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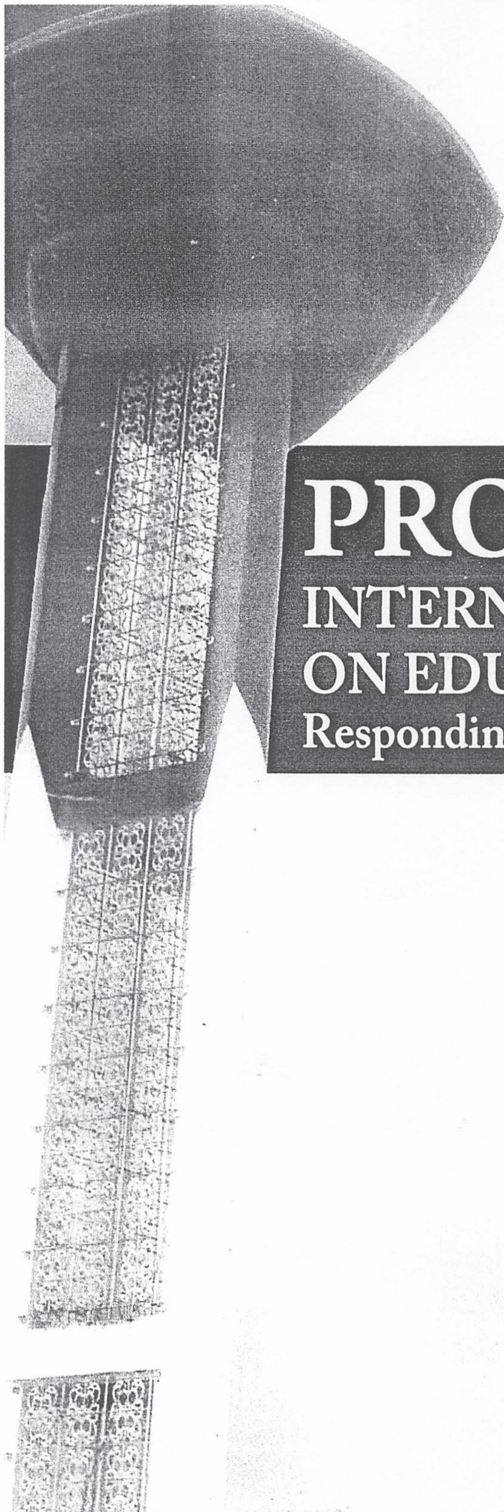
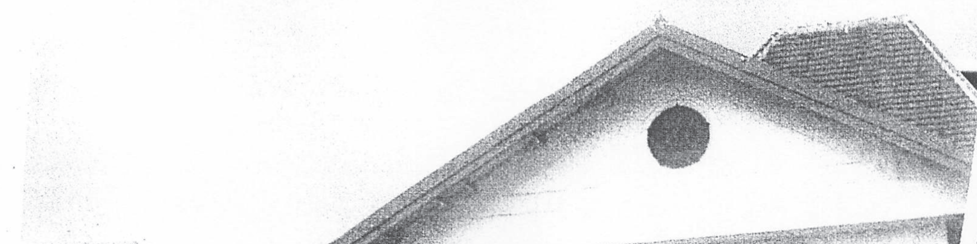
PROCEEDING

INTERNATIONAL SEMINAR ON EDUCATION

Responding to Global Education Challenges





Yogyakarta State University

19 May 2009

INTERNATIONAL SEMINAR ON EDUCATION:
Responding to Global Education Challenges

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Words from the Editor

Our world now has become a global village for everyone to live in. For our future generation the challenges to live in such a place would call for education which is specially tailored for them. Therefore, it is wise if educators from various disciplines and all levels work hand in hand in interpreting what it means to go global and in turn, articulate the philosophy into more manageable and feasible pedagogical practices for teachers to implement in the field.

Such a philosophy as going global would be a meaningless piece of jargon unless it is then interpreted in many educational aspects and disciplines. The interpretation would make educators, teachers, parents and the society have a basis for developing educational efforts which provide Indonesian children with values, learning experiences and skills needed to face the global challenges. The International Seminar on Global Educational Challenges conducted by Yogyakarta State University has attracted many educators and educational practitioners to propose ideas in their respective disciplines in articles which are worth reading due to their relevance to our needs of the most current guideline for responding to the global challenges. Each of the topics elaborated in the article has been an effort to improve the quality of pedagogical practices in various fields and levels of education.

