Developing students’ collaboration skills through project-based learning in statistics

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Abstract. In the era of Industrial Revolution 4.0, teachers are required to facilitate learning that provides opportunities for students to develop essential skills needed in the real working world. Employees need to perform strong collaboration skills to work productively on a team to accomplish complex assignments. Project Based Learning (PBL) is one of the learning models that give opportunities for students to develop collaboration skills. This study aims to describe how students’ collaboration skills develop through PBL in statistics. The design of learning activities and the rubric of collaboration skills were adopted from the 21st Century Learning Design (CLD) framework developed by SRI International in collaboration with Microsoft Partners in Learning (2012). In this study, students were carrying out the project with the theme “Statistics in School”. During the project, students were able to apply statistics concepts through data collection, data representation, and data analysis. The results of this study indicate that students’ collaboration skills have developed to level 5 of the 21st-CLD rubric. The following indicators were representing the results: students make substantive decisions based on group agreement, students take an important role in implementing the project, students work also depend on each other in order to complete the project.

1. Introduction
To succeed in the era of Industrial Revolution 4.0, Indonesian youth generations have to possess essential skills to answer future challenges and to compete globally in the real working world. Thus, teachers are required to design and implement new models of learning that encourage students to develop 21st-century skills. On the contrary, most teachers still focus only on students’ academic achievement and only a few of them who have attention on students’ 21st-century skills. In many common situations, students do their own task and get their own scores. This kind of learning model does not prepare students well to face challenges in the real working place, where they are required to work on teams to accomplish complex tasks. Real project work often requires individuals to perform strong collaboration skills to work productively on a team and effectively incorporate individual ideas to complete the project. Therefore, teachers are required to design learning activities that can develop students’ collaboration skills. Teachers also need a framework as their reference in designing the learning activities and examining students' collaboration skills.

SRI International was funded by Microsoft Partners in Learning to develop a framework namely the 21st Century Learning Design (CLD) that used for the Innovative Teaching and Learning (ITL) research project (2012). The purpose of the 21st CLD framework is to help teachers design learning activities that give students opportunities to build 21st-century skills. The 21st CLD framework contains rubrics
that examines 21st-century skills: collaboration, knowledge construction, self-regulation, real-world problem solving and innovation, the use of ICT for learning, and skilled communication. There are two types of rubrics to examine each skill: the learning design rubric, and the student work rubric.

In particular, the purpose of the collaboration-learning design rubric is to help teachers to identify and understand the opportunities that learning activities give students to build collaboration skill. Whereby the purpose of the collaboration-student work rubric is to determine how strongly student work demonstrates collaboration skill. Table 1 shows the 21st CLD-collaboration skill rubrics which adopted from the framework of the ITL research project (2012).

| Level | Description                                                                 | Level | Description                                                                 |
|-------|-----------------------------------------------------------------------------|-------|-----------------------------------------------------------------------------|
| 1     | Students are not required to work together in pairs or groups.              | 1     | Students are not working together in pairs or groups.                       |
| 2     | Students do work together, but they do not have shared responsibility.      | 2     | Students are working together, but they are not sharing responsibility fairly.|
| 3     | Students do have shared responsibility, but they are not required to make substantive decisions together. | 3     | Students are sharing responsibility fairly, but they are not making substantive decisions together. |
| 4     | Students do have shared responsibility and they do make substantive decisions together about the content, process, or product of their work, but their work is not interdependent. | 4     | Students are sharing responsibility fairly and they are making substantive decisions together, but their work product is not interdependent. |
| 5     | Students do have shared responsibility and they do make substantive decisions together about the content, process, or product of their work and their work is interdependent. | 5     | Students are sharing responsibility fairly and they are making substantive decisions together, and their work product is interdependent. |

Based on the preliminary observations in a mathematics classroom at one of the public schools in Jakarta, it was found that the teacher has designed the learning activities which provide opportunities for students to work together to solve mathematics problems. The students were encouraged to share responsibilities while doing group discussion. The design of the learning activities has achieved level 3 of the collaboration-learning design rubric. But in fact, most of the students did not share responsibilities during group discussion. They rely on high achievers to solve the given problems. Thus, it can be concluded that the students' works were only in level 2 of the collaboration-student work rubric. Meaning that students did not get sufficient reinforcement to do collaboration through group work activities. Therefore, the teacher may need to revisit other learning activities that can be better in developing students' collaboration skills to the fullest level.

