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The Self-formation of Collaborative Groups in a Problem Based Learning Environment

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Abstract
The aim of this paper is to present *the three steps method* of the self-formation of collaborative groups in a problem-based learning environment. The self-formation of collaborative groups is based on sharing of accountability among students for solving instructional problems. The steps of the method are planning collaborative problem solving, self-evaluation of students, and building collaborative groups. The planning comprises determination of the nomenclature of higher order thinking (HOT) skills, defining the instructional problems and their complexity levels, creating problem groups according to the complexity levels, setting the problem-relevant HOT skills, determining the accountability measure and the assessments of accountability for solving the problems. The self-evaluation includes self-detection of personal HOT skills, measurement of the diversity between the personal HOT skills and the problem-relevant skills based on the proposed diversity measure, and self-evaluation of willingness and desire of a student to take accountability for solving the instructional problems. The personal willingness is evaluated by the diversity measure. The desire is guided by the accountability assessments for problem solving. Coordination of the self-evaluation outcomes allows building collaborative groups. A group's composition is adjusted by the specific requirements of an instructor.
Keywords: problem based learning, self-forming collaborative groups

1. Introduction

Problem based learning (PBL) is the most used model guiding creation of the favorable learning environment for development of higher-order thinking (HOT) skills of students (Amador, Miles & Peters, 2006; Barell, 2006; Barret & Moore, 2010). The most significant HOT skills are the skills needed for problem solving. Two distinct types of HOT skills needed for problem solving are analytical skills and creative skills. The analytical skills allow critical thinking and help select the best alternative. The creative thinking skills allow identifying the problem, producing original ideas of a broad range of problem solving, and developing ideas (Hmelo-Silver, 2004; Bednarz, 2011; Cottrell, 2013). PBL model can be significantly improved as a result of integration with Collaborative Learning model (Ornstein & Lasley, 2003; Lawrence-Slater, 2006). Collaborative learning promotes critical thinking, actively involves students in learning process, and improves classroom results (Panitz, 2001; Felder & Brent, 2001; Barkley, Cross & Howell, 2004). Collaborative PBL is aimed at acquisition of HOT skills by students while solving instructional problems by collaborative groups. It requires formation of groups with high level of interdependence among group members which facilitates group interactions. The self-formation of the collaborative groups by taking into account the specific characteristics of PBL environment can serve as the productive way leading to effective acquisition of HOT skills by students while PBL (Raiyn, 2016). The purpose of this paper is to present a method of self-forming collaborative groups through sharing of accountability among students for solving instructional problems.

