

## A New Approach to Learning Science under STEM: Peer Project Learning

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**Abstract.** Peer Project Learning (PPL) is an interactive student-centered curriculum, which can be easily adopted by any instructors who want to change their roles from delivering information to managing a complete set of instructions. PPL is designed to meet the goals of STEM, and consists of Peer Learning in the classroom and Project Learning in the lab. In PPL, students take an active role to build up their scientific knowledge through the pre-class reading, conceptual questions in Peer Instruction, team problem solving, development and presentation of project.

**Key Words:** Peer Project Learning, Peer Instruction, student-centered curriculum, STEM

**Abstracto.** El Aprendizaje en Pares y Proyecto (PPL) es un modelo interactivo de aprendizaje centrado en el estudiante, que puede ser fácilmente adoptado por cualquier instructor que quiera cambiar su rol clásico de entregar información a sus estudiantes, a un modelo donde su rol principal es administrar un conjunto completo de instrucciones. PPL se diseña para cumplir los objetivos de STEM y está constituido de dos partes fundamentales; de aprendizaje en pares en el aula y de aprendizaje basado en proyecto en el laboratorio. En PPL, los estudiantes toman un papel activo para construir su conocimiento científico, los que van desde la Lectura Previa a la Clase, Preguntas Conceptuales en la Instrucción en Pares, Trabajo en equipo para la solución de Problemas, Desarrollo y Presentación del Proyecto.

**Palabras clave:** Aprendizaje Basado en Proyectos, Instrucción en Pares, Modelo Centrado en el Estudiante, STEM

### 1. Introduction

In the 21<sup>st</sup> century, we are living in a rapidly changing technological world. STEM, which is an acronym for Science, Technology, Engineering and Math

education, has become a central topic because of its critical role in the nation's competitiveness [1,2]. Indeed, each nation's well-being depends upon how well it educates its children in STEM, since its economic and national security is derived from technological creativity [3,4].

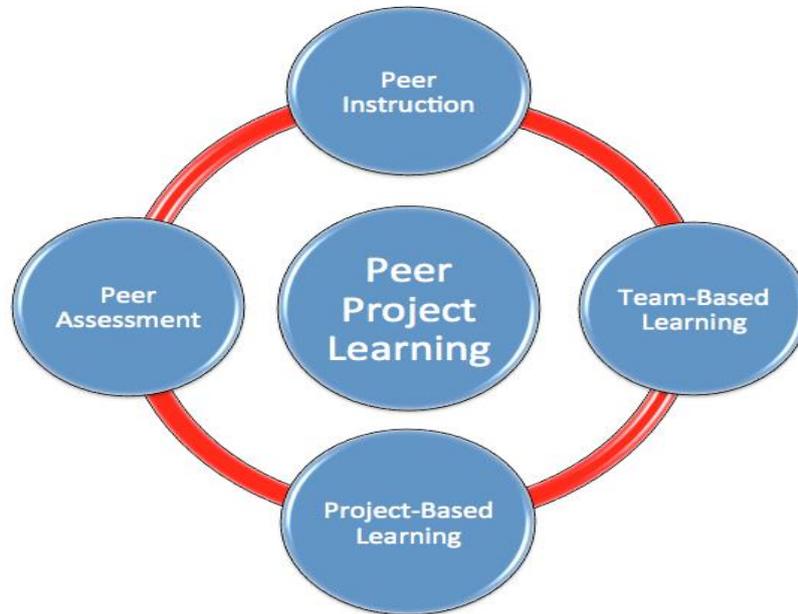
In U.S., the number of STEM occupations will increase continuously, while students who are interested in STEM and pursue STEM career are not sufficient for the future needs [5,6]. Consequently, goals for U.S. STEM education are to expand the number of students with advanced degrees and careers in STEM fields, produce the STEM-capable workforce, and increase STEM literacy for all students [7].

To attain those goals, STEM education has attempted to transform the typical teacher-centered classroom by encouraging a student-centered curriculum that is driven by problem solving, discovery, exploratory learning, and required students to actively engage in a situation to find its solution [8]. In the student-centered curriculum, the primary role of instructors shifts from delivering information to managing a complete set of instructions and process, and that of students also moves from being passive recipients of information to accepting responsibility for the initial exposure to the course content [9].

In accordance with the need for curriculum change, we suggest a new approach to learning science under STEM, Peer Project Learning (PPL).

## **2. Theoretical Background of PPL**

In recent years, various instructional methods have been introduced to offer students flexible, innovative and engaging learning experiences [10,11]. Among them, PPL adopted the following four instructional methods: Peer Instruction, Team-Based Learning, Project-Based Learning, and Peer Assessment (Figure 1).