The topics that have been proposed, shared and discussed cover many disciplines. From the field of education there are life skills, citizenship and character building. From the teaching of school subjects English, mathematics, sports and science are also investigated and discussed. The educational levels vary from those of primary to tertiary. Some topics present to us teacher professionalism and pre service teacher training which give us insights how significant the role of human resources is. Topics presented in the plenary sessions cover the most current issues in our educational system today on internationally standardized schools and vocational education. Since ideas come from different fields and disciplines as well as proposed by scholars from various countries and background

Apart from being diverse, the edited articles give us almost a whole picture of the face of our today education. They have convinced us that educators must work with and learn from other experts from other disciplines to search for a new and better educational concept for the nation.

Nury Supriyanti
Chief Editor

Foreword

Practitioners from emerging international-standard schools have expressed the need for multidisciplinary forums where participants may share ideas, problems, and possible solutions on matters related to their new school status. Although at the national level there have been KONASPI (the Indonesian Education National Convention) forums where participants from diverse disciplines share their ideas on different fields of study, such a forum, which was formulated as an international seminar at Yogyakarta State University, was the first of its kind. It was in response to the above need that the seminar was conducted.

The International Seminar on Education: Responding to Global Education Challenges, with the proposed theme "Current issues in global education and their implications for pedagogical practices" aims at facilitating teachers' professional development through the sharing of ideas, problems, and their possible solutions. Research results and opinion-based papers were presented to enable the participants to see what others are doing in trying to help learners achieve the competence they were expected to possess.

Therefore, in the plenary session there were Mr. Coleman presenting a topic on English language teaching and international standard schools, Prof. Dr. Takeshi (majoring in history) on professional teacher development, and Prof. Dr. Abdul Wahid Mukhari on vocational education. In the parallel sessions there were 38 papers on diverse disciplines under the subtopics of language teaching, language tests and assessment, citizenship and character building, teaching mathematics, science teaching, sports education and research, instructional system, electronics and electrical engineering, teaching in primary schools, and life skills. Speakers in the seminar represented their respective university or institution from The UK, Japan, Malaysia, The Netherlands, Guyana, Surabaya, Klaten, Semarang, Mataram, Gresik, Bandung, and Yogyakarta.

While the speakers and the audience of these diverse disciplines must have learned from each other during the seminar, we do hope that readers can find this seminar proceeding inspiring and broadening their horizon.

Yogyakarta, May 2009

Sugirin
Chairman of the Seminar Committee

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Toward the Improvement of Group Learning Using Goal-Free Problems

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Abstract

Responding to global education challenges, students should be encouraged to be productive thinkers. It is argued that a productive thinking is as a consequence of having a well defined knowledge and therefore learning process should encourage an effective knowledge acquisition. In mathematics, problem solving is the major activity during learning. This paper aims to explore how students effectively solve mathematics problems while learning in small groups and find out a possible cognitive load which **occurs** while students organise their thought.

The Cognitive Load theory illuminates our understanding that to construct well defined knowledge, instructions should be designed to minimise cognitive burden to individual. Goal-free problems have been proved to be an effective way of eliminating the use of a mean-end analysis for an individualised learning environment. This strategy is likely to be effective for a group learning situation because it will impose a minimum extraneous cognitive load on each group members and it will improve interactions among group members due to many alternatives that could be generated.

Keywords: *problem solving, goal-free effect, group learning, cognitive load theory*

A. Introducation

Responding to global education challenges, students should be encouraged to be productive thinkers. It is argued that a productive thinking is as a consequence of having a well defined knowledge and therefore learning process should encourage an effective knowledge acquisition. In mathematics, problem solving is the major activity during learning. This paper aims to explore how students solve effectively mathematics problems while learning and find out possibly cognitive load occurs while students organise their thought.

Furthermore, it is argued that learning can be more effective in group environment. The idea of dividing a classroom into small work groups has been applied by many teachers for decades. Recently, school curricula in some countries have recommended teachers use group learning, for example, the mathematics curriculum used nationally in the USA that was developed by the NCTM (National Council of Teachers of Mathematics) in 2000. NCTM (2000, p. 10) stated in its teaching principles that teachers should encourage "students' discussion and collaboration" as well as encouraging students to "construct mathematical arguments and respond to others' arguments".