2. Related research

Analysis of various methods, models and means of organization of teaching and learning tells us that collaborative PBL is a student-centered learning model providing the development of lifelong learning skills, thinking skills, and problem-solving abilities (Savery, 2006). The approaches, methods, models, and tools of organizing collaborative PBL are examined here. An approach to integration of collaborative learning into the learning environment is proposed in (Wessner& Pfister, **2001)**. An instructor forms appropriate collaboration groups for certain blocks of a web based course through using information about the collaboration context. The paper (Lawrence-Slater, 2006) describes formation of environment for learning an online course. The students formed online groups and successfully completed a collaborative project. In order to achieve this, students posted their interests, their academic majors, email addresses and other information. Such approach makes it easy to form collaborative groups as a result of posting an informational profile by each student. Maltese (2012) affirms collaborative learning is both the strategy and the goal of PBL. It serves as a means of student engagement in creative problem solving, and learning to work together. The author reveals skills of a group that functions efficiently. These skills are communication, trust, shared leadership, and creative problem solving. Students are induced to collaborate through their reflection and through the interdependence of learning within the group. Zimmerman (2002) specifies self-directed, lifelong learning skills enabling autonomous learning. Schmidt & Moust (2000) emphasize the particular importance of collaboration because it affects intrinsic motivation and learning outcomes. Graham and Misanchuk (2003) determine the principal stages of organization of collaborative learning: structuring of learning activities, creation of groups, and facilitation of group interactions. Authors give preference to heterogeneous composition of a collaborative group, but do not link group heterogeneity to facilitation of group interactions. The authors stress the need for a high level of interdependence among group members for facilitation of group interactions, but do not give evidence of means of creation of a learning environment leading to group interactions (Dillenbourg, 1999). Choice of homogeneous or heterogeneous composition of a collaborative group according to the work (Chuen-Tsai Sun &Sunny, 2001) is realized by online opinion polling of the students. It does not provide impartial forming of collaborative groups on the basis of knowledge of the students. Paulus & Nijstad (2003) emphasized that heterogeneous groups may be more creative and innovative. Debbie (2009) emphasizes significance of group composition in PBL. An impact of different kinds of models of a collaborative group on its functioning is researched by Ellis & Hafner (2007). A type of a model determines the role of a student in a group. However, organizing of functioning of a collaborative group directed to providing stimulation and facilitation of acquiring HOT skills was not examined. Such organization assumes dynamic change of the role of a student in a group depending on his/her ability to lead problem solving. The work (Orvis Kara & Lassiter, 2008) takes a look at dynamic management of group organization. Daradoumis, Xhafa & Marques (2002) suggest an approach to creation of PBL environment facilitating interaction between students. Forming collaborative groups and managing the composition of a collaborative group for facilitating interaction among students is left to students. However, an influence of role dynamics on collaborative problem solving is not shown. Soller& Lesgold (2003) developed a computational approach to analysis of online knowledge sharing interaction. Yet, they did not examine dynamic organization of a favorable PBL environment for stimulating and facilitating problem solving interactions. **Daradoumis, Martínez-Monés & Xhafa (2006) use** a social network analysis of the group activity and a quantitative analysis of group effectiveness **for evaluation of collaborative interactions.** However, the authors have not considered the dynamics of students' HOT skills while problem solving **as a factor for evaluating interactions.** Stanton & Fairfax (2007) have determined a productive collaborative environment. It should provide interdependence of the students, individual accountability, face-to-face interaction, appropriate use of collaborative skills, and group processing. Shavelson (2009) emphasizes the need to provide mutual adjustment of formative function of accountability, conducive to changing the organization of teaching and learning, and the summative function of accountability directed towards determining the extent of accountability. Improvement of teaching and learning can be attained through coordination of assessment and accountability systems, learning outcomes, cognitive outcomes, and individual and social responsibility outcomes. The analysis of publications above shows that there is no a method of self-forming collaborative groups through sharing accountability among students for solving the instructional problems. The method should provide: the planning of collaborative problem solving; the self-evaluation of willingness and desire of students to take accountability for solving the instructional problems; the self-formation of collaborative groups through coordination of self-evaluation outcomes providing a balance between competition and collaboration among students.

3. The method of self-forming collaborative groups for problem solving

The proposed method is aimed at the self-formation of collaborative groups in a problem-based learning environment through sharing of accountability among students for solving instructional problems. The method promotes effective acquiring HOT skills by students while collaborative problem solving. The method consists of three steps.

Step1: The planning of collaborative problem solving

The planning of collaborative problem solving comprises:

- Determination of the nomenclature of HOT skills

Example1. The HOT skills are $k_1, k_2, k_3, k_4, k_5, k_6, k_7, k_8, k_9, k_{10}$.

- Defining the instructional problems. Dividing the set of the instructional problems on the groups according to the complexity levels.

Example2. The instructional problems are $p_1, p_2, \ldots, p_9$. Three complexity levels c_1, c_2, and c_3 are determined. Then, the problem groups can be built by dividing the set of the problems according to the determined complexity levels. As a result of this, the groups are $F(c_1) = p_1, p_2, p_3$; $F(c_2) = p_4, p_5, p_6$; and $F(c_3) = p_7, p_8, p_9$.

