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Project Based Learning: Are There Any Academic Benefits for the Teacher or Students?

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Synopsis

In this paper, I raise an issue often neglected in Project Based Learning (PBL) literature. What *academic benefits*, if any, does the teacher or the student gain by adopting PBL pedagogy in college? I argue that PBL by its structure yields little academic benefit for the teacher or the students, and this could affect motivation as well. I present some examples from my personal teaching experience in mathematics. And thus, as I explain, a more “traditional” project-based approach could be better for both teacher and students.

Keywords: project, research, students, teacher, benefits

1. Introduction

Project Based Learning (PBL) is a student-centered pedagogical approach with which students supposedly gain knowledge on a certain subject through projects. The projects usually relate to real-world problems and the students work on them in groups. The students are largely responsible for the organization of the activities, those being research, writing, discussion, presentation, time management, etc. The teacher takes more of a role of a facilitator and a counselor who, of course, must make all arrangements so that the students have the material and equipment necessary to bring about a project and learn. The teacher will also typically guide students along the way and discuss with them the various issues that might arise, and ultimately will evaluate the final project presented by the students [5, 16].

Historically, inquiry-based learning goes back to ancient Greece; many point to Socrates, who seemed to be interested in imparting knowledge to his interlocutors not by lecturing but by active personal inquiry and reflection (the so-called “Socratic Method”).¹ Aristotle, too, advocated a more hands-on approach, characteristically saying that “*For the things we have to learn before we can do them, we learn by doing them, e.g. men become builders by building and lyreplayers by playing the lyre; so too we become just by doing just acts.*” Aristotle, II.1 [1]. This emphasis on experience and real life is reflected centuries later in the works of John Dewey, an American philosopher and educator (usually most associated with PBL today), who promoted the idea of a style of learning facilitated through constructive activities. As he said [7]:

I believe that the school must represent present life—life as real and vital to the child as that which he carries on in the home, in the neighborhood, or on the playground. The teacher is not in the school to impose certain ideas or to form certain habits in the child, but is there as a member of the community to select the influences which shall affect the child and to assist him in properly responding to these influences . . . I believe, therefore, in the so-called expressive or constructive activities as the centre of correlation.

In modern times, PBL gained traction in the 90s with seminars organized by the Buck Institute for Education (BIE) and their publication of the *Project Based Learning Handbook* in 1999 [12]. Nevertheless, even though many teachers incorporated PBL into their teaching practice in the following two decades, PBL remains controversial in terms of its definition² and benefits, with most teachers still using more traditional teaching practices.

¹The canonical example of the Socratic method is given in Plato’s dialogue *Meno* [15]. Here Socrates teaches a slave-boy an interesting geometric fact by guiding the boy in approaching the problem by hands-on doing and reflecting. Given a square, how can one construct a new square which has area twice the area of the original square? If one takes the diagonal of the original square to be a side of the new square, then one in fact can construct a square as required.

² Apparently, the definition of PBL is not unique and certain differences exist between different PBL models. Here I follow Blumenfeld *et al.* [5] and Thomas [16] for PBL’s defining characteristics. In regards to PBL’s efficiency, interestingly, in the *PBL Handbook* published by the BIE it is stated that “there is not sufficient research or empirical data to state that PBL is a proven alternative to other forms of instruction” [12, page 5].

2. Issues with PBL

Proponents of PBL reported some of the benefits of the PBL teaching method in several studies [5, 13], mainly claiming student improvement in what are usually called “21st century skills” (e.g. critical thinking, creativity, communication, and collaboration) but also in academic skills and content knowledge (e.g. long-term knowledge retention). In mathematics, however, I know of only a few such studies at the high school level (Boaler [3, 4]; Horpyniuk [10]) and only one at the college level (on Inquiry Based Learning by Caswell and LaBrie [6]). The latter actually examines the rewards and challenges of Problem Based Learning (PrBL) rather than PBL. Furthermore, I am not aware of any study that reports academic benefits for the teacher or students by adopting PBL.³

On the other hand, PBL faces many challenges in terms of definition, scope, efficiency and benefits. These are well-documented in a recent publication by the Education Endowment Foundation (EEF) in [14], in which the authors conclude that:

1. Adopting PBL had no clear impact on either literacy (as measured by the Progress in English assessment) or student engagement with school and learning.
2. The impact evaluation indicated that PBL may have had a negative impact on the literacy attainment of pupils entitled to free school meals. However, as no negative impact was found for low-attaining pupils, considerable caution should be applied to this finding.
3. The amount of data lost from the project (schools dropping out and lost to follow-up) particularly from the intervention schools, as well as the adoption of PBL or similar approaches by a number of control group schools, further limits the strength of any impact finding.
4. From our observations and feedback from schools, we found that PBL was considered to be worthwhile and may enhance pupils’ skills including oracy, communication, teamwork, and self-directed study skills.

