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Using Problem-Based Learning (PBL) in an Undergraduate Ergonomics Course

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ABSTRACT

Ergonomics courses typically cover a range of topics related to the design and organization of workplaces to optimize human performance and well-being while minimizing injury risk and discomfort. This study introduces the PBL application steps to attract attention to the importance of noise not only in workplaces but also in daily life. The driving question is determined as "How can we assess and minimize the perceived daily noise exposure of people to sustain hearing health?". Then, the students are asked to evaluate the PBL activities at the end of the term. Among the students who completed all activities, 60% strongly agreed, 32% agreed that PBL contributed to the understanding of the subject, and only 8% stated that PBL didn't make a significant contribution when learning the topic of concern. The PBL framework developed for "noise" has the potential to be enhanced and adapted for other topics in this course.

Keywords: Ergonomics, noise, undergraduate course, PBL

INTRODUCTION

There are several methodologies to transfer knowledge and skills to the students. Problem-based learning (PBL) is a student-centered approach in which students learn about a subject by working to solve an open-ended problem that drives the motivation and learning (Blumenfeld et al., 1991). Project-based learning (PjBL) is defined as an approach designed to give students the opportunity to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world (Brundiers & Wiek, 2013; Krajcik & Shin, 2014). PBL aims to enhance

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instructor/student interaction and enhance creativity, critical thinking, collaboration, and communication skills of students. This study summarizes the application steps and outcomes of PBL for an undergraduate course. First, the studies related to PBL and PjBL are identified and a limited number of applications for engineering courses are discussed. Blumenfeld et al. (1991) state that PjBL helps students pursue solutions to non-trivial problems by asking and refining questions, debating ideas, making predictions, designing plans and/or experiments, collecting and analyzing data, drawing conclusions, communicating their ideas and findings to others, asking new questions, and creating artifacts. By this means, PjBL has the potential to motivate students and enhance disciplinary learning. Guo et al. (2020) also confirm that PjBL is a promising approach that improves student learning in higher education. Boisadan et al. (2022) implemented a PjBL approach during mid-March to mid-May 2020 (the Covid-19 pandemic) with 281 engineering students that were grouped into 48 teams. The results regarding the motivation were very positive and the flow and self-rated performance were high.

Hallinger (2021) reviews 14130 Scopus-indexed documents on PBL published between 1972 and 2019. It is concluded that research on PBL is significantly larger than other approaches related to active learning. Gonzales & Batanero (2016) summarize the results of a PBL research project on student learning to compare with more traditional teaching methods in Construction Engineering courses at the University of Huelva. PBL was identified as an effective and more efficient teaching method and the students have tended to show greater creativity in their problem-solving approach. Condliffe et al. (2017) state that the methodology is extensively used in engineering with good results. The design of PBL promotes students flexibility and connections to working community (Potvin et al., 2022).

Gomez-del Rio & Rodriguez (2022) apply PBL in the mechanical design subject of the Mechanical and Chemical Engineering lab. Rehmat & Hartley (2020) focus on science, technology, engineering, and mathematics (STEM) education. The quasi-experimental and repeated measures design study considered the content knowledge and critical thinking skills. The application results for problem-based learning and traditional learning groups revealed a significant difference.

The professional world is not satisfied with the traditional curriculum, also, many countries shift to outcome-based accreditation procedures in Engineering. Beddoes et al. (2010) state that these are the main reasons that project and problem-based learning is becoming more common.

The problems for the engineering disciplines should derive from real life or be a very close representation of it. The applications that the students are likely to meet in the context of their future professional lives should be considered in the curriculum.

However, based on the current accessible literature, it can be stated that there are a limited number of PBL applications in engineering courses and almost no study related to "Ergonomics". The main contributions of this study are structuring a PBL application for an undergraduate Ergonomics course and assessing the students' perception for the learning process.

The PBL application in this study aims to inspire learners and motivate good learning experiences with practical experiences. The overall implementation of the application has been presented in following sub-sections. Section two provides the problem statement and the methodology and steps of PBL-based learning. The relevant evaluation of each activity of the methodology is defined in detail. The third section provides the attainments and results obtained. The paper is concluded in the fourth section.