According to the Buck Institute for Education (BIE) Research Summary: PBL and 21st Century Competencies (2012), PBL can develop students’ ability to do collaboration and resolve conflicts (Beckett & Miller; Chan Lin, 2008). As students work on the project, students develop the fundamental skills of productive communication, respect each other, team-work while generating ideas together, and negotiation to solve the problems (Bell, 2010). The National Council of Teachers of Mathematics (NCTM) Principles and Standards for School Mathematics (2000) also support inquiry, or discovery-based learning, which are part of PBL components. Students are actively engaged in PBL that promotes the inquiry of new knowledge, experiences, and skills in mathematics. In addition, students gain
important skills in problem-solving, reasoning, and communicating mathematics, while learning how to conduct the project, manage resources, and collaborate with others. Moreover, by referring to the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 69 the Year 2013, it is stated that one of the characteristics of 2013 Indonesian curriculum is the learning activities must encourage students to develop their positive attitudes, knowledge, and essential life skills, and apply them in the real situations within schools and communities. Thus, it is relevant for the teacher to use PBL in order to develop students’ collaboration skills as well as their applying their knowledge in the real situation in the school context.

Based on the explanation, this study is aiming to discover, describe, and compile in-depth information about the development of students’ collaboration skills through PBL in mathematics class, specifically in statistic topic. The statistics topic was selected because it has many real-life applications that offer more flexibility for students to generate ideas in determining the project topic. The study was conducted in a public senior high school in Jakarta where most of the teachers did not pay much attention to students’ collaboration skills. It is expected that students’ collaboration skills can be developed to the fullest level of the collaboration-student work rubric through PBL in statistics topic.

2. Methodology
2.1. Research design
This study uses qualitative descriptive research in order to describe and compile in-depth information about the development of students’ collaboration skills through PBL in statistics topic. The qualitative descriptive study was to gain a deep understanding of how strongly student work demonstrates collaboration skill through PBL. Students’ collaboration skill was examined by using the collaboration-student work rubric adopted from the ITL research project (2012). Thus, the researcher has categorized the data as follows: (1) students are working together; (2) students are sharing responsibility fairly; (3) students are making substantive decisions together, (4) students work product is interdependent.

2.2. Research setting and respondents
This study was conducted in one of public senior high school in Jakarta. The respondents of this study were a teacher and 36 students from a ten-grade class. The students were formed into 6 heterogeneous groups by referring to mathematics achievement levels. Each group decides the project topic that relates to the use of Statistics for School Data. Moreover, the researcher select 6 key informants representing each group to provide in-depth information on how students do collaboration within the project work. Table 2 shows students grouping, key informants, and project topics.

Table 2. Students grouping

| Group  | List of group members  | Project topic          |
|--------|------------------------|------------------------|
| Group 1| SP5, SP6, SP9 *(i1)*, SP10, SP 30, SP27 | Sport Competitions     |
| Group 2| SP13, SP15, SP16 *(i2)*, SP24, SP29, SP33 | Students’ vehicles    |
| Group 3| SP3, SP4, SP28, SP21 *(i3)*, SP35, SP36 | Favorite Subject      |
| Group 4| SP2, SP12, SP18, SP19 *(i4)*, SP22, SP34 | Our School and the Universities |
| Group 5| SP1, SP8 *(i5)*, SP11, SP14, SP20, SP32 | New Students Intake   |
| Group 6| SP7, SP17, SP23 *(i6)*, SP25, SP26, SP31 | Students’ Achievements|