³ By *academic benefits*, I basically mean any by-product of an activity that could boost teacher’s or the student’s academic and professional development. For example, a publication in a scientific journal could be such a by-product. Academically it enhances research, creativity, knowledge, etc., and professionally it improves one’s C.V., opening opportunities for scholarships, funding, promotions, etc. Of course other types of benefits may be prioritized by other scholars; my focus is exclusively on these benefits in this essay.

5. PBL was generally delivered with fidelity but requires substantial management support and organizational change. The Innovation Unit training and support program for teachers and school leadership was found to be effective in supporting this intervention. [14, page 4]

The above results refer mainly to elementary and high school surveys, but due to the lack of surveys at the college level to show otherwise one would expect similar issues to appear when using PBL. Especially issues related to item 5 above might be concerning.⁴

In what follows, I focus on an issue often neglected in the literature: the academic benefits in the sense of Footnote 3, if any, to the teacher or the students of PBL. I present some evidence from my own college teaching experience when I used projects. Overall, I argue that PBL by its structure is probably not the best way to go, both for teachers and students, in terms of academic development, whereas, well-chosen projects or problems (or a combination of the two), within a standard lecture-type course, could be very beneficial to both teachers and students academically.

3. More Specific Issues with PBL

To my knowledge, no study shows any positive effects of PBL for the teacher or the student, in terms of research and academic development. In fact, since PBL is construed as a highly student-oriented style and with sole purpose of the projects for students to learn core concepts and material, then little room is left for genuine research by teachers and students beyond the curriculum. PBL promotes specific and guided projects designed to understand better certain concepts, not genuine research projects. This could be quite restrictive as a method in college instruction, at least in certain courses, and could affect motivation. Pre-selected projects might be good for students who need help learning or mastering certain mathematical concepts, but they could also inhibit imagination and creativity for students who are advanced and want to explore.

⁴One could also add to the critique PBL's overdependence on technology. Beyond the technical difficulties that might appear in the learning process (e.g. no internet), dependence on technology contradicts PBL's purpose to include all students in the learning process, as some students might not be fortunate to have access to technology (e.g. no computer at home, etc.). In a talk by J. Parker, at the EdmodoCon 2017, PBL's technology dependence could not be made more explicit. The whole teaching approach exemplified in the talk, in my opinion, should be an example to be avoided rather than to be promoted.

Furthermore, considering that PBL is highly time-consuming for the teacher and the student, as many surveys indicate [11, 10], this too could restrict actual research opportunity. The teacher has to make a significant change of his role. Instead of focusing on finding ways to deliver course content in pedagogically sound ways, now he has to focus more on managerial issues and making arrangements that facilitate self-learning, such as pre-selecting all supporting material and resources, pre-selecting real-life projects, organizing class structure, organizing groups and communication, finding and providing the appropriate technology, etc. All these demand an increase in management skills that a teacher has to learn. Hence, training, support and familiarization with related tools and resources is required, and these all take time that the teacher might not have or that the teacher's workplace might not have available.

Finally, due to greater volume of material to be covered in college mathematics and their more specialized nature (e.g. abstract concepts such as "infinity" or practical issues such as "factoring") it is hard to see how a PBL approach would help students understand those key concepts which they may need later in their academic career. We simply do not have any available studies to support claims that PBL would help. And based on my own class experience, some mathematical concepts (e.g. factoring, polynomial division, infinity, limits, etc.) are better taught on the board, explained with examples, mastered through practice problem and assignments, and linked to their historical development. And only after could those concepts possibly be used in projects. Reversing the order, as PBL suggests, sounds problematic.

Let us look, for example, at a simple project such as constructing a rectangular open box with a given volume from a rectangular paperboard where its dimensions the students need to figure out. This is an application that teachers occasionally give after they cover factoring and quadratic equations. This could easily also be a project that falls within the standards of PBL, i.e. a real life project, designed to teach, which produces an end-product etc. According to PBL one should first give this project to the students and via that, with minimal guidance, they would somehow learn the related mathematical concepts. But then, the students have to deal with all the difficulties involved with factoring, especially factoring quadratics of the form $ax^2 + bx + c$ ($a \neq 1$), which is quite a challenging topic to students [9] even when they get proper instruction on it. My claim is not that the students could not learn the required factoring in order to complete their project, but rather I am concerned about what exactly they will learn, how well they will learn it and how long it will

take them. Learning one or two factoring cases, perhaps the ones needed for their project, does not necessarily imply they learned factoring thoroughly or cases involving, say, identities, group factoring, etc. If the students need only certain cases of factoring for their project, then what motivation is there to learn the other cases? In addition, students would perhaps also need to review or learn all those topics related to factoring, such as polynomial multiplication, rules of exponents, etc., and that would require even more time spent.