METHOD

This section aims to provide basic information on how PBL is used in an engineering course when teaching the concepts of an environmental factor that is critical not only in industry but also in real-life. This application aims to emphasize the importance of noise, one of the environmental factors, in working environments and daily life. The students are expected to learn main principles of noise (sound, pressure, loudness, etc.), the importance of obtaining and organizing data, and they will be able to experience and practice different noise levels in various real-life environments.

Participants

The PBL application is completed with undergraduate students enrolled to an Ergonomics course in Industrial Engineering, at the Faculty of Engineering and Architecture, Eskisehir Osmangazi University. It is assumed that no student requires Special Educational Needs (SEN).

Research design

The main steps of the PBL application and its relationship with the action words for Bloom's Taxonomy are given in Figure 1. Knowledge is related to definition, identifying, and describing the basics of the problem. In this step, the basic concepts related to noise must be reviewed from the written documents and conducting related experiments. By this means, it is possible to understand, explain, describe, interpret, and summarize the problem in concern. In the apply step, the sources of noise can be defined and illustrated. After the required modifications, the shared database can be structured. Based on several new location suggestions, the database for noise measurement locations can be compared, classified, and analyzed. In the evaluate step, the noise measurements are recorded and values are assessed. In the final step, a written product such as a poster can be created.

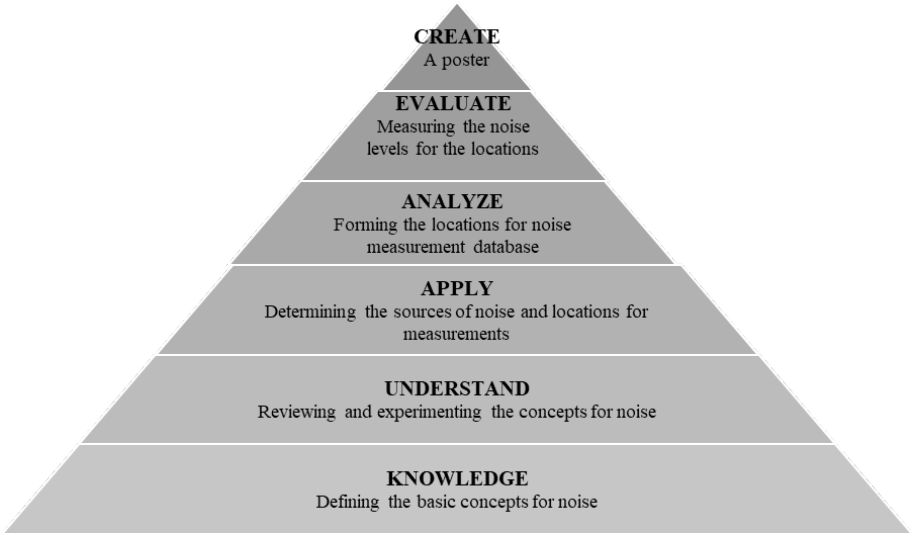

Figure 1. The main steps of the PBL application related with Bloom's Taxonomy.

The PBL application is structured for a 5-week period and integrated into a 15-week undergraduate course. Basic activities for the PBL application are summarized and described in Table 1.

No	Name of the activity	Work process	Description
1	Introduction	Introducing PBL principles	*Discussing the project aim, defining the activities and schedule. *Information on ethics.
2	Basics	Remembering and experiencing main principles of noise	*The students are requested to: *Review the course notes shared at DLP *Make a visit to the Science and Experiment Center
3	Assessment	Quiz 1	*Aims to assess if the main principles are understood
4	Specifying measurement locations	Identifying the main locations to measure sound level	*Professor suggests locations from daily life *Students discuss other possible locations for measurement *Students submit their suggestions by use of DLP
5	Measurements	Data collection and reporting	*Students download and select a free app for noise measurement. *The location of the measurement, data, and time is recorded. *Students submit their measurements
6	Reports	Forming a database of noise level measurements	*The students share their measurement values and related critical information
7	Written product	Forming a poster	*The students design a poster to summarize the activities and achievements during the project *Students submit their file by use of DLP
8	General assessment	Quiz 2	*Aims to get the feedback from students concerning the project and activity design

Table 1. The activities defined for the PBL application.