Latterell also observed that the NCTM curricula are widely used in many countries; so it can be assumed that many other countries have applied this method at schools, including Indonesia. Apparently, however, a clear set of principles for organising group settings in authentic classroom situations has not yet been proposed. In the 2000 NCTM curriculum, for instance, principles concerned with how to prepare students and guide them into successful interaction and academic improvement are not stated, even though they are highly recommended. This paper also proposed to find out how to design effective instruction for group learning, while studying problem solving in mathematics.

B. Group Learning Perspectives

Group work may be defined as a small set of students who learn collaboratively to accomplish desired tasks. This setting is largely concerned with social interaction while solving problems for cognitive development.

The perspective of cognitive development is largely based on the studies of Piaget and Vygotsky. Daniels (2001) discussed the meta-cognitive concepts derived from Piaget and Vygotsky as follows. He stated that Piaget's theory assumed that *cognitive conflict* during discussion about learning tasks among students creates *cognitive disequilibrium* which, in turn, stimulates inadequate reasoning, modification and cognitive development.

On the other hand, Vygotsky's theory assumed that mental processes or thinking is mediated by social activity and cultural practice because of the *Zone of Proximal Development*. In this zone, students should have an opportunity to learn collaboratively with others by presenting their previous knowledge to others, exchanging information and understanding by correcting one another and then learning from others' explanations in order to understand knowledge that they could not acquire by themselves.

Complementary to Piaget's and Vygotsky's theories, Vidacovic and Martin (2004) argued that to achieve higher understanding, *externalisation,* in which thought is expressed or reflected, is as important as *internalisation* in which meaning is constructed individually.

Mayer (1999) suggested that discussion in small groups could be used to develop strategic knowledge for deriving solution planning and monitoring when solving problems. Strategic knowledge is needed to represent the problems in mathematical operations and to establish sub goals in a multiple step problem (Mayer, 1999). According to Mayer, this training can be done by working in small groups because, while working in a group, students could have a chance to describe their methods and to compare their methods with those used by other students. In this process, they could exchange and gather information as well as work on alternative versions of the problem.

Schmidt, Loyens, Van Gog & Paas (2007) argued for group work settings using cognitive load theory terms. They assumed that discussion during group work decreases intrinsic cognitive load because students can activate and share prior knowledge with group members and so enable them to deal with complex problems. In addition, they suggested that group members be instructed to spend less time on irrelevant information to decrease the possibility of an extraneous cognitive load from the presented tasks, and to provide self-explanation or reflection on their input in the discussion to increase a germane cognitive load.

If group work is considered as an appropriate teaching process or if it could facilitate learning, factors that support positive interaction should be considered before grouping the students so that understanding knowledge remains the main objective.

C. Cognitive Load

Typically, teachers start a new topic by presenting some material, show one or two worked examples and then instruct students to practice the material by solving lots of problems. A method to teach problem solving skills without explicitly facilitated guidance is widely called a problem solving approach. Learning that is defined as knowledge acquisition and automation, may occur during problem solving (Sweller, 1999). Some good students may be persistent in doing the problems and so may learn better. These students may devote most of their time to problem solving and may learn slowly. There are also some students who give up earlier and do not obviously learn. As a consequence, the effectiveness of problem solving in facilitating student knowledge construction and automation is questionable. Therefore, to assist students to be expert problem solvers with an ability to transfer acquired knowledge, a substitute for a problem solving search strategy that can manage cognitive load is required.

Problem solving can be described as an activity to reach one or more adequate solutions to a problem (Bruning, Scraw, Norby, & Ronning, 2004). Kantowski (1977) categorised a question as a problem if it cannot be answered immediately using one's knowledge available at long term memory, and so has to be consciously worked out. Here is an example of problem solving: "Suppose five days after the day before yesterday is Friday. What day of the week is tomorrow?" While this problem is simple it is hard to solve immediately. Recall that our working memory capacity is limited when dealing with novel information (Miller, 1956). Our working memory capacity may become exhausted from holding the information of this problem and just a few resources are left over to solve the problem.

The amount of mental activity occurring in working memory at a given time is defined as a cognitive load (Cooper, 1998). There are three sources of cognitive load: intrinsic, extraneous and germane cognitive loads (Pass, Renkl, & Sweller, 2004; Sweller, 1999). These three categories of cognitive loads are additive.

