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PROJECT-BASED LEARNING: DILEMMAS AND QUESTIONS!

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Abstract. In this new era of fast communication and fast change of the technology, fast changes in the process of education are inevitable. Obtaining universal knowledge and skills in the schools is more than necessary. Experiential, hands-on and student-directed learning which are recommended by the educators more than 100 years ago, every day become more and more our need and reality.

One of the approaches, which offer these features, is the Project Based Learning (PBL). There are many discussions on what PBL really is, what are the steps that must be followed, when the approach is PBL and when it is not PBL, how to use it, how to adjust PBL approach to our needs defined by the curriculum and the syllabus etc. Probably the biggest question is how to assess the individual knowledge and skills of each student obtained in the team during PBL.

Here, we will try to clarify some of the most important dilemmas and questions about the essence of PBL, differences and similarities with other approaches. We will also discuss few examples of PBL use in physics teaching and learning for the students of low secondary school (grades 8 and 9).

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1. THE HISTORY OF PROJECT BASED LEARNING

Project Based Learning (PBL) has a long history.

Socrates in 5th century BC says, “Learning is not a process of serving information … it is neither the only nor the most important task of the teacher. The teacher’s task is to lead the student, so the student can conclude. I cannot teach anyone anything. I can just make him think.”

In the 19th century, Maxwell asked the colleagues to apply more research and research based learning and less wittily formulated mathematical problems. Cavendish laboratory for physics, established in 1874 by Maxwell was a result of the movement for reform in the education.

The famous German mathematician, Leopold Kronecker, was the first constructivist. Later, Piaget [1], Vygotsky [2] and other researchers set the scientific foundation.

Why do we mention constructivism when talking about the Project Based Learning? Because in the core of the PBL is the process that involves the students in discovering and constructing their knowledge. It is a process based on research, design and everything that

means intellectual and physical engagement of the student. It is process which engages minds-on and hands-on.

2. CHARACTERISTICS OF PBL

There is no one accepted definition of PBL. Many authors try to define PBL.

Markham et al. explains that Project Based Learning (PBL) is the use of in-depth and rigorous classroom projects to facilitate learning and assess student competence and defines it as a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks [3].

Jones et al. [4] and Thomas et al. [5] explain that PBL is a model that organizes learning around projects, and projects are complex tasks based on challenging questions or problems, that involves students in design, problem solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended period of time; and culminate in realistic products or presentations.

More important than the definition itself, are the attributes of effective projects.

Project-based learning:

- Recognizes students' inherent drive to learn, their capability to do important work and their need to be taken seriously by putting them at the center of the learning process.
- Engages students in the central concepts and principles of a discipline. The project work is central rather than peripheral to the curriculum.
- Highlights provocative issues or questions that lead students to in-depth exploration of authentic and important topics.
- Requires the use of essential tools and skills, including technology, for learning, self-management, and project management.
- Specifies products that solve problems, explain dilemmas, or present information generated through investigation, research, or reasoning.
- Includes multiple products that permit frequent feedback and consistent opportunities for students to learn from experience.
- Uses performance-based assessment that communicates high expectations, present rigorous challenges, and requires a range of skills and knowledge.
- Encourages collaboration in some form, either through small groups, student-led presentations, or whole-class evaluations of project results.
- Include wider community in the activities.

The activity, which by teachers is called project, is often used as a fun or change-of-pace events completed after students have been pushed through homework assignments, lectures, and tests.

In PBL, students are pulled through the curriculum by a Driving Question or authentic problem that creates a need to know the material.

PBL is sometimes equated with inquiry-based learning or experiental learning. If you try to google PBL, very often you get to the Problem-Based Learning, which abbreviation is also PBL. Though PBL shares some overlapping characteristics with these terms, there are differences between them.

3. ASSESSING KNOWLEDGE GAINED IN PBL

When talking about the PBL, assessment is one of the biggest problems that teachers face. There is often confusion about what and how to assess the individual student, when students work in a team and when everybody has different tasks and activities within the team. But, teacher most often forget that the project activities arise directly from the topics and standards in the curriculum and syllabus. The whole project is shaped in a way to meet the outcomes and standards of the curriculum. The students' activities converge towards one and the same goal – the final product of the project. In order to realize their activities, students have to acquire knowledge first. This knowledge is in accordance with the objectives in the curriculum. If so, then the teacher can assess the students' knowledge and achievement with the tools and techniques that she usually uses.