The students are informed about the aim of PBL and the schedule is provided during the course hours. The students are requested to review the course noted shared from Distance Learning Platform (DLP) and make a visit to Eskisehir Science Experiment Center [URL.1.]. There are several experiments and detailed information in this center related to astronomy, pressure, balance, mechanics, basic machines, electric and magnetism, optics, chemistry, energy, natural events, and scientists. The students are suggested to visit the noise experiments such as whispering bowls, speech pipes, xylophone pool, audible pipes, and buzzer in a vacuum.

A Quiz, given in Appendix 1, is defined at the DLP and conducted in the second week. The first question in Quiz 1 aims to identify whether the students have any prior information on PBL and if they think the methodology is suitable for the Ergonomics course. The second and third questions aim to gather information on whether the students completed the defined review activities. The rest of the questions aim to assess if the main principles of noise are understood.

Examples of main locations for sound measurements are shared by use of DLP with the students such as construction site, house, transportation, and the like. Then, the students are encouraged to discuss possible locations to measure noise levels. By use of DLP, each student submitted more specific locations from daily life such as cinema, shopping mall, bazaar, apartment elevator, classroom, canteen, and urban transportation (i.e., tram, bus). During the data collection and reporting activity, the students downloaded a free app to their cell phones. The sound levels that can be exposed in daily life were measured and recorded. Based on the reported data, the database for measurements was revised and shared with students by the course instructor. The students compared measurement values with standard limit values and made comments on daily exposure values.

The “written product” of the PBL application was defined as forming a poster. The posters, highlighting the importance of hearing health, summarized the activities and achievements during the project and were uploaded to DLP as a file by each student. The rubric for posters is formed of three elements as context, performance, and visuality. The assessment is made as distinguished, proficient, basic, and unsatisfactory. A detailed rubric for poster can be requested from the author. As the final step of the PBL application, the feedback from students concerning the project and activity design was received by a Questionnaire with five questions (Appendix 2).

RESULTS

116 students were enrolled in the Ergonomics course during the 2021-2022 Spring term which lasts 15 weeks. The PBL application influenced 25% of the final exam, which counted 60% towards the overall course grade. The remaining 40% of the overall course

grade was assessed with a written midterm exam. The activities related to PBL were assessed considering the results of Quiz1-review of the topic (20%), Submitting data collection location suggestions (5%), Submitting data reports on time (10%), Submitting the poster (50%), and Quiz 2-questionnaire for feedback (15%).

The schedule for PBL activities and assessment criteria is announced in the second week of the course. However, all students who are registered to the course did not participate in the quizzes or submitted the requested documents from DLP. It is not mandatory for the students who have failed the course in previous terms to attend the face-to-face classes. There is also a possibility that these students have not followed the instructions announced from DLP.

To avoid any misleading comments for the PBL application, the comments for the 45 students who completed all PBL activities (Quiz 1, Suggestion, Data collection, Poster, and Quiz 2) during the Ergonomics course are considered.

The comments of students for the first question of Quiz 1 "*Choose the answer that best describes your opinion on PBL and PBL application for the Ergonomics course.*" are as follows:

- *I heard about PBL. I think that the methodology is not suitable for the Ergonomics course*: 2%
- *I heard about PBL. I think that the methodology is suitable for the Ergonomics course*: 44%
- *No idea*: 3%
- *I did not hear about PBL. I think that the methodology can be applied for the Ergonomics course*: 46%.
- *I did not hear about PBL. I think that the methodology can not be applied for the Ergonomics course*: 5%

89% of the students answered the second question of Quiz 1 "*I read the document shared from Distance Learning Platform.*" as "Yes", confirming that they have reviewed the file shared by the instructor. 46% of the students declared that they had visited the Science Experiment Center and gave a positive answer to the yes/no question of Quiz 1 "*I visited the Eskisehir Science and Experiment Center during the stated time period to support the basic knowledge I learned about noise*."

The Science and Experiment Center visit and participation in discussions aimed to help students to review the concepts of sound and noise. Answers to the first three questions were not included in the grading. Considering the rest of the questions, the average of Quiz 1 is 71 and it can be considered that students have a basic knowledge of the topic in concern.