- Setting the problem-relevant HOT skills (the skills needed for solving a problem).

Example3. The problem-relevant HOT skills are

$K(p_1) = k_1, k_2, k_3$ $K(p_2) = k_2, k_3, k_4$ $K(p_3) = k_1, k_3, k_4, k_5$

$K(p_4) = k_5, k_8$ $K(p_5) = k_6, k_7, k_9$ $K(p_6) = k_4, k_7$

$K(p_7) = k_6, k_8$ $K(p_8) = k_9, k_{10}$ $K(p_9) = k_8, k_{10}$.

- Determination of the accountability measures, and the accountability assessments for solving the instructional problems.

The accountability measure for solving a certain problem corresponds with the group containing the problem.

Example4. The accountability measure for solving the problem $p_1$is equal by one since this problem belongs to first problem group. Analogically, the accountability measure for solving the problem p_4 is equal by two since this problem belongs to second problem group and so on.
The accountability assessment for solving a problem is set pro rata the accountability measure of the corresponding problem group.
Example5. The fixed assessment of accountability for solving nine problems is set equal 36. Then, assessments of accountability for solving the problems p_1, p_4, and p_7 belonging different problem groups (Example2) are equal 2, 4, and 6, accordingly.
Step 2: Self-evaluation of the students
The self-evaluation includes self-detection of personal HOT skills, measurement of the diversity between the personal HOT skills and the problem-relevant skills, and self-evaluation of willingness and desire of a student to take accountability for solving the instructional problems.
At first, the self-detection of HOT skills is realized after completion of the personal problem solving. Example6. The personal HOT skills of students resulted by the self-detection are: $k(s_1) = k_2, k_5, k_6, k_9$; $k(s_2) = k_1, k_3, k_7, k_{10}$; $k(s_3) = k_5, k_7, k_8, k_9$.
Next, the diversities between HOT skills of the students and the problem-relevant HOT skills are measured. Measurement is provided through a diversity measure between HOT skills of a student and the problem-relevant skills. The diversity measure is understood as:

$$\eta(k(s_i), k(p_j)) = \| k(s_i) \oplus k(p_j \| = \| k(s_i) \cup k(p_j) \setminus k(s_i) \cap k(p_j) \| \quad (1)$$

where
$k(s_i)$ – the HOT skills of student s_i,
$k(p_j)$ – the problem-relevant skills of problem p_j.
Example7. The diversity measures between the students' HOT skills and the problem-relevant skills are presented by Table1.
Table1. The diversity measures

The HOT skills of a student	The problem-relevant skills		
	$k(p_1) = k_1, k_2, k_3$	$k(p_4) = k_5, k_8$	$k(p_7) = k_6, k_8$
$k(s_1) = k_2, k_3, k_5$	2	3	5
$k(s_2) = k_1, k_3$	2	4	4
$k(s_3) = k_4, k_6$	5	4	2

At last, self-evaluation of willingness and desire of a student to take accountability for solving certain instructional problems is performed.

The willingness is determined on the basis of diversities between the student HOT skills and the problem-relevant skills. If the diversity measure between skills of a student and the skills relevant to a certain problem is minimal, then the student is willing to assume full accountability for solving the problem. Example8. The student s_1 is willing to assume full accountability for solving problem p_1 since the diversity measure between his (her) skills and the skills relevant to the problem p_1 is minimal (Table1).

The desire of a student to take accountability for result of solving of a certain problem is guided by the accountability assessment for its solving. As appears from the above, the accountability assessment corresponds with the complexity level of the problem. The desire of a student to take accountability for solving the more complex problem is caused by his (her) aspiration to achieve high assessment of problem-based learning. Example9. The student s_1 desires to take accountability for solving the problem p_4 since the assessment of accountability for its solving is equal by four (Example5). Yet, the measure of diversity between his (her) skills and the skills relevant to the problem p_4 is equal three (Table1). It means the student $s_1$is not willing to assume full accountability for solving this problem.