3. DIFFERENCES AND SIMILARITIES WITH OTHER TEACHING APPROACHES

In order to see the differences and to get to the essential characteristics of project-based learning, we will start from the beginning i.e. from Research-Based Learning (RBL). In the foundation of RBL lies the scientific method. There are many different definitions and explanations about scientific method, but we will see here the steps that can be found in almost every version. In the process of the research, researchers:

- Observe
- Pose a question.
- After additional observation and analysis, construct a hypothesis.
- Design research/experiments.
- Analyze the results and make a conclusion.
- Publish the results.

After this, researchers rethink and start the process all over again. When students use this approach for learning, of course, they do not start all over again, but they can rethink, put the results in slightly different situation and circumstances, which will take them to the next topic in the syllabus. In this way, they discover new knowledge by their own. They construct their own knowledge. The activities are directly related to the topics and standards in the curriculum and the syllabus.

Next step in getting closer to the project based learning is the Problem-Based Learning (PbBL). During this process, students:

- Recognize a problem from a situation in the classroom.
- Need new knowledge in order to solve the problem.
- Design research in order to come to this new knowledge.
- Find a solution for the problem based on the acquired knowledge.

The underlined activities are new in this approach, compared to RBL. Since the problem emerges from a situation in the classroom, the problem is authentic. On the contrary, in RBL the problem does not have to be authentic. In RBL the goal is to come to a new knowledge, which is defined by the curriculum and the syllabus. Unlike in RBL, in PbBL the goal is to find a solution for a problem, which emerges from an everyday life, from a real world situation. The acquired knowledge is not a final goal in itself as in RBL. It is only a tool to find a solution for the problem. Knowledge is something that is acquired on the way to the solution. But, it is not acquired because students have to spend their extra time, or for fun. They fill the need for this knowledge. In both approaches students work in teams and they collaborate/cooperate.

Finally, we came to the project based learning. During PBL students:

- Face with a problem outside the classroom.
- Need new knowledge in order to solve the problem.
- Design research in order to come to this new knowledge.
- Find a solution for the problem based on the acquired knowledge.
- Design a final product, which emerges from the solution of the problem.

The underlined activities are characteristics of PBL. They are not present in the PbBL activities. At first sight, it seems like there is not big difference between PbBL and PBL. But, let us take a closer look at the first and the last activities, which are new. Like in PbBL, the problem is authentic and comes from the real world. But, unlike in PbBL, the new flavor here is that this problem is not single. This problem is multilayered. It is complex and consists of more, smaller problems. What is also interesting at this moment is that the problem is interdisciplinary, something that enables us to relate the problem to more than one subject i.e. to integrate more subjects or more topics from one subject.

The last activity, designing a final product in PBL is known from the beginning of the project. Actually, the idea of the project starts from the final product. Unlike in PbBL, the product in PBL is something that has wider significance. It can be applied in the wider community. The final product can be in the form of a program, procedure, document, campaign, theater play, technical product etc.

4. WHAT STUDENTS GET FROM PBL

PBL covers all modern trends in education.

Students are at the center of the learning process.

Students work in teams and they collaborate. Collaboration in the process of learning is a level higher than the cooperation. Note that the student takes the responsibility for its acquired knowledge, but also he/she takes responsibility for the knowledge of the whole team. PBL creates collaborative relationships among diverse groups of students [6, 7].

Students cooperate with the community. Learning community is not only the classroom anymore. The Learning Community becomes multidimensional, public and unpredictable [8]. No matter of the subject and the topic, students learn how to do a research, how to organize the teams, how to communicate.

Very important moment is that they learn to articulate their thoughts, they learn how to explain, how to convince.

PBL creates positive communication. Students learn to advocate, to defend their ideas, but at the same time to listen the opponent and to be open for others opinion.

PBL overcomes the gap between knowledge and thinking. Students "know" and "do".

PBL develops the habit for lifelong learning.

PBL meets the needs of learners with varying skill levels and learning styles.

Students with different abilities and different interests work together: organization, experimenting, crafts, drawing, writing, designing…

Very often, the engineers do not have communication and teamwork skills. Current programs do not provide sufficient design experience to students, too. There is a lack of awareness amongst students of the social, environmental, economic and legal issues that are part of the reality of the modern engineering practice [9]. All these moments can be recognized in the skills that students can obtain by practicing PBL.

Very important moment is that PBL enables application of the technology [10, 11].