The students were asked to suggest locations for data gathering and then measure noise levels. The average grade for the activities is 76 and 77 respectively. Based on the noise level database, the students formed a scenario, calculated a noise exposure level, designed a poster, and submitted by DLP. Interested readers can request example posters from the author.

Quiz 2 is conducted to obtain students' feedback and suggestions.
The comments of students for the first question of Quiz 2 "*Evaluate the contribution of your PBL application to the understanding of the subject*." are as follows:

- *It was very helpful*: 60%
- *Was useful*: 32%
- *Didn't make a significant contribution*: 8%
- *Did not contribute*: 0%
- *I have no idea / I did not participate in the application*: 0%

The students were asked to evaluate the PBL activities. 51% specified that they had difficulties when creating the poster. 30% stated that they had problems in creating a daily exposure scenario.

Based on the feedback from the students, it is possible to revise and restructure future PBL applications. The comments of the students provided for the open-ended question in Quiz 2 can be grouped under the outcomes of PBL, difficulties faced during PBL activities, and suggestions for a specific PBL activity.

Students' comments reveal that the PBL application was useful in learning and practicing the concepts related to noise. A number of selected comments are given as follows:

- *It was an application that we had not done before.*
- *It will be very useful to implement project-based learning for different subjects in other courses too.*
- *It was a very instructive application.*
- *It was enjoyable to research and measure about the noise.*

The PBL application was new for the students. Therefore, students suggested that further in-class demonstrations and examples might be helpful. Related comments are as follows:

- *I think this and similar activities can be made. The duration for analyzing data can be longer.*
- *An exemplary study can also be done during the class. Such as measurement and evaluation from the phone.*
- *I had difficulties in forming the exposure chart. I didn't know exactly how to do it.*

To enable consistency and ease of evaluation, instructions for poster preparation were shared with the students. Students suggested that there would not be any limitations for the page number and the style. On the other hand, some of the students suggested to present the poster in the class and discuss the activities.

- *The poster preparation instructions make the preparation process more difficult.*
- *I'd prefer to make a presentation rather than preparing a poster.*
- *Discussion of the poster face-to-face in class with friends would be better.*
- *New arrangements can be made in the size and outline of the poster.*

CONCLUSIONS

This study revealed that the PBL application, a new teaching method for the students, had attracted attention and was stated to be very useful for learning the topic in concern. The information and document transfer for the PBL application was conducted by utilizing the internet computer technologies that the students are familiar with.

There are a few limitations that may impact the findings of this study. The PBL application was designed for a specific topic of a single course, which may be considered as a limitation. Instead of bolting the PBL activities, integrating PBL more into the course program can be more useful for the students. The successful outcome can depend on the detailed and well-structured PBL design.

The majority of the students enrolled in the Ergonomics course found this PBL application very useful to learn the topic. However, this result cannot be generalized for other topics of the course. In the following studies, the PBL application can be restructured to cover other environmental factors in the Ergonomics course such as illumination. The students may be encouraged to present their posters with other students enrolled to the course, the groups from workers of the metal industry, medical school undergraduate students, and/or high school students. By this means, it can be possible to discuss the importance of "noise" from different points of view.

The PBL application can be considered a promising approach that improves student learning. In this study, the PBL application steps for a course are introduced and the students who are enrolled in the course participated in the PBL activities. Further studies can be structured to assess and quantify how PBL improves student learning. A comprehensive study by defining control and experimental groups can be conducted and the results of statistical analysis can be compared.

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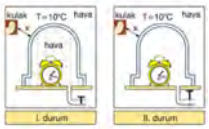
Appendix 1: Quiz 1 – Assessment of main principles of PBL and noise

1. Choose the answer that best describes your opinion on PBL and PBL application for the Ergonomics course.
- o I heard about PBL. I think that the methodology is not suitable for the Ergonomics course.
- o I heard about PBL. I think that the methodology is suitable for the Ergonomics course.
- o No idea.
- o I did not hear about PBL. I think that the methodology can be applied for the Ergonomics course.
- o I did not hear about PBL. I think that the methodology can not be applied for the Ergonomics course.