Consequently, the student should find a balance between the willingness and the desire to take accountability for solving a certain problem through joint analysis of the diversity measure and the accountability assessment. Furthermore, a student should follow a limitation during the self-evaluation process. The limitation is set by an instructor and caused by the aspiration to provide quality of the problem solving process. The limitation is a student should take accountability for solving a fixed quantity of different problems.

A table containing results of the self-evaluation of students' willingness and desire to take accountability for problem solving can be created. The rows of the table correspond to students. The columns of the table correspond to the problems that should be solved. The problem-relevant skills, the accountability measures, and the accountability assessments (Examples2-5) are presented in a heading of a column. Intersection of a row and a column contains result of self-evaluation.

Example10. The problems $p_1, p_2, \ldots, p_9$ are determined. The set of the problems are divided on the groups according to the problems' complexities determined by an instructor. A study group contains 6 students. During the self-evaluation process the students should follow the limitation: quantity of the problems for solving of which a student may be accountable is equal three. Thus, the student s_1 makes decision to take accountability for solving the problems p_1, p_3, and p_5.The self- evaluation outcomes of the students are presented by Table2.

Table2.The self-evaluation outcomes

The students	The problems								
	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9
	The problem relevant skills								
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9
	The accountability measures								
	1	1	1	2	2	2	3	3	3
	The accountability assessments								
	2	2	2	4	4	4	6	6	6
s_1	A		A		A				
s_2	A			A					A
s_3				A			A		A
s_4		A			A			A	
s_5			A			A		A	
s_6	A					A	A		

The table containing the self-evaluation outcomes of the students is manifested. The objective of manifestation is to foster coordination of the self-evaluation outcomes to realize the self-formation of collaborative groups in PBL environment.

Step 3: Building collaborative groups

Building collaborative groups for solving the instructional problems assumes the need to provide a balance between competition and collaboration among students. If a student doesn't have sufficient HOT skills for solving of a certain problem, he (she) can't compete with peers for taking accountability for its solving. If a student has needed skills for solving of a certain problem, he (she) competes with his (her) peers for taking accountability for solving this problem. Moreover, he (she) collaborates with other students while solving other problems.

Building collaborative groups is realized by coordination of self-evaluation outcomes with taking into account the specific requirements.

The requirements are:

- One member of a collaborative group should be accountable for solving a problem. It conduces qualitative problem solving
- The quantity of students in a collaborative group should not be less than the quantity of problems in a problem group. It allows sharing accountability for problem solving
- Each problem should have a student who is accountable for its solving. It provides taking the full accountability for solving all problems
- Compatibility of students should be provided. It induces effective skill transfer among the student of the collaborative group
- Each student of a collaborative group should participate in solving all problems. It promotes interaction among the student of the collaborative group.

During the coordination process every student compares the problems for which he would be accountable with those problems chosen by peers and the performance for which they would be accountable. The coordination process is realized with participation of an instructor. The aim of comparison is to build collaborative groups for solving the problems through coordination of personal accountability of students. A problem selected earlier by a student can be replaced by other one due to coordination with peers. If some students would like to be accountable for solving the same problem (there is competing for taking accountability), despite coordination of their outcomes, then the instructor determines the student who should be accountable for solving this problem. If there is not a student who would like to accept accountability for solving a problem (there is lack of accountability), the instructor delegates accountability to the most suitable student. Hence, building collaborative groups leading to complete accountability of students for solving all offered instructional problems through comparison of students' choices is realized.

Example11: Building the group versions with taking into account incompatibility between students $s_1$and s_2 is based on self-evaluation outcomes (Table2). The characteristics allowing comparison of the group versions are determined. The characteristics are taking accountability, lack of accountability, and competing for taking accountability. The versions of the first and the second collaborative groups and their characteristics are represented by Table3.