5. WHAT TEACHERS GET FROM PBL

Perhaps the first question that usually arises is: do I have time to do this project? PBL should not be taken as taking time away from the regular curriculum. Project should be considered as a central method of teaching and learning that replaces conventional instruction method. This project teaches students the same essential information you might teach them through lecture and discussion. Of course, it is not possible to go through the whole project just during the classes. One of the reasons is that the project involves cooperation with the community. In some situations, it is possible to bring people from institutions outside of the school. For example, at the beginning of the project or during the realization of the project, when there is need to make short discussion, short overview of what has been done or short consultation. But, the real interaction with the community is at the institutions. The second reason is that the activities are too many and too complex to do it only during the classes. Part of the activities can be done as homework, sometime even extended homework.

This shows that there are some activities that have to be done by the students. Traditional instruction engages teachers whole time of the class with talking, explaining, doing

experiments, watching students…This is not easy, in particular for the novel teachers. PBL shifts all activities towards students. The students take part in designing the whole project: communication with the community, designing research, doing research, collaborating between themselves, they have responsibility for the success of the whole project. And all that with the help of the teacher. This means that the teacher is not passive. The teacher leads the students, give them direction if they got lost, helps them with the organization. The teacher is their older partner who is always there to help them if they get stuck.

The teachers' experience shows that once the teachers fell comfortable with PBL, they usually find teaching with projects to be more fulfilling and enjoyable.

Most of teachers claim that active learning is vital. But, not all of them react in the same way to such way of learning. Some teachers say that projects are chaotic or messy. This a good reason for a teacher to ask herself/himself on the teaching style and skills. How will he/she operate in PBL environment?

The teacher has to test herself/himself, whether he/she is a leader or a manager. Leaders facilitate problem solving in a group and help the group find their own solutions. Managers, on the other hand, prescribe outcomes and control the process on the way to finding those outcomes. The best way is to go back and forth between the two roles. But, if the teacher is not sure what will happen when the control is left to the students during the project activities, he/she does not have to avoid projects. Teachers already know many of the elements of PBL, and have used them, but may not be aware of it. It is good to start with those small elements and build them up step-by-step. This results in small projects at the beginning, which will grow and finally come to a big project.

PBL does not offer possibility to cover all or many topics. Sometimes it is the topic, which is not possible to go through PBL. Sometimes, it is the time that limits us. But in the case of good education, less is more. If the teacher is pressed for time and need to include many topics in the instruction during a year, it is good to think about the concept of "uncoverage" i.e. cover-discover approach. This means making a deliberate decision about topics that you want to teach in depth versus topics that can be simply "covered". Which of the topics can be easily and successfully handled through lectures or textbook assignments? Which of the topics require more depth? Identify the topics with the most important ideas and concepts in your curriculum and incorporate those topics into projects. Those are the topics with which you want the students to tackle. The remaining topics you can deal with through direct instruction. In other words, the teacher can use direct instruction and less time for the concepts that are easier to handle and maybe on the lower level of the importance scale (if it is possible to grade) in order to cover the topics and goals in the syllabus. But, the concepts that are more important have to be discovered by the students.

Teachers in low-performing school often pose a question: can PBL work in my school? Yes, it can, because, as it was mentioned earlier, many of the PBL elements teachers already know and apply. Of course, it is not possible to quit direct instruction. Discussion with the students and between the students, inquiry, experiments, cooperation with the community, designing things is all elements of PBL. The relative quantity of each element in the PBL

depends on the topic, circumstances in the school and community, teacher's and students' skills. Sometimes, if the students are less skilled, it will be necessary to include more direct instruction. But, teachers must not quit projects!

When the teacher develops a project, she has to start thinking backward from a topic. Project ideas come from articles, issues, current events, conversations and wonderment. Often, they emerge from discussions between members of a teacher tea. Once an idea comes to the teacher, she has to work backwards to shape the idea in order to meet outcomes and standards of the curriculum.

6. EXAMPLES

Let's take a look at one example in order to see and understand the difference between the three approaches explained before.

Example Research Based Learning

Objective: Discover the dependence of the electric resistance on the characteristics of the conductor.

The research and experiments are designed by teacher and students, jointly.

Students are organized in teams. Each team has different task. Each team has to come to some conclusion about the dependence of the electric resistance. After the experiments are done, the students exchange the results between themselves; discuss the results and come to the final conclusion. The law for electric resistance is discovered.

Example Problem Based Learning

The students study different electric circuits. The students have to construct a circuit with few resistances. There is not a resistance with certain value in the physics classroom. The students have to make such resistance. In order to make it, first they have to discover the dependence of the resistance on the characteristics of the conductor. It means in this part of the PbBL comes the module of RBL. After the research is done and the law of electric resistance is discovered, the students can make the required resistance.