2. I read the document shared from the Distance Learning Platform.
- o Yes
- o No

3. I visited the Eskisehir Science and Experiment Center during the stated time period to support the basic knowledge I learned about noise.
- o Yes
- o No

4.



State I. The noise from the striking clock can be heard easily
State II. There is no air in the bell glass and no sound is heard from the striking clock
Select the correct answer based on the results of this experiment.
- o Air insulates sound
- o As the ambient temperature increases, the sound travels faster
- o The clock cannot work in an environment without air
- o As the ear approaches the bell glass, the sound intensity increases
- o Sound cannot propagate in an environment without air

5. Which of the following information about sound waves is incorrect?
- o The louder the sound, the greater the distance the sound can reach
- o The speed of sound waves depends on the type and temperature of the medium
- o The speed of sound in solid medium is greater than its speed in liquid medium
- o Sound waves emanating from the source propagate globally
- o As the temperature of the air increases, the speed of sound in the air environment increases

6. I- In a period of one period, sound waves travel as long as the wavelength
II- Whether the sounds are high-pitched or low-pitched is a result of the frequency of the sound
III-High-pitched sounds are called loud sounds, low-pitched sounds are called low loudness
IV-The intensity of sound waves is inversely proportional to the amplitude of the wave
Which of the following is the correct answer?
- o I-II-III-IV
- o I-II-III
- o II-III
- o III-IV
- o I-II

7. Which of the following information about sound waves is incorrect?
- o Sound waves exert pressure on surfaces by transferring energy
- o Sound waves are transverse waves
- o Sound is a mechanical wave
- o Every vibrating object is a source of sound
- o When an object vibrates, it transmits sound waves as a result of the compression and dilution of air molecules

8. *"A person who cannot see or hear the sound of the train can hear the sound of the train when he puts his ears on the tracks."*
Based on the given statement, in which option is the information(s) given correct? (Temperature is constant)
I-Sound propagates faster in solids than in gases
II-The speed of propagation of sound in solids is higher than the speed of propagation of light in air
III-As the train approaches, the speed of sound propagation increases

- I-II
- I-III
- II
- I-II-III
- I

9. "*The speed of sound is measured as 430 m/s in K, 1400 m/s in L and 745 m/s in M.*"
Based on the given statement, assuming that the ambient temperature is equal, in which option are the states of substances K, L, and M correctly given?
- Liquid-Gas-Solid
- Solid-Liquid-Gas
- Gas-Liquid-Solid
- Gas-Solid-Liquid
- Liquid-Solid-Gas

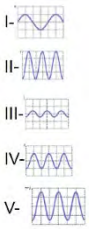
10. "*Different sounds are obtained from a sound source whose amplitude can be changed.*"
Which of the statements given in the options is true?
- Sound with a low amplitude is carried farther away
- Variability in amplitude does not affect the frequency of sound
- The amplitude of the sound decreases as the amplitude is increased
- The frequency of the sound increases when the amplitude is increased
- The amplitude of the sound increases, the intensity of which is reduced

11. Which option provides the expressions to fill in the blanks?
When an object vibrates ..... occurs. But the object should be in a material such as .... or .... When the object vibrates in .... no sound is generated.
- sound, air, water, ın vacuum
- energy, air, vibration, air
- movement, sound, air, water
- sound, solid, liquid, excess
- with sound, space, air, energy

12. Which of the statements given about sound frequency is true?
- The loudness of the sound depends on its frequency
- It is a measure of the energy of the sound source
- The human ear can hear sounds of any frequency
- It is a measurement related to the intensity of the sound
- The loudness of the sound is related to the frequency of the sound

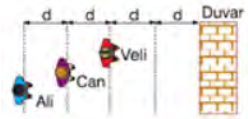
13. The sound wave of a cat is represented in Figure-I. Accordingly, which of the graphs given in Figure-II can be correct for the sound waves of bears, bees and tigers? (Graphs have equal time intervals.)
- Bear, Tiger
- Bee, Bear
- Bear
- Bee, Tiger
- Bear, Bee, Tiger

14. Wave graphs of some sounds produced in equal time have been created. Accordingly, in which option is the frequency of the given sound wave different from the others? (The pods are evenly spaced.)