The intrinsic cognitive load refers to the nature of element interactivity (Chandler & Sweller, 1991; Sweller, 1999). Material that is low in element interactivity does not contain many interacting elements and thus each element can be learnt individually. The intrinsic cognitive load is low. Conversely, some material is high in element interactivity where the elements are associated with each other and so have to be processed by working memory simultaneously. The intrinsic cognitive load is high.

The manner of presentation of to be learned material is the primary factor determining the extraneous cognitive load (Pass et al., 2004). A problem-based learning approach may inhibit novice learners from learning effectively because a working memory load may be imposed by an activity that is irrelevant to learning such as the means-ends analysis (Ayres & Sweller, 1990). Other sources of the extraneous cognitive load are split attention presentations or redundant information (Sweller, 1999).

While the extraneous cognitive load is caused by an ineffective organisation of instructional design, a germane cognitive load occurs when learners use working memory resources to acquire and automate knowledge (Pass et al., 2004). The germane cognitive load involves activities, that are relevant to learning, such as eliciting self-explanation (Paas & Van Gog, 2006).

Managing cognitive load at an optimal level is necessary for facilitating learning because, as described above, an overload in the working memory reduces the chance of changes to a long term memory. More importantly, when intrinsic cognitive load is high, it is essential to reduce the extraneous cognitive load and thus free cognitive resources that can be used for the germane cognitive load. However, when the intrinsic cognitive load is low, the reduction of the extraneous cognitive load is less important because the addition of intrinsic and extraneous loads is unlikely to exceed the limits of working memory capacity.

The Cognitive load theory is primarily focused on instructional learning that maintains cognitive loads. As yet, this theory does not specifically derive instructions that effectively manage cognitive load in group learning or as a means of social interaction during cognitive processing. However, instructions could possibly be applied in group work settings, because they are created based on natural information processing in human cognition. By working together in a group, the available cognitive resources may be increased because learning tasks are tackled together and thus the cognitive burden may be reduced because of task distribution among group members (Hoogveld, Paas, & Jochems, 2003; Schmidt et al., 2007).

D. Problem Solving Strategy

Brunning et al (2004) assumed that successful problem solvers engage five component skills: (1) identifying the problem, (2) representing the problem, (3) selecting an appropriate strategy, (4) implementing the strategy, and (5) evaluating solutions. Identifying the problem requires creativity, persistence and willingness to think carefully about the problem over sufficient time. The degree to which the problem solver acquires domain-specific prior knowledge can determine a successful problem finding since prior knowledge facilitates perception and elaboration of new information.

After problem finding, problem solvers may need to represent the problem externally as the amount of information needed to deal with complex problems is constrained by the working memory load and so too difficult to solve mentally. In order to find a strategy path, problem solvers should represent the more important components of the problem space: goal state (what we want to accomplish), initial state (what is the given information), operators (objects or concepts that can be used to reach the goal) and constraints on operators (rules or procedures to be used by the operator).

Thirdly, problem solving requires selecting an appropriate strategy: that can be a highly structured strategy, namely, an algorithm, or a general problem solving strategy (Geary, 2007), which is broad knowledge that is not connected to a specific domain but generally needed for completing problem solving tasks, for example vocabulary to express ideas, general search information skills or meta-cognitive knowledge to carry out problem solving activities.

The problem of finding the volume of a geometrical shape which can be solved using the volume formula is an example of the use of an algorithm based strategy. Expert problem solvers in the domain, not surprisingly, are able to retrieve or to select the appropriate algorithm because of their proficient knowledge of planning strategies. However, using an algorithm based strategy is impossible for novice problem solvers because either the algorithm does not exist in their long term memory or they lack expertise in using it. Subsequently, novice problem solvers will use a general problem solving strategy that is traditionally called a heuristic or "*rule of thumb*", trial and error, or means ends analysis.

Brunning et al (2004) indicated that people who deal with a very unfamiliar problem may not have sufficient information or experience to derive a strategic solution plan. They might use "trial and error" at the start and then, after reaching some preliminary conclusion to the problem, turn to a more efficient strategy. This strategy may work to obtain a solution but such a strategy is considered the least efficient method of problem solving because it does not direct the problem solvers' attention to acquire practical knowledge in their long term memory (Sweller, 1999).