Example Project Based Learning

For some reason the school has to construct and design electric heater. In order to fulfill this task the school addresses to a factory which produce electric devices. During this process, students should take the next activities:

1. Take into account the power of each heater.
2. Discover the law of resistance.
3. Adjust the power and the resistance of the heater.
4. When constructing the heater think about its design, which has to answer the application.

5. Construct and incorporate the safety device in the heater.

6. Construct and incorporate temperature controller (thermostat).

7. Write and design a manual for the heater, which will contain the procedure for using and safety precautions.

7. Write and publish a report?

From the last example, one can see that the integration in PBL is inevitable. Besides the physics, which lay in the core of this project, subject related to technology can also be involved, since one of the goals of the project is to construct and design the heater. Design of the heater can also be included in the classes of arts. All written material can be included in the classes of mother tongue or even in foreign language. Report can also be given in electronic form (power point presentation, website, blog etc) which means that the classes of computer science (informatics) can also take part in this project.

Example Introductory Project

One of the projects, which will introduce the teacher and the students in PBL and will help with the later projects, is mapping the community. Design a project to discover all institutions in the community. The final product will be a categorized list of factories, faculties, museums, institutes, ballet studios, churches, theaters, cinemas, galleries, building enterprises etc. Later this list can be used as a source for ideas and some of those institutions and companies could be involved in the future projects.

Here are some examples of projects and possible questions to answer and activities to do within those projects.

Example: Campaign for recycling "Why recycle at all?"

Why should we recycle? What can be recycled? Visit a factory that produces paper, glass, aluminum, rubber, plastic or anything that can be recycled. From the experts obtain information on the energy and water consumption for production, on the emission of harmful substances etc.

Visit an NGO, which would be interested in participating and supporting such project. Visit the ministry of environment or similar.

Visit an institution which works in the area of recycling and obtain interesting information. Are they satisfied with the way of collecting material, is there any problem, is there anything that can be improved etc. Is there a possibility to expand the recycling with other materials and under what conditions?

What the people know about recycling? Organize an inquiry. Design a questionnaire.

Make a material for the campaign: leaflet, play, show, website etc.

Which materials decompose in the nature? Make a research: bury fruit, vegetable, piece of meat, paper (with a various quality), plastic (with a various quality), can etc.

Example: Industry "How to improve the quality of a product? What is the competition?"

Make e list of the factories in the town, in wider area or in the state?

Find out is it possible to buy their products in the stores?

Find the products and manufacturers of similar products that can be found in the stores?

Discuss with the sellers/merchants: why do they supply these products and not some others?

Test the products. Prior to testing establish criteria, what and how to evaluate.

What would the students change: quality, shape, packaging, commercials or something else?

7. CONCLUSION

PBL is not the ideal approach. PBL cannot be applied in every situation. For example, PBL is not appropriate as a method for teaching certain basic skills such as reading or computing; however, it does provide an environment for the application of those skills.

Research component in the project must not be forgotten. Investigating authentic problems [12], designing experiments with devices that are used in everyday life [13] and analyzing results, gives more quality knowledge, understanding of the basic concepts and fights common misconceptions [14].

However, PBL is still in development stage. Some authors say that there is not sufficient research or empirical data to state that PBL is a proven alternative to other forms of instruction. However, PBL is so complex that it gives opportunity to use all possible forms of instruction. Blended learning finds its natural environment in PBL. But, nothing is ideal.

REFERENCES

[1] Piaget, J. Science of education and psychology of the child. New York: Viking (1969).
[2] Vygotsky. L. S. Mind in Society: The development of higher psychological processes. Cambridge, MA: Harvard University (1978).
[3] Markham, T., Larmer, J., Ravitz, J. Project-Based Learning. A Guide to Standard=Focused Project Based Learning for Middle and High School Teachers, Buck Institute for Education, Novato, California (2003).
[4] Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1997). Real-life problem solving.: A collaborative approach to interdisciplinary learning. Washington, DC: American Psychological Association.
[5] Thomas, J. W., Mergendoller, J. R., and Michaelson, A. (1999). Project-based learning: A handbook for middle and high school teachers. Novato, CA: The Buck Institute for Education.
[6] Zajkov, O. Influence of hypermedia on the secondary school students' conceptual and conventional knowledge in mechanics, PhD Thesis, Faculty of Natural Sciences and Mathematics, Skopje (2004).
[7] CUSE (Committee on Undergraduate Science Education) Science Teaching Reconsidered, (p. 15-16). Washington, D.C: National Academic Press (1997).
[8] Arends, R. I., Learning to teach, 4th ed. (p. 80-83). McGraw-Hill (1998).