- III
- IV
- V
- II
- I

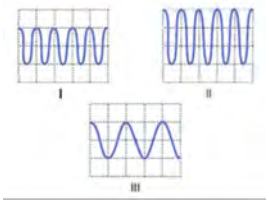
15. In the figure, the distances of three people to the wall are represented.



I-Only Ali and Can's voices reflect off the wall
II-Ali, Can and Veli can hear the echo of their own voice
III-Can hears the echo of his voice before Ali
Which option gives the correct statement(s)?

- I
- II-III
- I-II-III
- III
- II

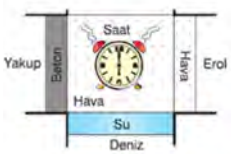
16. Sound waves obtained in 1 second in the same environment are modeled as in I, II and III.



For these sound waves
A-The sound with the highest intensity is the sound II
B-The sound with the lowest height is the voice III
Sounds C-I and II have equal intensities and different heights
Which option gives the correct statement(s)?

- A
- A-B-C
- B-C
- B
- C

17. As stated in the figure, there are different items between a room with an alarm clock and the environments where students are located.



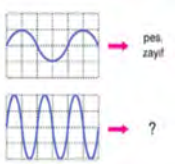
Three students listen to the sound of the alarm clock and make the following comments.
Yakup: I hear the sound of the clock first.
Deniz: Since sound propagates slowly in liquids, I hear the sound at the latest.
Erol: The voice reaches me at the latest.
Which option provides the right comments?

- Yakup
- Yakup, Deniz
- Erol
- Yakup, Erol
- Yakup, Deniz, Erol

18. When the sound encounters an obstacle, ...
When written in the blank place, which option leads to an incorrect sentence?

- may be reflected.
- it spreads in the form of waves in all directions.
- part of the sound passes through obstacles.
- part of the sound is swallowed up by the obstacle.
- the intensity of the reflected sound is less than the intensity of the incoming sound.

19. Wave graphs of the sounds produced in the same period of time by two different sound sources, K and L, are given in the figure.



According to the definition for the sound wave K, which of the information given in the options for L is correct?

- high pitched-intense
- low-pitched-loud
- low-pitched-intense
- high-pitched-loud
- high-pitched-weak

20. A person cannot hear the sound of the clock ringing, which is placed in glass bells as shown in the figure.

Which of the interpretations given in the options is correct?

- If the watch is made to sound more violently, the sound can be heard
- If the air in the innermost bubble is evacuated and the air is filled between the two lanterns, the sound of the clock can be heard
- In order for the sound of the clock to be heard, the ear must be very close to the lantern
- If the space between the two lanterns is filled with water, the sound can be heard
- If the innermost bubble where the alarm clock is located is deflated, the sound can be heard

21. Your views on the topic of sound and noise...

- I think it's very important for working life.
- I have no idea.
- I think it's important in our work and daily lives.
- I think it's very important in our daily lives.

Appendix 2: Quiz 2 – Questionnaire for feedback

Question 1. Evaluate the contribution of your PBL application to the understanding of the subject.

- It was very helpful
- Was useful
- Didn't make a significant contribution
- Did not contribute
- I have no idea / I did not participate in the application

Question 2. In the following years, when it is planned to repeat the implementation of PBL with the subject of sound, do you have a different proposal?

- No changes are required
- The application scope is extensible. (e.g. taking measurements in enterprises, etc.)
- The application time can be increased.
- The application can be carried out with groups of students (e.g. minimum 2, maximum 10).
- The results of the application can be presented to other students, high school students, relevant business employees.

Question 3. In your opinion, which subject is the most suitable subject for PBL application within the scope of the Ergonomics course?

- Lighting
- Vibration
- Musculoskeletal Disorders
- Manual materials handling
- Instrument and panel design
- Sound-Noise
- I have no idea

Question 4. Specify the activity that challenges you the most during the implementation of PBL.

- I completed the application steps without difficulty.
- I had difficulty in determining the measurement locations.
- I had difficulty in choosing and using the application to take measurements.
- I struggled with the daily exposure scenario design.
- I had a hard time creating a poster.
- I had difficulty recording the measurement values.

Question 5. Other topics that are not included in the questions, that you want to specify with the application...