem based on the previously obtained information. The next step is making a plan to solve problem based on the adequacy of information. Students use all information and link the information in the concept of learned material. After well planning, students move on to the next stage, specifically the applying the plan. In this step, students describe the problems given into small parts (analyses). Then, students recognize the relationships among these parts so they can express the length of the sides in the form of mathematical equations including the lengths of BF, FG, and CG (synthesis). In the end, students can find solution for the problem that is the length of EF. After doing so, the students recheck the results of their works to be more confident with the problem-solving. Clearly Figure 2 showed there appear four problem-solving steps, including understanding problem, planning, applying plan, and reviewing. Among those four steps, applying plan has the greatest portion, followed by planning, understanding problem, and reviewing solution, respectively. This indicates that research subjects considered the question a problem because this encouraged them to finish this, but the research subjects did not know directly what had to be done to find the solution [1].

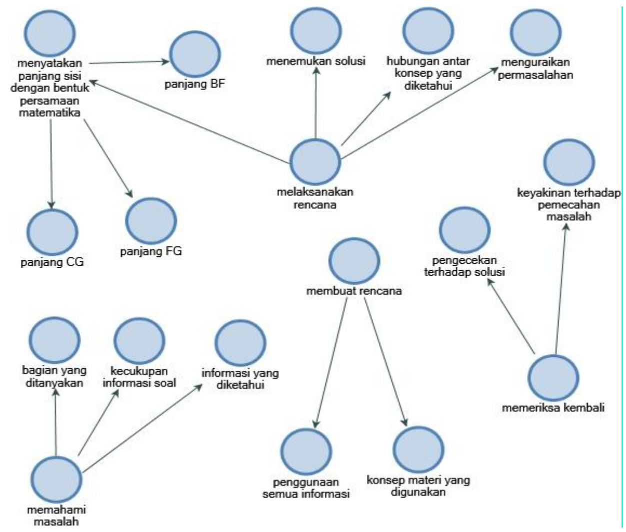

Figure 2: Project Map of Research Subjects' Problem-Solving (*in Indonesian*)

Once students' problem-solving step is accomplished, the researchers wanted to investigate the harmony and consistency of problem-solving step. The researchers conducted QSR NVivo-assisted cluster analysis based on word similarities, meaning that the words contained in data sources or nodes were later compared and costrasted. Data sources or nodes with higher level than the similarities based on the presence and frequency of the words would be displayed in groups. Data source or nodes with lower level than the similarities based on the presence and frequency of the words would be separated from group. Cluster analyses used Pearson's correlating coefficient. The results were supported with correlations belonging to medium and high categories. The seven pairs of nodes represent the side length with mathematical equation and FG length (0.740), the question and finding solution (0.435), explaining problem and CG length (0.655), sufficient information about question and the use of all information (0.592), the relationship between identified concept and information (0.593), confidence on problem-solving and solution review (0.788), and implementation plan and planning (0.775). The information indicates that: (a) students were able to describe FG length into mathematical equation, (b) students understood the question and were able to find proper solution based on the question, (c) students were able to explain problem by determining CG length as a bridge to solve problem, (d) students understood information adequacy in the question and used all provided information to solve problem, (e) students were able to correlate concepts based on identified information to solve problem, (f) students were confident with problem-solving since they had reviewed solution they found, and (g) students were able to design a plan and implement the plan consistently.

Responses provided by all research subjects related to the questions were very detailed and correct. However, seen from a problem-solving process of each subject, there appeared some differences and similarities. The researchers performed QSR NVivo-assisted cluster analysis based on word similarities in the previous discussion. Based on the analysis, it is obtained that those three subjects appeared to have quite high correlations (AR-HFNL = 0.840031, DP-AR = 0.773034 and DP-HFNL = 0.772935). Examining the aforementioned correlating coefficients, subjects AR and HFNL with higher correlating coefficients would be put into one group, while correlating coefficient between subjects DP and AR or correlating coefficient between DP and HFNL that is lower would make DP separated from group of subjects AR and HFNL.

Table 3: The Comparison of Research Subjects' Problem-Solving Steps

Frequent Questions from Data Sources	**Subjects**		
(*Node* and *Child Node*)	**AR**	**HFNL**	**DP**
1. Understanding problems	+	++	+
a. Identified information	+++	+	++
b. Questioned part	++	++	+
c. Available information	+++	+	++
2. Planning	+	+++	++
a. Uses of all information	++	+	+
b. Concept of used material	+++	++	+
3. Applying plan	+++	++	+
a. Explaining problem	++	+	+++
b. Explaining side length using mathematical equation	+	+	+
1) BF length	++	++	+
2) FG length	++	++	+
3) CG length	+	++	++
c. Understanding the relationship among identified concepts	++	+	+
d. Finding solution	+	+	+
4. Reviewing	+	+	++
a. Being confident on problem-solving	++	+	+++
b. Reviewing solution	+	++	+++

Notes. If more (+) signs appear, there are many more problem-solving processes significantly mentioned.

