The Problem Solving Cognitive Strategies Used by High Achievers of the Hashemite University

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Abstract: This study aimed at investigating the cognitive strategies used by high achievers of higher education system while solving geometrical problems. Sixteen first ranking students (according to their GPA) of three faculties of the Hashemite University participated in this study. Each one was asked to tell the strategies (s)he was thinking of while trying to reconstruct six geometrical pieces in order to obtain a plane figure that constituted them. The results revealed that two constituent operation-trial and error strategy is the dominant one in solving the problem. In addition, this study revealed several basic geometrical misconceptions. And although the sample of the study was the high achievers, they could be described as dependent learners, they want to be guided and informed about what to do and how to do it regardless of their majors. This result can be understood in the light of the fact that what students learn is fundamentally connected with how they learn it.

Introduction

The concept of job-related skills goes beyond mere reading and writing. Among the 'skills employers want' are creative thinking and problem solving (Kerka, 1990). Problem solving could be described as a form of inquiry learning where existing knowledge is applied to a new or unfamiliar situation in order to gain new knowledge (Killen, 1996). It represents higher order domain of inquiry (Sternberg, 1995). Also, sometimes it is regarded as a strategy which is used to develop the reasoning skills of learners as it involves research to identify problems, analyses of various perspectives on the problem, evaluation of the merit of the different perspectives, and synthesis of findings (Howley, Howley and Pendarvis, 1986). Mastery of problem solving requires the development of higher order thinking skills, a conceptual understanding of systems, and a more holistic point of view (Sisk and Whaley, 1987). Accordingly, equipping students with strategies to solve problems help them to overcome the initial panic that wells up when they face a tough problem, it enables them to monitor their thought processes through assessing: the potential use of each idea before applying it, whether a sub-task is complete, what they have learn from mistakes, and monitoring their progress (Sisk, 2000). Furthermore, the cognitive abilities of problem solving are essential to succeed in any scientific or professional field (Benito, 2000). And Since the role of the learner should be transferred from that of an exercise-doer to that of a first hand inquirer (Horst, 2000), and, also, our students, especially high achievers, are going to be engaged in the work place within a limited time, the question of their ability to tackle a problem and solve it was raised and investigated, in order to help the decision maker to plan appropriately and taking the right decisions before the students enter the market.

This paper will explore high achievers' problem solving cognitive strategies.

Methodology

Sample

Participants in the study were sixteen first ranking students (according to GPA in their majors at the last semester before graduation) at each of the majors of the three faculties: Sciences and Arts, Educational Sciences, and Economic and Administrative Sciences.

Tool of the study

To achieve the aim of the study, a geometrical transformation problem was constructed. The problem that was used for this purpose is the following

"a familiar plane geometrical figure (rectangle, triangle, trapezoid, square, quadrilateral, or circle) was cut into six pieces (as in figure 1). You are supposed to reconstruct it, and to tell what was it. Please tell me what are you thinking of and how you are going to solve this problem".

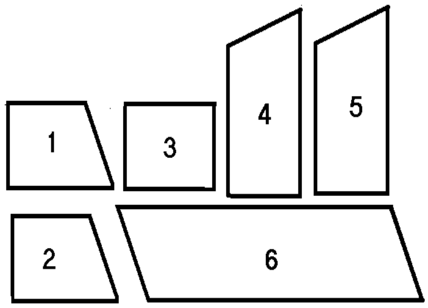

Figure 1: the pieces of the plane geometric figure

Method

In order to determine the upper limit time to complete this task, four professors (three of them are Math Education specialists, one is Measurement and Evaluation specialist) were asked to estimate the time needed to solve this problem. The average of the estimated times was calculated and it was five minutes. Each subject of the sample was exposed to the problem and interviewed individually. This study was administered at the second semester of the year 2000/2001, i.e. at the last semester before graduation from University. Although the time was five minutes, one student willingly stayed for seven minutes, to enable the researcher to explore her way of thinking. However, ten of them left after two minutes. During the interview, each student was asked to speak aloud while trying to reconstruct the geometric plane figure. The researcher was writing what the subject was saying, and trying to ask him/her questions either to probe into the reasons for their responses, or to elicit responses when s/he stops speaking. Notes on the observations were jotted down and comments were recorded after each interview. Each of the subjects was provided with a piece of paper to use it to sketch the figure that could be the end product from his/her point of view. These journals and the observation notes on each interview were analyzed afterwards in order to identify the cognitive strategies that were used by each subject while solving the problem. And in order to validate the analysis, the professors who estimated the time for completing the task analyzed each of the journals individually, and then a meeting was held and their analysis were discussed, ending with agreed analysis to all journals.

Results of the study

The journals and observation notes of the sample were classified into three categories according to the number of constituent operations applied at each strategy: applying more than six operations, applying between five and six operations, and applying two operations. Following is an example of each of the categories.