**Fig. 1.** Theoretical Background of PPL

### **2.1. Peer Instruction**

Peer Instruction (PI) is an interactive teaching method, which is a widely used student-centered approach [12,13]. The basic goals of PI are to exploit student interaction during lectures and focus students' attention on underlying concepts [14]. In PI, lectures consist of a number of short presentations on key points, each followed by a short conceptual questions on the subject being discussed. After each conceptual question is posed, students are given one or two minutes to formulate individual answers and then discuss their answers with each other. During the discussion, students try to convince each other about the correctness of their own answer by explaining the underlying reasoning [15].

### **2.2. Team-Based Learning**

Team-Based Learning (TBL) has been increasingly used to provide students with both conceptual and procedure knowledge [16]. The four essential elements of TBL are properly formed and managed groups, student accountability for individual and group work, frequent immediate student feedback, and group assignments that promote both learning and team development [9]. With TBL, students can achieve higher grades, learn at a deeper level, retain information longer, acquire greater communication and

teamwork skills, and gain a better understanding of environment in which they will be working as professionals in real life [17,18].

### **2.3. Project-Based Learning**

Project-Based Learning (PBL) is an instructional model that organizes learning through projects, and provides a rigorous alternative to traditional instruction [19]. PBL is a dynamic approach to teaching in which students explore real-world problems and challenges. With this type of active and engaged learning, students are inspired to obtain a deeper knowledge of the subjects they're studying [20]. In PBL, projects are complex tasks that involve students in design, problem solving, decision making, or investigative activities [21]. The five criteria to be considered as an example of PBL are these: PBL projects are central, not peripheral to the curriculum; PBL projects are focused on questions or problems that drive students to encounter the central concepts and principles of a discipline; projects involve students in a constructive investigation; projects are student-driven to some significant degree; projects are real-life challenges [22].

### **2.4. Peer Assessment**

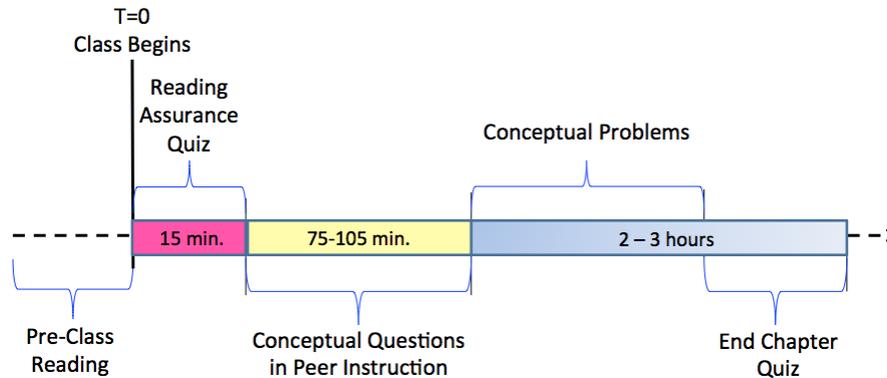
Peer Assessment (PA) is essential to prevent free riders in team activities, motivate each student's performance, raise the professionalism, and nurture self-monitoring and regulations among students in TBL [23,24]. PA scores, which are individual student grade incentives in TBL, are derived from contributions to interpersonal group dynamics, team maintenance, cohesion, and team productivity [25]. In the professional world, individuals who do not pull their weight on work teams eventually suffer consequences far worse than low grades [26]. On the other hand, previous researches noted that implementing PA is not only difficult but also heavy workload to the teachers, and PA cannot achieve the original goals without high professionalism of students [27]. However, students tend to concern the fairness of PA and the lack of instructor input in the PA process [28].

## **3. Application of PPL**

PPL consists of two parts: Peer Learning and Project Learning. They must be intimately connected one another so that students can apply and revisit what they have learned in the course.

### **3.1. Peer Learning**

In Peer Learning, students have an opportunity to master course contents in an interactive and student-centered curriculum. Figure 2 shows an example of learning process in the course where 2 or 3-hour class is twice in a week.



**Fig. 2.** The Learning Process of Peer Learning in PPL

### ***Pre-Class Reading***

To participate in a lecture with PI effectively, students must understand the basic knowledge of key concepts in each chapter. Therefore, the instructor should assign pre-class reading materials such as textbook, research paper, article, video clip etc. before starting a new chapter. The instructor can also provide a set of challenging conceptual questions which will be solved and discussed during the lecture.