Schoenfeld (1980) defined a heuristic strategy as: "a general suggestion or technique which helps problem-solvers to understand or to solve a problem" (p. 795). Heuristic strategies include strategies used by expert problem solvers that are stated as short explanations or clues. Heuristic strategies use working backwards, or a looking back strategy to search for a solution (Kantowski, 1977). Schoenfeld (1980) provided an example of the use of a heuristic strategy in mathematics as follows.

"To solve a complicated problem, it often helps to examine and solve a simpler analogous problem. Then exploit your solution."

Problem : Two points on the surface of the unit sphere (in 3-space) are connected by an arc A which passes through the interior of the sphere. Prove that if the length of A is less than 2, then there is a hemisphere H which does not intersect A.

(Schoenfeld, 1980, p. 795)

A heuristic method applied to the above examples shows that the problem can be solved by examining and applying a simpler analogous problem to the given problem. Apparently, this heuristic strategy should be applied differently to each problem because of the nature of the problem; therefore, arguably, the heuristic method may be a source of an extraneous cognitive load.

In problem 4, for example, because visualising a 3-space sphere can be a complicated problem, an analogous circle can be used to observe the arc and the diameter relation as described in the problem. After finding how the operator works in the analogous problem, problem solvers should turn back to the given problem applying the same method found in a 3-space sphere.

The heuristic method imposes a heavy working memory load because, rather than facilitating knowledge acquisition and automation, a heuristic strategy suggests learners create sub goals or analogous problems that will result in slower learning and the hazard of misconception. Breaking down a problem into smaller sub problems and examining each step before proceeding to the next one is a form of "a means-ends analysis" that imposes an extraneous cognitive load. Using means ends analysis, problem solvers try to reduce the distance between the given information and the problem goal by creating sub-sub goals and then examining them individually to find the solution.

Ayres and Sweller (1990) investigated the effect of using means ends analysis during geometry problem solving. It was found that most errors occurred during the calculation of the sub-goal preceding the goal in either two or three step geometry problems. The authors stated that the means-ends analysis is often used not only when calculating the goal of the problem, but also in the sub goal prior to the goal. The use of a means-ends analysis might be beneficial for some problem learners when dealing with unfamiliar problems, because it can increase the chance of completing the goal of the problem; however, it does not necessarily facilitate learning.

In addition, the difficulty level of the problem (or the intrinsic cognitive load) may contribute to the use of a means-ends analysis. Ayres and Sweller, in their experiment, confirmed this fact and demonstrated that after the unfamiliar problems were altered to reduce the use of a means-ends analysis by constructing configurations that had a clear solution path thus encouraging a forward strategy, the calculation error location is random. This means that the use of a means-ends analysis can be minimised by tailoring the configuration of the problems. The authors concluded that the use of a means-ends analysis imposes a heavy cognitive load and can be minimised.

It has been indicated that a heuristic strategy can be applied differently to different problems and to do so, one needs to retrieve other knowledge in order to find an analogous problem and then apply a means-ends analysis or a trial and error approach. Prior knowledge possessed by problem solvers is the reason for this. In addition, it can also be argued that a heuristic method does not always guarantee a solution and even makes problem solving more difficult. Notwithstanding the fact that a heuristic method may provide a stepping stone, it is obvious that a heuristic strategy is inefficient for learning novel problem solving because it imposes a high cognitive load.

The fourth problem solving skill, implementing the strategy, largely depends on the result of previous stages. Expert problem solvers pose a well-developed declarative knowledge base about how a problem is structured, procedural knowledge about how to perform a problem solution and conditional knowledge about when and why to use declarative and procedural knowledge. In contrast, novice problem solvers coordinate the problem solution phase poorly, consider single solutions based on a noticeable problem space and reach conclusions that may be less transferable to another problem.

The fifth problem solving skill is evaluating the solution both in terms of the process and the product of problem solving (Brunning et al, 2004). Evaluation of the solution allows us to reflect more deeply on the process of problem solving and so understand the application of a specific strategy. Expert problem solvers are more likely to consider more solutions and carefully evaluate solutions before discarding them, unlike novice problem solvers (Brunning et al, 2004).