<u>Example 1:</u> applying more than six operations, (only one student).

Journal no. (1): Major classroom teacher/Educational Sciences

She spent 30 seconds looking at each of the figures, examining the sides and areas of each of the pieces, then she said I want to compare and contrast the figures. What are their characteristics? How are they classified? Since the pieces 1, 2, 3 have the same length, I guess they could be gathered in a way to construct a geometric figure. I'll try to draw this figure (in mind). It's trapezoid. I'll add 4 & the reverse of 5 over the previous figure. No, because of 6. It is not a figure. I'll try to reconstruct another figure. What is in the original figures that I miss? Ah, it seems that the key is in figure 6. What is in it? The sides are not straight. It is not a rectangle. If I can let the other sides match these sides, I'll have a figure. Now I'll try the following combination of the figures. (She began to move her hands in the space as if she is drawing, not on paper). Now I'll begin with 6. On its right the reverse of 4, the not straight sides beside each other, the same with 5 on the other side of 6. It will end up with huge rectangle. Over it 1 after rotating it upside down, then 3, then 2. No, the result is wrong. I know the solution is in figure 6, it is the key. Okay one last attempt. The first layer is 6. The second is reverse of 1, then 3, then 2, the third layer is 4, the reverse of 5. I don't know it is there but I can't see it. I solved the problem partially but I can't solve it totally. I'm sorry.

R: could you pleas plot the resulted figure?

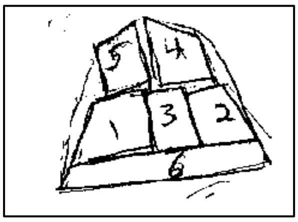

Figure (2): out put of journal (1):

R: couldn't you rethink of the result? Are you happy with it?
S: I know it is not right, I feel it, it is not like the ones I studied during high school. I don't know how to correct it. I spent too much time, but I'm not accustomed to this kind of questions. I'm sorry.

This recursive medium-end strategy consisted of the following subordinate operations: 1) being totally engaged in the problem; 2) understand the problem through analyzing the elements; 3) trying to understand and explore the relations between the elements; defining the constraints or critical features of the situation; identifying the criteria by which she'll judge the acceptable answer; playing around with problem statement through searching for reasonable assumptions to identify what can be left out and what must be considered; 4) classification 5) relation-finding; 6) guestimate the solution; 7) plan through mapping out the sub-problems and steps to be taken; 8) carrying out the plan; 9) monitoring the progress, corrective feedback; reflecting on what was achieved; 10) medium end analysis, through going back to input, in order to define what critical features are missing (the result doesn't match the expected); 11) create another hypothesis from the givens; 12) implement and test the hypothesis; 13) monitor and evaluate the progress and result; 14) use a criteria to judge the accuracy and reasonableness of the output (though it was not suitable).

<u>Example 2:</u> applying between five and six operations, (only two students).
Journal no. (2): Major: Computer Sciences
He looked at all the pieces for two to three seconds, then:
S: I'll do some possibilities. No, it is trapezoid.
R: what are the bases for your possibilities? What do you mean? Why trapezoid?
S: (ignoring all the questions, drew a trapezoid first). I want to put the same pieces together. Put 6, on the right 5, on the left 4, over them 3 horizontally, 1 on the right, 2 on the left. See, the resulting figure ranges from triangle to trapezoid. I prefer trapezoid.
R: why? Is it really a trapezoid?
S: I don't spend too much time on any thing, I can't continue, I don't Know why? I feel it is right. That's it.

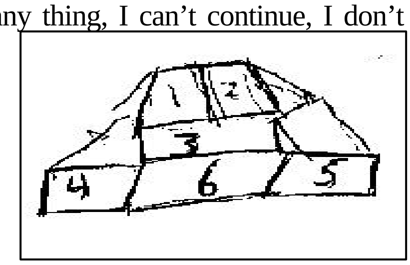

Figure (3): out product of journal (2) (Trapezoid)

R: is it so?
S: (ignoring the question) he closed the figure ending in a trapezoid.

This backward-closure Strategy consisted of the following subordinate operations: 1) intuitive-assumptions (possibilities or alternatives); 2) backward; 3) experimenting assumptions; 4) guestimate; 5) closure.