Table3. The collaborative group versions

The group version		Taking accountability (the problem numbers)	Lack of accountability (the problem numbers)	Competing for taking accountability (the problem numbers)
The first collaborative group	$<s_1, s_3, s_4>$	1,3,5 4,7,9 2,5,8	6	5
	$<s_1, s_3, s_5>$	1,3,5 4,7,9 3,6,8	2	3
	$<s_1, s_3, s_6>$	1,3,5 4,7,9 1,6,7	2,8	1,7
The second collaborative group	$<s_2, s_5, s_6>$	1,4,9 3,6,8 1,6,7	2,5	1,6
	$<s_2, s_4, s_6>$	1,4,9 2,5,8 1,6,7	3	1

Analysis of the versions of the first collaborative group allows to conclude that the most preferable versions are $<s_1, s_3, s_4>$ and $<s_1, s_3, s_5>$. These versions have the best characteristics (Table 3). If first group $<s_1, s_3, s_4>$ is chosen then second collaborative group includes the student s_2, s_5, and s_6. If first group $<s_1, s_3, s_5>$ is chosen then second collaborative group includes the student s_2, s_4, and s_6. Comparison of the characteristics of the versions of second collaborative group (Table 3) allows concluding that the group $<s_2, s_4, s_6>$ is the most preferable. Hence, the collaborative groups $<s_1, s_3, s_5>$ and $<s_2, s_4, s_6>$ are built. The student s_1 competes with the student s_5 for taking of accountability for solving problem p_3. Furthermore, there is lack accountability for solving problem p_2 (Table3). The coordination of self-evaluation outcomes between the student s_1 and the student s_5 with the participation of an instructor is realized. As a result of that, the student s_5 accepted accountability for solving the problem p_2 instead of the problem p_3. The student s_2 competes with the student s_6 for taking of accountability for solving problem p_1. There is lack accountability for solving problem p_3 (Table3). The coordination of self-assessment outcomes between the student s_2 and the student s_6 with the participation of an instructor is realized. Owing to that, the student s_6 accepted accountability for solving the problem p_3 instead of the problem p_1. The built collaborative groups and the changed self-evaluation outcomes reflecting complete accountability of students for problem solving are presented by Table4. The groups satisfy the aforementioned requirements.

Table4: The built collaborative groups

The collaborative groups	The students	The problems								
		p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9
		The problem relevant skills								
		K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9
		The accountability measures								
		1	1	1	2	2	2	3	3	3
		The accountability assessments								
		2	2	2	4	4	4	6	6	6
The first collaborative groups	s_1	A		A		A				
	s_3				A			A		A
	s_5		A				A		A	
The second collaborative groups	s_2	A			A					A
	s_4		A			A			A	
	s_6			A			A	A		

Conclusion

The proposed *three steps method* sets the order of the self-formation of collaborative groups in a problem-based learning environment. The self-formation of collaborative groups is realized by sharing accountability among students for solving instructional problems. Dividing the set of the instructional problems on the groups according to the complexity levels allows determining the accountability measures and the accountability assessments for solving the problems of different complexity. The more assessment of accountability induces a student to take accountability for its solving. It is caused by his (her) aspiration to achieve more high assessment of the PBL results. The proposed measure of the diversity between the personal HOT skills and the problem-relevant skills serves as a constructive mean sustaining the self – evaluation of the personal willingness to take accountability for solving the suitable problem. If the diversity measure between skills of a student and the skills relevant to a certain problem is minimal, then the student is willing to assume full accountability for solving the problem. A student's decision to take accountability for solving a certain problem is promoted by finding a balance between the willingness and the desire to take accountability for its solving through joint analysis of the diversity measure and the accountability assessment. The coordination of the self-evaluation outcomes allows building the collaborative group versions. The characteristics of the versions are proposed. The characteristics and the specific requirements determined by an instructor guide self-formation of the suitable collaborative groups. Further research will be directed towards development of a support tool for the self-formation of collaborative groups based on the proposed method.

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