[9] Mills, J. E. Engineering Education – Is Problem-Based or Project-Based Learning The Answer?, Australian J. of Engng. Educ. (2003-04). Retrieved April 18, 2012 from (www.aaee.com.au/journal/2003/mills_treagust03.pdf
[10] Solomon, G. Project-Based Learning: a Primer, Technology and Learning (2003). Retrieved April 23, 2012 from http://pennstate.swsd.wikispaces.net/file/view/PBL-Primer-www_techlearning_com.pdf
[11] David Moursund Project-based learning using information technology 2nd ed. Eugene, Or. : International Society for Technology in Education (2003).
[12] Zajkov, O. Simple way of video measurements helps discovering conservation laws, Macedonica Physica, (2008).
[13] Jonoska, M., Tuntev, A., Zajkov, O. Hands-on Experiments with a Voltage Tester, The Physics Teacher, January, Vol.41, p.14-15, (2003).
[14] Zajkov, O., Jonoska, M., Graph and Graphic Understanding Among Secondary School Students, Proceedings of the Fifth General Conference of the Balkan Physical Union, Editors: S.Jokić, I. Milošević, A.Balaž, Z.Nikolić, Serbian Physical Society, p.1849-1854, Belgrade, (2003).

УЧЕЊЕ БАЗИРАНО НА ПРОЕКТИ: ДИЛЕМИ И ПРАШАЊА!

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Апстракт: Во време на брзи комунукации и брз развиток на технологијата, неизбежни се брзи промени и во образованието. Добивање универзални знаења и вештини е повеќе од потребно. Учењето базирано на искуство и настава насочена кон ученикот, кои се препорачуваат последниве 100 години секој ден стануваат се повеќе потреба и наша реалност.

Учењето базирано на проекти (УБП). Постојат многу дискусии за тоа што точно значи УБП, кои се чекорите кои мораат да се следат, како да се усогласи со наставната програма, како да се имплементира во наставата и таканатаму. Можеби најголемиот проблем кој ги доведува наставниците во недоумица е како да се оцени знаењето стекнато низ овој начин на учење.

Многу наставници не можат да направат разлика помеѓу учење базирано на истражување, на проблем (УБПб) и на поект. Учење базирано на истражување е основна клетка на другите два приода. Тоа е составен дел на учењето базирано на проблем и проект. Малку потешко се прави разлика помеѓу УБПб и УБП. Кај УБПб ученикот е доведен во проблемска ситуација.За да ја реши, потребно е да помине низ процесот на учење (пожелно е тоа да биде учење низ истражување). Стекнатото знаење ученикот го користи за решавање на проблемот. Решението има локален карактер, односно го решава проблемот во училницата/училиштето.

Кај УБП, проблемот не е од локален карактер, туку тој доаѓа од надвор, од поширокатa заедница. Проблемот е комплексен, односно повеќеслоен, се состои од повеќе помали проблеми. Во процесот на решавање на проблемот е вклучена и поширокатa заедница. Дел од

процесот на учење може да се одвива и надвор од училницата, од практични ситуации и заедно со експерти од други институции, различни од училиштето. УБП може да вклучува и интегрирана настава. Решението е готов производ во вид на изграден уред, производ, презентација, документ, претстава, кампања и слично.

Кога зборуваме за оценувањето стекнато низ УБП, мора да се каже дека целите кои УБП си ги поставува се идентични со они дефинирани со наставната програма. Тоа значи дека материјалното знаење кое треба да се стекне е истото тоа кое би се стекнало и низ традиционална настава. Оттука следи дека оценувањето на индивидуалното знаење на секој ученик може да се направи на устаљениот начин кој наставникот го применува вообичаено. Дополнително, низ УБП се стекнуваат универзални знаења и вештини, како што се тимска работа, соработка и комуникација во рамките на тимот и надвор од него, организација, одговорност за стекнатото знаење и крајниот производ од проектот.

Се разбира, УБП не може да се применува во секоја прилика и за секоја наставна единица и тема. Тука станува збор за процесот на покривање и откривање. Работа на наставникот е да оцени кои се поимите кои може да се поминат низ традиционална настава, а кои е потребно да се проучат подлабоко. Поинаку кажано наставникот треба да оцени кои се поимите кои не можат да се совладаат со УБП, кои може лесно да се совладаат со традиционална настава или кои не мора да се проучуваат подлабоко, односно поими кои треба да се покријат, затоа што се дел од наставната програма. Од друга страна, има поими кои може да се совладаат низ УБП, кои не може да се совладаат со традиционална настава или кои поради својата важност треба подлабоко да се проучат, односно поими кои ученикот треба сам да ги открива.

Примерите во трудот ги илустрираат овие моменти.