<u>Example 3</u>: applying only two operations (13 students)
Journal no. (3): Major: English language Teacher / Educational Sciences

After looking at the pieces for a second, she began to draw the figure on the paper.
S: the figure is a box
R: but do you think it goes with what is required?
S: (without thinking) no, it is a triangle.
R: why?
S: it might be trapezoid? But it is not.
R: why?
S: I can't think of any logical figure that convinces me, I feel that the figure contains angles that constitutes 3-dimensional. if these pieces were cut and reconstructed, are you sure that it will result in a 2-dimensional figure?
R: but why do you doubt it?
S: I can see a box only.
R: why?
S: I like its shape. I want to cut the pieces.
R: no, think of them, but don't cut the pieces.
S: it is a cube, if it is not, I hate to fail, so it is an ugly rectangle, no a triangle. Yes… .
R: are you sure?
S: No, I spent too much time. I' accustomed not to spend too much time for any problem. In fact, no problem I faced took me more than two seconds to solve. This took me too much time, so, what I reached is right it is triangle. It is a Right angled triangle (fig 4) or just triangle (fig 5).

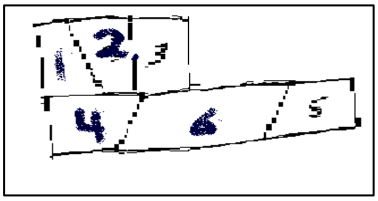

Figure (4): out put of journal (3)
Right angled triangle

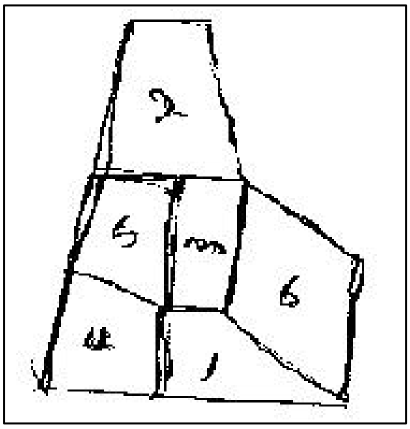

Figure (5): another out put of journal (3). A triangle

This general trial and error strategy consisted of the following subordinate operations:
1) Trial and error using drawing; 2) dominant- first idea

Conclusions

The findings of this study could be addressed in terms of two aspects: the operations and strategies the high achieving students use; and the quality and accuracy of the product they have produced.

Taking into consideration the aspect of operations and strategies they used while solving genuine problem; we could say that the prevailing strategy was the general trial and error. Although systematic trial and error, if followed by monitoring the learning process and evaluating the outcome, could be considered part of the plan stage. However, the situations in this study didn't indicate that there is any plan; it was just trial and error. In these thirteen journals and notes, there were no sign of trying to understand thoroughly the situation, determine the givens, what is required, what are the limitations in the situation. Most of the subjects didn't spend enough time to be engaged in the problem, to be prepared mentally before driving into the details and trying to solve it. Two of them try to monitor and evaluate their way of thinking while progressing, but it was, only, to some extent. Only, one tried to guestimate the shape of out-put, he used working backwards, although he failed to continue. This result could be understood in the light of the fact that what students learn is fundamentally connected with how they learn it. Students' learning could be characterized as informative not transformative learning, as was deduced from analyzing their journals and interviews. However, several studies aiming at investigating the dominant ways of teaching in higher and general education revealed that the dominant one was labeled as Banking Instruction, where the teacher deposited certain information at students' bank (mind), and this same information is recalled during examinations.

0ne of the strategies that two students (out of sixteen) used was the backward- closure one. Backward strategy indicates the presence of possible solutions that can be imagined and tested. This requires knowledge of number of solution plans and proficiency in applying these plans to actually resolve problems (Beyer, 1987). However, reflecting on the way it was used, it could be inferred that the first hand thinking of output was the only possible solution, although it is wrong. The closure operation was used as a way to say that their first hand thinking or solution is right. It was noticed that most of the students (14 out of 16) didn't use assessment to monitor their processes, and to review their product development and its accuracy, although they were geared indirectly to do so by the researcher. It is assumed that they use assessment that should be reflective, and should be viewed as a work in progress. In addition, feedback should be used to improve the quality of the product, because, the ultimate evaluation is a function of viewer feedback (Renzulli, 2000); but they did not use it.

From the product point of view; this study revealed that no one of the high achievers was able to solve this problem, not even the ones that used cognitive and metacognitive strategies, though it was addressing a very basic content problem. Also, the findings revealed that high achieving students have many geometrical misconceptions, such as the concept of triangle; trapezoid, slope of line, congruent triangles.

In summary, the study revealed that the higher education students lack:

1. flexible application of a well organized, domain-specific knowledge base, which constitute the substance of a subject-matter field.
2. heuristic methods, i. e., systematic search strategies for problem analysis and transformation, such as carefully analyzing a problem, specifying the unknowns, decomposing a problem into a sub-goals, finding an easier related or analogous problem, working backward from the intended goal or solution.
3. metacgonitive knowledge and skills involving knowledge concerning one's own cognitive functioning, on the one hand, and activities relating to the self-monitoring and regulation of one's cognitive processes, on the other. The second category include such skills as planning a solution process; monitoring an ongoing solution process; evaluating and, if necessary, correcting an answer or solution; and reflecting on one's learning and problem-solving activities.

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