I am almost inclined to suggest that PBL supporters assume that PBL is somehow something revolutionary which arrived to replace the bankrupt “traditional” teaching style. And, that one somehow must choose between PBL and traditional teaching. Well, a few clarifications are required here: First, the traditional style is not simply lecturing. It could be all sorts of styles and, in particular, it could incorporate projects too. Some courses could incorporate Problem Based Learning (PrBL), some Projects (P), some can combine the two, and some do not incorporate any of the above. Second, PBL is simply a style of teaching that incorporates projects with usually the extra unjustified requirements that: it should be applied for all students, projects must be real-life based, students must use technology, etc. That sounds, if not a bit dogmatic, at least pedagogically restrictive considering the fact that: (a) no studies clearly show yet PBL’s superiority over traditional methods; (b) that traditional methods could produce (and have been producing) learning outcomes within the PBL’s demands and positive academic outcomes beyond the PBL’s objectives (e.g. publications). Furthermore, PBL certainly does not have a monopoly as a method that leads to increased motivation. Projects that could yield academic benefits for the teacher or students could be a great motivating factor, especially in college. It seems that PBL misses this important motivating factor.

4. Another Way to Teach with Projects

Since 2006, when I started implementing projects in my courses, I realized a few important facts: (a) *One must consider the audience*, i.e. projects are not usually appropriate for every course or every student; (b) *Projects could be a beneficial two-way activity for student and teacher*. It seems to me that both the above run contrary to PBL principles, yet I could easily characterize my teaching style as project-based. And, with all modesty, I could also characterize my method relatively successful. I explain.

4.1. Consider the Audience

Some mathematics courses are better-suited for project implementation than others. For example, in a Discrete Mathematics course I believe one can suggest more project ideas than in a College Algebra course. There are also teacher's preferences or expertise, as one might prefer Algebra over Geometry, etc., and this can affect the student projects. In addition, in most courses some students have more mathematical background than others, some students are more self-motivated than others, some perform better by working alone, some prefer tests, some enjoy more exploring their own topics and some have other life constraints such jobs, children, etc. All these considerations, I believe, are being trivialized by the PBL approach. By pretending that all courses are well-suited for a project, and that all students are level-ready or willing, and that all students must work in groups on pre-decided projects, I think the standard PBL approach defeats the purpose of a project.

I too encourage students to work in groups on projects, but forcing group work is a different thing. In my experience, projects usually are chosen by the students halfway in the semester and after they learned some basic course content. Not in advance. The project ideas stem from the topics covered, via student and teacher analysis and inquiry, and not the other way around. One learns something, and with imagination and inquiry tries the "extra step". This applies for students and teachers. In research projects, of course, the role of the teacher is exactly to assist, guide and manage this "extra step".

4.2. Projects as a Two-Way Activity

Nowhere in the PBL objectives have I noticed a point which speaks for academic benefits to the teacher of implementing PBL. Especially in the college environment, this eliminates one important motivating factor for both teacher and students. It is not therefore surprising that most institutions of higher education have not adopted PBL. Just as learning should be a two-way process, so should the projects. If students gain academic benefits by working on a project, this is great, but if both the students and teacher achieve that then it is even better.

Since 2006, some (not all, for reasons explained in §§4.1) of my course projects achieved exactly that. That is, they were academically beneficial to both students and teacher. I provide some concrete examples of these successful projects in Section 5.

Some of the courses these projects were assigned in were designed with the following weights for the various grading components: Test 1, Test 2 (70%), Project (20% paper + 10% 15-min presentation) or Test 1, Test 2 (40%), Homework Assignments (take-home - 30%), Project (20% paper + 10% 15-min presentation). The syllabi always contained the following descriptive paragraph about the projects:

“The project could be of practical or theoretical nature, but [must] always [be] related to the material and objectives of the course. Concepts from the material taught should be used within the project. Students should form groups of two⁵ individuals and cooperate. Equal contribution from both members of the group, in both the project and presentation, is expected. Each group should come up with its own project. The projects could be related to works from other courses, but they should always be relevant to the topics covered in this course.”

In other courses I used the following weighting: Test 1, 2, 3 (60%), Take-Home Homework Assignments (20%), Final Exam (20%). In these courses I included the following paragraph in the course syllabi:

“There are a few projects available for students of this course. Some of them come out of the [text]book and are related to the concepts taught (some require the use of computers). The student(s) can choose the project of his/her preference, always in cooperation with the instructor. Nevertheless, not all students are eligible for these projects. Only students that score high on their tests are eligible. A project [...] will waive the Final Exam, and it will have the same grade weight as the Final (20%).”