Table 3 shows that each node and child node made in NVivo contained coding from various research data sources. This indicates that all research subjects used the same strategy in problem-solving. This is also illustrates the thinking process of research subjects to solve mathematical problems. Their thinking processes included assimilation and accommodation. Assimilation is a process in which new information and experience come together into mental structure. This process does not have to change the existing scheme for the problem structure has met the available scheme. Meanwhile, accommodation is a change in the existing scheme in order to make this suitable for the existing information. In the understanding problem, subjects only apply assimilation process by mentioning identified information, question, and available information. In planning problem solving, subjects were able to mention the concept of other material or knowledge used to solve problems and identified the relationship among objects. Students' thinking process in this step was accommodation, in which students planned problem-solving by combining some information to modify trapezium AEDG scheme into right-angled triangle EHG and rectangle AEHD by drawing EH line. Subjects were able to change information to find other new information. In problem-solving planning, all subjects applied problem-solving plans, which had been arranged and they successfully responded to the questions. In this case, subjects also applied accommodation-thinking process. Students executed this process when they explained the problems into several small parts and rearranged them to find solution. Further, in reviewing step, all subjects only used assimilation by reviewing or rechecking problem-solving obtained to make them confident with the solution. However, the proportion of reviewing for each subject was varied. Subject DP did more reviewing, and therefore, he was more confident with the solution he found, compared to the other subjects.

The research results were encouraged by Glover [20] explained that assimilation to mean taking in information for which the learner already has structures in place, enabling him or her to recognize and attach meaning to the information being received. This is so for stimulus comes in accompliance with existing scheme, and therefore, an individual can directly respond to the stimulus. When conducting assimilation, somebody does no longer need to change the existing scheme because problem structure is already suitable for the scheme. Accommodation occurs when students are not able to assimilate new experience with the existing scheme. This is because new experience is not suitable at all for the scheme. Further, when doing accommodation, an individual can: (1) creates new scheme that is suitable with new stimulus and (2) modifies the existing scheme so that it will be suitable with the stimulus. In this study, accommodation happened when subjects were able to modify trapezium AEDG scheme which was changed into right-angled triangle EHG and rectangle AEHD) by drawing line EH and in this case, subjects changed information to get new information. This is supported Qayumi [6] that accommodation is changing existing qualitative to include new information.

In order to find out the reliability of this research, the researchers used Coding Comparison Query in QSR NVino 11 software. This feature was used to compare coding performed by two users or two groups of users. This feature provided two ways to measure qualitative research reliability by examining agreement level of inter-users by calculating percentage agreement or measuring inter-user reliability using Cohen's Kappa coefficient. Therefore, the output of Coding Comparison Query in QSR NVivo shows the level of percentage agreement between researcher team A and researcher team B; Cohen's Kappa coefficient to determine qualitative data reliability. Cohen's Kappa coefficient is so-called Kappa coefficient. Kappa test using QSR NVivo is indeed an adaptation from Kappa statistical test. This type of test is to determine the consistency of coding results among researcher teams. Kappa coefficient considers the number of agreement expected to happen accidentally. This is what the strength of Kappa coefficient compares to percentage agreement so that many researchers consider that Kappa coefficiently is more beneficial than percentage agreement.

In this research, the output of Coding Comparison Query and the calculation of average Kappa coefficient and agreement percentage without weighing, the Kappa coefficient was 0.7809 or the percentage agreement reached 99.45%. The interpretation of Kappa coefficient value as displayed in Table 1 on the guideline of Kappa value interpretation is that with Kappa coefficient = 0.7809 exceeding 0.75, the reliability of this research belongs to excellent agreement. This is show that two researcher have a perfect agreement about the content of data source that has to be coded, the Kappa coefficient is one. If there not an agreement between two users (except for what can be expected accidentally) on the content of data sources that have to be coded in nodes, and therefore, Kappa ≤ 0. The score between zero and one shows partial agreement. QSR NVivo measures individual Kappa coefficient for each node combination and data source. As mentioned before, QSR NVivo calculates Kappa coefficient and percentage agreement individually for each node combination and data source, and therefore, calculation of average Kappa coefficient or percentage agreement in several sources or nodes in order to reflect comprehensive qualitative research reliability. The output of Coding Comparison Query can be exported from NVivo in the form of spreadsheet so the further calculation is possible to do. If we want to measure average Kappa coefficient or percentage agreement for one node in some data sources, or for some data sources or nodes, we need to consider the weight or data source with a different calculation.

CONCLUSIONS

Three students with high ability could accomplish mathematical solution for Pythagoras concept properly. There were different ways taken by the subjects to solve problems, but the differences did not affect solution because they had similarities of concept in problem-solving. The thinking processes in mathematical problem solving of students with high thinking level included assimilation and accommodation. Assimilation is a condition where subject understands and feels confident with the accuracy of the result by reviewing problem-solving steps. Meanwhile, accommodation is a condition when subject is able to plan problem-solving comprehensively and implements the plan by describing the problem completely.

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