### ***Reading Assurance Quiz (RAQ)***

RAQ is a multiple-choice conceptual test at the beginning of a new chapter. The goal of RAQ is to make all students complete the pre-class reading before they come to the class, which is a crucial part of implementing Peer Instruction. The difficulty level of RAQ is normally easier than that of conceptual questions during the lecture. The instructor can add open ended conceptual questions to prevent students from covering pre-class reading materials superficially.

### ***Conceptual Questions (CQ) in Peer Instruction***

In PPL, lectures cover the most important and difficult concepts in the course. During the lecture, students are given one or more CQ of each concept. Following the PI, students have an opportunity to solve the given question, explain their answers to their fellow students, and then report their final answers to the instructor. The instructor decides to proceed “revisit concept”, “peer discussion”, or “explanation” depending on the content and student population of correct answers [12].

**Conceptual Problems (CP)**

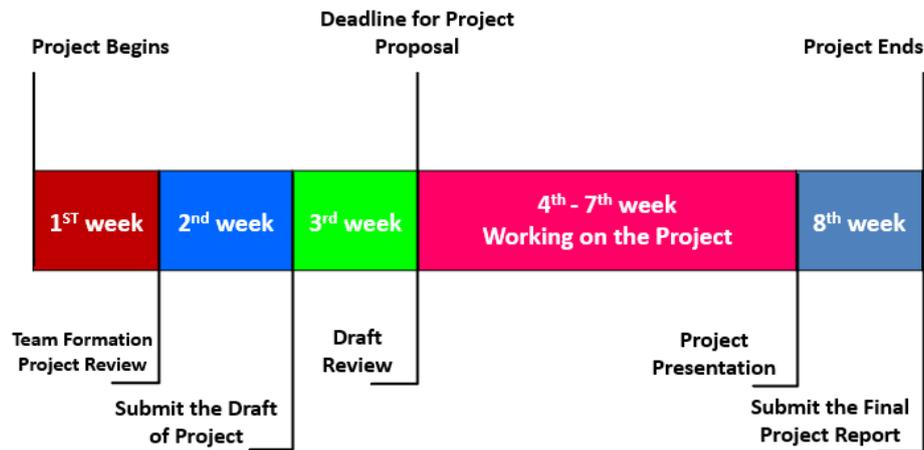
The instructor distributes CP to each student after finishing all CQ in a chapter. Students have sufficient time to solve CP individually, and then turn around to make their teams which the instructor strategically organized in advance. Students on the same team share, explain, and discuss their own answers to submit one final team report to the instructor. The team report must include a demonstration of the solving process, which will be reviewed by the instructor and other teams.

**End Chapter Quiz (ECQ)**

ECQ is comprised of essay-type questions, and must be relevant to the CP. The goal of ECQ is not to evaluate students’ conceptual knowledge, but to ensure their participation through the course. Accordingly, ECQ should deal with the basic and core concepts in a chapter, and not exceed 30 minutes.

**3.2. Project Learning**

In Project Learning, students have an opportunity to apply the knowledge acquired through the semester. Figure 3 shows the procedure for developing a project for 8 weeks.



**Fig. 3.** The Procedure of Project Learning in PPL

### ***Team Formation***

In the process of team formation, the instructor should follow these three principles: never use student-selected teams; create diverse teams; make the selection process transparent [9]. In PPL, the open-source team formation program, GroupEng [29] is recommended. GroupEng assigns groups according to a prioritized list of factors chosen by the instructor. As an example, we decide the four factors to be considered in PPL: gender, overall GPA, final score of Calculus-based course, and preference for group work.

### ***Project Review***

The project in PPL consists of teamwork activities in which students have a chance of gaining knowledge and skills by applying concepts and underlying principles covered during lectures. Therefore, the final outcome of project is strongly recommended to be a real product built by students' hands-on activities. By making the real product, students can deepen both conceptual and procedural knowledge. During the project review, the instructor informs students about the main goals of project, essential requirements, major evaluation factors, limitation of budget, and important deadlines. Specifically, the project in PPL should meet the following criteria:

- 1) The project is composed of open-ended problems, which are intriguing and challenging for students.
- 2) The project covers contents in the lecture for students to apply concepts and skills.
- 3) Through the project, students reinforce the competencies especially valuable nowadays such as problem solving, critical thinking, collaboration, communication, and creativity.
- 4) The project allows students to make decisions about how they manage their time efficiently and concretely to meet the deadlines.
- 5) The project includes reflective processes like peer and team assessment to give feedback on the quality of their work.

