An inquiry approach to learning EM waves and quantum physics with photonics-based Nobel prizes

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Abstract: To engage students with EM waves and quantum physics, connecting it to their everyday lives and to promote “photonics awareness,” a five-part, twelve-week group research project on a photonics-based Nobel prize was developed.

1. Introduction

For many college science students, learning about electromagnetic waves and quantum physics is a challenging endeavor. Connecting the class content to their everyday lives and their future careers is not completely obvious. Furthermore, when surveyed and asked, “Do you know what photonics is? If yes, describe it,” 92% of 113 college students do not know what photonics is or cannot describe it on the first day of class. To engage students with class content, connecting it to their everyday lives and to promote “photonics awareness,” a group research project on a photonics-based Nobel prize was developed.

The research project is set in a Québec (Canada) college level Waves and Modern Physics course taken by all students pursuing the Natural Sciences (including Health Science and Pure & Applied Science). This course is like a freshman year physics course elsewhere in North America. The first iteration of the project began in a pre-pandemic setting which transitioned into a fully online project after the mid-term break. The following two iterations of the project were done completely in an online setting. Much of the work was done asynchronously as homework, but some of the work was done synchronously online during class (e.g., weekly group meetings and Q&A with the teacher). The project follows elements of inquiry-based learning [1-3]; that is, students get to choose their Nobel prize, the research questions to study, what elements of the Nobel prize to present to peers in class and their final presentation style. It is scaffolded [4] into five parts, helping students to stay on task and to respect a timeline.

2. Project timeline, tasks and deliverables

A project overview is first presented in class; see Fig. 1. Students are informed of the multiple parts, the timeline, the individual and group tasks and deliverables, and the final presentation assessment rubric [5]. In their final presentation, groups must be able to describe the physics of the Nobel prize (or a component of) and be able to connect it to course content and to their everyday lives. Making these connections, refining, and elaborating them, are deliverables for each step of the project as the students progress with class content during the semester. Students are provided with an online group space for video conferencing and document sharing.

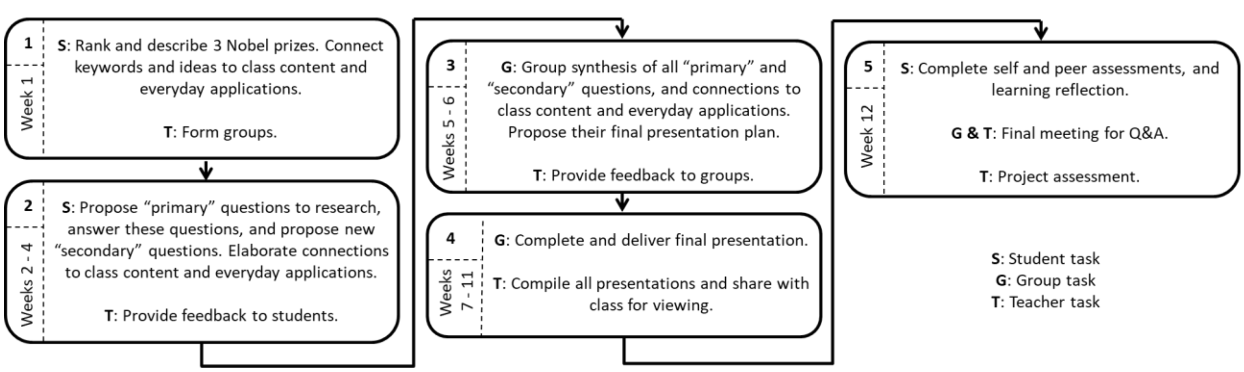

Fig. 1. Five-part, twelve-week project overview containing all tasks and deliverables.

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In part 1, students are presented with a list of photonics-based Nobel prizes, from 1964 (Maser-Laser Principle) to the present, similar to figure 2 of [6]. Each student ranks and provides a short description for three prizes. They begin listing keywords/ideas and connecting them to course content and to everyday applications (e.g., for the 2014 Blue LED Nobel prize, students typically write, "Blue light means blue waves and/or photons, and these LEDs are used in graphical displays and for white light generation."). The teacher then forms groups of 3-4 students, trying to respect student preferences whilst minimizing project repetition.

In part 2, as an individual task, students are to propose four "primary" questions they wish to research and answer these questions. They provide detailed answers to their questions, include references, and are to propose new "secondary" questions to be answered in part 3. The students refine and elaborate to their list of connections between keywords/ideas and course content and to everyday applications. The teacher reviews the questions, answers and references, and provides written feedback to the students.

For part 3, the groups prepare a synthesis of all their individual work from part 2. They compile all their primary and secondary questions and answers, complete their list of connections between keywords/ideas and course content and to everyday applications, and are to propose a final presentation plan. For the final presentation plan, they must include the medium (most groups do a narrated slide show video), students' roles for part 4 and indicate if they have more research to conduct. The teacher reviews the synthesis and plan, and provides written feedback to the groups.

The groups complete and deliver their final presentation in part 4. All presentations are compiled and shared with the class. For part 5, students must complete self and peer assessments based on their contributions and quality of work during the project. There is also an individual learning reflection about the project. Last, each group has one final meeting with the teacher and must answer questions relating to the project and course content.

3. Assessment rubric

The group grade component of the final presentation is worth 75% and includes the following performance criteria: 1) general description of the Nobel prize (10%), 2) physics description of the Nobel prize (20%), 3) ability to connect to course content (15%), 4) ability to connect to everyday applications (15%), and 5) production quality of final product (15%). There is a 25% component for each student in the group and is based on the overall self and peer assessment scores (15%) and the performance when answering questions during the final meeting (10%).

4. Project quality and student survey

The rubric allows the students to better evaluate the quality of their work before they submit the final project. Including the three cohorts, the overall average project grade was 87.3% with a standard deviation of 11.7%. The projects were of great quality, creative, informative, and appreciated by classmates. One of the survey questions included in the individual learning reflection was, "Was a project setting a good one in order to better learn and understand complex topics associated with EM Waves and Quantum Physics?" 93% of the 100 students who completed the learning reflection wrote yes. Students who elaborated listed reasons that made their learning experience positive. The two most popular reasons were, working in a group setting (the social aspect of group video meetings during pandemic online learning and the peer instruction involved when explain their work to groupmates), and being engaged in a research setting (i.e., being able to research a topic as opposed to relying on lectures, the textbook and rote laboratory experiments). Other reasons include understanding the course content via their applications in science and everyday life, being able to choose their project topic and to work at their own pace.

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