E. Goal-Free Effects

Goal free problems discourage students from creating sub-goals and separate the problem state and the problem goal because the problem goal is not given. Instead, students are required to work forward from given information in order to assist knowledge construction. The figures below shows geometrical problem solving, in which the first figure, the goal is free, but in the second one, the goal of the problem is given (x).

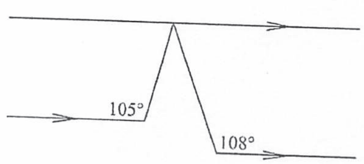

Figure 1: Goal-free problem

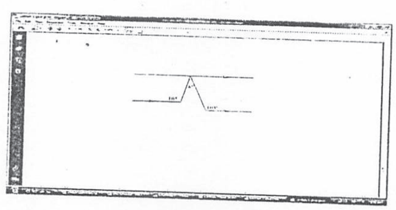

Figure 2: Goal-given problem

Sweller, Mawer and Ward (1983) conducted a series of four experiments to test the hypothesis that goal free problems eliminate the use of a means-ends analysis using geometry problems. The geometry problems used theorems such as *vertically opposite angles are equal* and *the external angles of a triangle equal the sum of the opposite internal angles* to carry out angle measurement of triangles. It was predicted that substituting the instruction to find a specific angle with goal free instructions will reduce the use of a means-ends strategy of working backwards from the goal trying to find sub goals that match the given information.

In the experiment, a group was instructed to study conventional geometry problems and calculate a given specific angle value. The goal free group was instructed to study identical problem and calculate as many angle values as they can, instead. The general results indicated that the goal free group was more likely to work forward and the conventional group consistently used the means-ends analysis. This suggested that students who were given goal free problems during the acquisition phase had constructed relevant knowledge and so were able to work forward in the tests.

In the trigonometry area, Owen and Sweller (1985) ran several experiments comparing errors presented by a goal-free problem group and a conventional problem solving group. Both groups received an individual test after a short period of instruction to familiarise them with the basic principles of trigonometry. Owen and Sweller instructed students to think aloud and to state verbally the trigonometry rules to find a specific length of the given triangle for conventional group, and to find all the unknown triangle sides for the goal-free group. Overall, the results indicated that goal-free problems resulted in fewer total errors and increased transfer. The authors pointed out that by reducing the specificity of the goal enhanced the acquisition of accurate cognitive representations of relevant operators.

The Cognitive load theory that generated the experiments using goal free problem solving illuminates the suggestion that by preventing the use of a means-ends analysis, goal free problems should reduce the extraneous cognitive load and as a consequence, free resources can appropriately be used for knowledge acquisition and automation. Research on goal-free effect has been mostly conducted in individualised learning environments, which shows that this instruction discourage students from irrelevant activities while solving problems. This instruction might also be effective if the teacher lets students learning in a small group because if each group members experience a low extraneous cognitive load, then the total extraneous cognitive load should be low. Therefore, there will be cognitive resource available for the group constructing knowledge.

A possible limitation in applying a goal free problem is that, under some conditions, a very large number of manipulations that may be performed. By this condition, however, if a goal free problem is implemented on group learning, it seems that interaction among group members could be increased. Students might share many legal moves that can be generated. As suggested by Cohen (1994), teachers should give group tasks that could produce interactions, such as tasks that require multiple resources of skills, knowledge or materials and can be solved using different solutions or have more than one solution.

F. Conclusion

Problem solving might be an ultimate instruction. The discussion above has shown that knowledge acquisition while solving problems is assisted when learners think in forward direction from the given information to the goal of the problem. However, novel learners often think backward or use a means-ends analysis. Using a means-ends analysis, problem solvers try to reduce the distance between the given information and the goal of the problem by creating sub-sub goals and then examining them individually to find the solution. This strategy might be beneficial for solving some problems but it requires a heavy cognitive load.

A Cognitive load theory illuminates our understanding that to construct a well defined knowledge; instructions should be designed to minimise cognitive burden to individuals. Goal free problems have been proved to be an effective way of decreasing an extraneous cognitive load for individualised learning environment. This strategy is likely to be effective for group learning situation because it will impose a minimum extraneous cognitive load on each group members and therefore possibly minimise the group's cognitive load. It will also improve interactions among group members due to many alternatives that could be generated.

Nevertheless, more research on cognitive load of group learning facilitated with goal free problems might give more insight on how to improve group performance. By this way, teachers could assist students to have a sophisticated knowledge to face global challenges.

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