### ***Submission and Review of the Draft***

Each team has to submit the first draft of project by the 2<sup>nd</sup> week of the course. Then the instructor starts to review the draft and give constructive feedback to improve the quality of project proposal. Through this review process, students can minimize the chance of failure beforehand, and concentrate on the project from the beginning. After the deadline of project proposal, the instructor prohibits any major revision from the original proposal to prevent the tendency that students postpone the project until near the deadline.

### ***Project Presentation***

In the project presentation, students have an opportunity to present and share their outcomes to the other team members and appointed evaluators. The format of the project presentation is to combine oral presentation with real-time demonstration. Each team member must take a specific role, and be actively involved during the project presentation, since its main goal is to enhance students' social responsibility and communication skills.

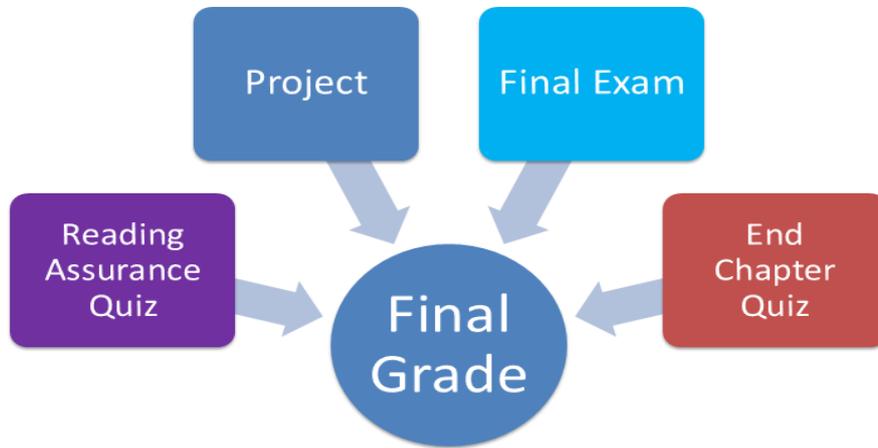
### ***Final Project Report***

To create a more authentic writing experience and promote STEM literacy of students, the final project report in PPL follows the writing style of Letter Project Report [30] as an alternative to the traditional lab report. The final project report in PPL must satisfy the following criteria:

- 1) Each team selects a real person, recipient, to address the final project report, but the recipient should not be an expert in science.
- 2) The recipient must be able to learn some scientific knowledge from the final project report.
- 3) A team writes the final project report in the tone of a letter, considering both the correctness of information and the clarity of expression.
- 4) The final project report includes the setup of project in sufficient detail, the scientific laws and formulas used, and the results and discussions obtained.
- 5) The description of the project should be clear and precise enough so that other students in the course can easily repeat the whole process.

### **3.3. Assessment in PPL**

The final grade in PPL consists of four components: Reading Assurance Quiz, End Chapter Quiz, project, and final exam (Figure 4). The instructor uses the average score for Reading Assurance Quiz and End Chapter Quiz, and multiplies the average between the final project report and presentation by the weighting factor of Peer Assessment for the project. The final exam is a summative assessment covering all chapters in the course. We suggest the 10% weight to Reading Assurance Quiz, 10% weight to End Chapter Quiz, 40% weight to the project, and 40% weight to the final exam in an ideal PPL course, although the instructor determines the weight of each component for the final grade. In PPL, homework is not a component of the final grade, because the instructor has sufficient components to check students' readiness for the class continuously.



**Fig. 4.** Four Components of Assessment in PPL

#### **4. Discussion and Further Work**

Many researchers have insisted that teacher-centered classroom is not efficient for students to develop essential skills and solve real-life problems nowadays. Hence, various instructional methods have been introduced, seeking more active participation and interaction of students both in and out of the classroom. Each method, however, must be applied properly depending on the level of society, economy, technology and education. Therefore, we designed PPL to be easily adopted by any instructors who decide to change their classrooms more student-centered either partially or completely. In PPL, students take an active role to build up their scientific knowledge through the pre-class reading, conceptual questions in Peer Instruction, team problem solving, development of project, and written and verbal presentations of their outcomes. All those activities can make PPL become a possible alternative to the teacher-centered classroom.

Further work is needed to investigate the effects of PPL in both cognitive and affective domains. After applying PPL for the coming semester, we will collect and analyze data on students' performance, satisfaction, self-efficacy, and STEM interest. We have also written the PPL user's manual, and developed the open-source Peer Assessment webpage to help other instructors to implement PPL more conveniently.

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