2.3. Techniques of data collection
Techniques of data collection used in this study are observations, focus group discussions (FGD), and documents and records. In this study, the respondents were aware of the researcher's observation
activities. As Adler and Adler (1994, p.380) stated, this kind of observation method enables the researcher to observe and interact closely enough with respondents to establish an insider's identity without participating in those activities constituting the core of group membership. Documents and records used in this study consist of photographs of PBL activities and products, and students' individual reports. The students were asked to write an individual report describing group project progress along with an individual’s contribution to finish the project. In addition to that, the FGD sessions were also conducted right after the researcher collect observation data and students' individual reports. All data were coded into categories based on all aspects of the collaboration- student work rubric adopted from the ITL research project framework (2012).

2.4. Data validity
According to Campbell and Fiske (1959), triangulation is a powerful way of demonstrating concurrent validity, particularly in qualitative research. The purpose of triangulation is not restricted to combining different kinds of data but to relate them in order to enhance the validity of the findings. The type of triangulation that used in this study is methods triangulation which occurs at the level of data collection. In doing so, the researcher uses three different techniques of data collection: observations, FGD, and documents and records. The purpose of combining the data collection techniques is to provide a more holistic and better understanding of the phenomena under the study of how strongly students’ collaboration skills developed.

2.5. Data analysis
According to Miles and Huberman (1994), qualitative data analysis consists of data reduction, data display, and conclusion drawing and verification. Data reduction can be defined as the process of selecting, focusing, simplifying, abstracting, and transforming the raw data that appear in written-up field notes. The researcher has gathered all data, then select the data by focusing on all aspects of the collaboration- students work rubric: (1) students are working together; (2) students are sharing responsibility fairly; (3) students are making substantive decisions together, (4) students work product is interdependent. The second component of data analysis is the data display. In this stage, the researcher uses a narrative text to display qualitative data that have been reduced. The third component of data analysis is drawing conclusion and verification. The researcher draw conclusion made toward the data in such a manner that the researcher is able to obtain an in-depth description of students’ collaboration skills through PBL implementation (Creswell, 1998; Lodico et al., 2006). The conclusions are also verified as the analyst proceeds.

3. Results and discussion
3.1. Students were working together
During the PBL, students were working together in their respective groups starting from the project planning stage up until creating the product and project presentation. In the project planning stage, students work in groups to discuss the statistics applications in their school environment. Then they have further discussion about: the project title, its description and objectives, step by step of project implementation, the project calendar, tasks of each group member, tools and materials needed to create the product, and etc. Figure 1 representing group discussion during the project planning stage.

Figure 1 Group discussion during the project planning stage
In addition, it was known that group discussions have also occurred after school hours through social media. Some groups were using LINE group to facilitate their discussion. This information was confirmed by i2, i3, and i6 in FGD session.

3.2 Students were sharing responsibilities fairly
Each group has distributed all tasks for its members and decided the deadline. Therefore, students were required to complete their associated tasks before the deadline. Students were sharing responsibility fairly when they took a turn to explain about what they have learned about statistics, which consist of the mean, median, mode, data representation in a form of tables, diagram, and pie charts, data analyze, and how they use the statistics to solve problems in their projects. This situation showed that each group member has the responsibility to build together their understanding of statistics concept and its application in their project. Moreover, all students also have contributed to their project presentation slides, whereby they have shared responsibility in developing the presentation slides and explaining the presentation materials. Figure 2 shows the situation when students took a turn to explain the materials.

![Students taking a turn to explain materials](image)

**Figure 2** Students took a turn to explain the materials

In creating the final products, students were sharing responsibilities fairly in the following activities: cutting paper, put pictures images on the product, cutting the cardboard, decorate the product, etc. Figure 3 shows a sample of student’s individual assignment that confirmed students’ sharing responsibilities fairly in creating the product.

![Sample of student’s individual report](image)

**Figure 3** Sample of student’s individual report

3.3 Students were making substantive decisions
Students have decided some important issues such as the project topic, the activities that students do during the project, the timeline of the project, the responsibilities of each group members, the final product, the materials and tools to be used in the project, and the best way to present their project results
to others. In regards to determining the substantive decisions on content, process, and product of the project, students always conduct an initial discussion to collectively address individual ideas. The students negotiated their ideas to contribute to the final decision. It was found from the individual student’ report that the student learned to express her opinions during the group project. Figure 4 representing the student’ comment in the individual report.

![Figure 4](image1.png)

**Figure 4.** A sample of student’ comment in the individual report

In relation to the process of making substantive decisions, when students faced different opinions among other group members, they did voting and came up with the majority opinion. This information was confirmed by i3 and i4 in FGD session as stated in the following conversations:

R: “How to resolve differences of opinion among your team members?”
i3: “We did voting when we faced differences of opinion.”
i4: “In my group, we also did voting and then came up with the majority opinion.”

Furthermore, it was also found that there was a student who has difficulties in designing the product of the project, especially in the finishing process. The student was feeling worried about the decoration of the final product that might be too excessive and will decrease the aesthetic value of the final product. This information has shown that the student and her group were making fundamental design decisions that affect the final product. Figure 5 representing the student’ comment on this matter.

![Figure 5](image2.png)

**Figure 5.** Student’ comment on a substantive decision on product design

3.4 Students work was interdependent

According to the FGD results, it was found that each group member was required to develop some particular contents of power-point slides and after that, all contents integrated into coherent power-point slides. Therefore, if one of the group member unable to complete his/ her tasks, then the finalization of presentation slides can be hampered. This condition showed that students’ work were interdependent in conducting the PBL. The following conversations are an excerpt of the FGD results with several research informants regarding students’ interdependent works.

R: “Did your group project work was interdependent? If there is a group member who unable to meet the deadline of his/ her task, does it affect the final result?”
i6: “Yes, my group project works were interdependent. We have shared responsibilities, we work together on data collection, learn about statistics concept and use the concept to solve problems in the project, create the final product and slide presentation. If one member was unable to fulfill his/ her task, then certainly it will affect the project work to become slow down.”
i4: “My group works also depend on each other. In my own experiences, one of the group members who was assigned to find additional literature and collecting animation
pictures was unable to meet the deadline. Thus, we need to wait for him and the finalization of our presentation slides was delayed for several days.”

i5: “I also agree with i3 and i4. My group project works were interdependent. In my opinion, each group member needs to commit to the given tasks and also meet the deadline. Everyone has important roles to complete the project. One of my group members forgot to bring the tool, thus it makes us need to reschedule the meeting for making the final product.”

In addition, each group member also got tasks to prepare and bring the tools and materials needed to create the final product. If one member did not carry the tools or materials as requested, certainly it can hamper the process of product manufacture. This showed that students’ works depend on each other and significantly can affect the project. This condition encourages students to understand and to be aware of the importance of students’ role in accomplishing the project.

Through the completion of students’ project in statistics topic, students were able to apply statistic concepts, in which students were working together in a small group to collect data, describe data by applying statistic descriptive, present the data in a form of tables, diagrams, and graphs, and perform basic interpretation of the data. The final products of the students’ project were used as references representing several important school data and displayed in the counseling room, students’ club room, and school wall magazine. All students’ project products are shown in the following figures:
Based on the above results, it can be concluded that students’ collaboration skills have developed through PBL implementation in statistics topic. By referring to the 21st century students’ collaboration skills rubric, students have achieved level 5, where students have sharing responsibility fairly, they were making substantive decisions together, and the project-product was interdependent.

3.5 Discussions
Collaboration skills is an essential skill that prepares students to work productively on a team in today’s interconnected working world and global society (The Partnership for 21st Century Skill, 2012). Therefore, teachers as professionals are expected to design and enforce learning activities that provide opportunities for students to develop their collaboration skills. Students’ collaboration skills can be developed through any kind learning activities in schools, one of which is Project Based Learning (PBL). Bell (2010) state that group projects able to develop students’ skills in collaborating with others. Students are working together when they work in pairs or groups to discuss an issue, solve a problem or create a product (ITL, 2012).

PBL required students to work together in small groups. It was found that during PBL students were working together in their groups to discuss the issue that related to school data to be their project topic, create the project calendar, and create a product at the end of the project. In addition, it was also known that the group discussions were not only happened face to face during the school hours but also occurred through LINE group. Through PBL, students got opportunities to work together in groups to accomplish the project.

Students also have shared responsibilities when conducting the project. Bell (2010) states that PBL encourages students to own their responsibilities and to become disciplined learners. In line with Bell’s statement, ITL (2012) also states that students are sharing responsibility fairly when all students on a team are engaged in the work, and all are contributing toward the final outcome. In this study, students were sharing responsibility fairly when they took a turn explaining their understanding of statistical materials to answer the project problems. They also have shared the responsibility for explaining the presentation materials.

In creating the final products, students were sharing responsibilities fairly in the following activities: cutting paper, glue the images on the product, cutting cardboard, decorate the product, etc. While students were sharing responsibility, they understand that each group member has an important role in accomplishing the project. Based on the FGD results, it was known that some students were unable to fulfill their tasks handed on time. Thus the project work became quite obstructed. Beers (2012) states that effective collaboration occurs when students are able to see themselves as part of a group and to understand their role which gives strong influences to group success.

Moreover, ITL (2012) states that students are making substantive decisions when they are actively resolving important issues that will guide their work. Substantive decisions are decisions that shape the content, process, or product of students’ work. In line with the ITL statement, students were deciding together on several substantive aspects, such as the project topic, what activities they will do during the project, when to conduct the project, the responsibilities of each group members, the design of project...
product, what materials and tools to be used in the project, and how to present their project results to others. Sometimes students were facing different opinions in making substantive decisions together. They required to respect and to consider others’ opinion and finally to jointly arrive at their final decision. Some students said that they did voting and came up with the majority opinion when they have different opinions. Bell (2010) states that PBL help students to appreciate differences, to develop good communication skills, and to make decisions together. In addition, Beers (2012) also said that one aspect of collaboration is to appreciate any differences in groups, can be their gender, religion, ethnicity, point of view, and so on.

ITL (2012) also states that students’ work products are interdependent when there is evidence that all students contributed and the work was integrated into a coherent product. In relation to the ITL’s statement, students were required to develop contents of power-point slides, then all contents integrated into coherent power-point slides. Each group member also got tasks to bring the tools and materials needed to create the final product. Thus, students’ assignments depend on each other and significantly affect the project. This situation encourages students to understand and to be aware of students’ important roles in accomplishing the project.

Based on these discussions, students’ collaboration skills have developed through the implementation of PBL in statistics topic and achieved level 5 of the 21st century - collaboration skills rubric. Students have shown the following collaboration indicators: students have sharing responsibility fairly, they were making substantive decisions together, and the project-product was interdependent. In accordance to Beer’s statement (2012), that students’ collaboration skills can be seen when students work effectively in groups, like respecting other people's opinions, solving problems with mutual agreement, contributing and being responsible for group assignments, and open-minded to different ideas or perspectives.

In addition to the above discussion, students have experienced as independent learners through PBL implementation in statistics topic. Students build their own understanding of statistics concepts through their project. Students learning through PBL retain content longer and have a deeper understanding of what they are learning. (Penuel & Means, 2000; Stepien, Gallagher & Workman, 1993). This study has shown that through PBL in statistics topic, students were able to develop their collaboration skills to the fullest level as well as to apply statistics in real life situation.

4. Conclusion
Based on the results and discussion of this study, it can be concluded that students’ collaboration skills have developed to the highest level of the 21st century - students’ collaboration skills, through Project Based Learning in statistics topic. At level 5 of students’ collaboration skills, students have sharing responsibility fairly, they were making substantive decisions together, and the project-product was interdependent. Furthermore, students were also gain knowledge by applying statistics in their project.

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