Obviously, not all projects were successful or of interest. Some were though, and most times students continued working on them the following semester (usually in an Independent Study course). Those projects resulted in publishable papers, which with the guidance of the teacher were published with the students as sole authors or with the students as co-authors.

⁵For the project, working in groups of two in some courses was expected, but not strictly enforced. Occasionally we had groups of three, and some really good projects were done by students working alone.

I highly doubt whether this could have been achieved had I adopted a PBL style of instruction, where lectures are drastically reduced, projects are pre-selected and given in advance, projects are restricted to real-life problems and students are randomly grouped. In addition, working on something that had a potential of actually being published, benefiting academically both students and teacher, was certainly a huge motivating factor.

5. Two Examples

I now give two concrete examples of projects that stemmed out of some Mathematics courses and were academically beneficial for both students and teacher. The success is measured from the fact that: (a) the students did learn the material, since they were able to produce a high-level project (b) that the project was ultimately published in a journal, thus academically benefiting both students and teacher, and (c) that more opportunities and projects were opened to more students.

Besides these two, I have worked with students on several more projects in the next few years, some of which were published and some simply just received a grade in the course. Some were presented in Mathematics conferences or STEM events, where others set the foundation for other papers published later by the teacher. The academic benefits for both the students and the teacher were quite substantial.

5.1. *Fuzzy Steering for Autonomous MCU-Based Mobile Robotics*

This project (see Figure 1) was done by two students in a course entitled “Fuzzy Sets and Logic”, which I designed and delivered in the summer of 2006. It was initiated in a previous Robotics course in which the students encountered some problems when they were programming robot-cars that navigate autonomously. The students successfully applied fuzzy sets and fuzzy logic to a robot-car’s steering module which resulted in an improvement in the robot-car’s navigational capabilities.

As the college’s newspaper reported the next year:

“Casey and Hensler presented their work at a conference in Venice, Italy prior to publication. . . . Casey called it ‘a valuable experience, which gave us even more hope about the future and what can be done.’ In addition to feeling honored by the publication of

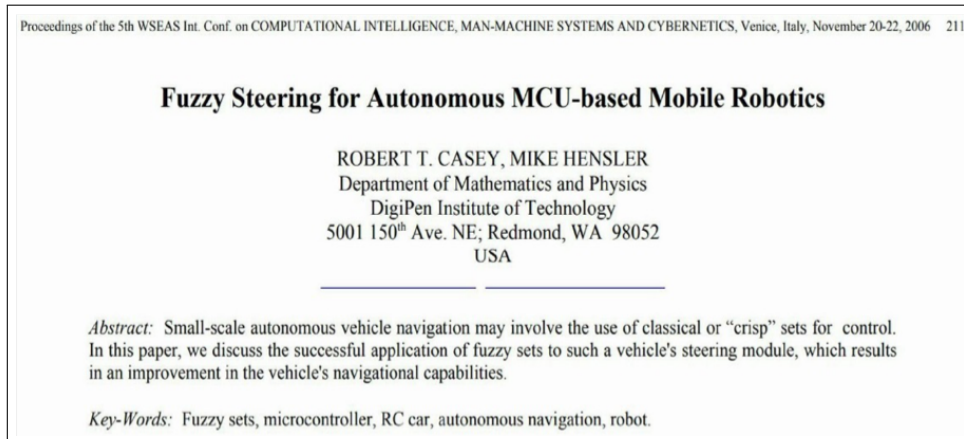


Figure 1: A paper resulting from a student project.

their paper, Casey and Hensler found the conference and publication experiences illuminating. ‘It’s a way to become more aware of what’s going on in the ‘real’ world and to be introduced to other professionals who are also making academic contributions to the fields we study in our classes,’ Casey felt. They also learned that writing an academic paper requires a certain amount of discipline and attention to detail with words and mathematical expressions. They recommend that other students seriously consider similar opportunities. Dr. Aristidou found the experience to be inspiring. The success of these two students motivated him to found the Undergraduate Research Group at DigiPen. The purpose of this new group is to seek student work for serious projects and interdisciplinary collaborations, to organize talks, and to look for funds to finance student research and conference opportunities.” [DigiPen, 2007]

5.2. Fuzzy Ordering of Fuzzy Numbers.

This project (see Figure 2) was done in the same course as above, entitled “Fuzzy Sets and Logic”, in the summer of 2007. Unlike the previous project, this project was theoretical in nature and its completion required another semester of work by the students and the teacher in an Independent Study course. The students were interested in fuzzy numbers, which we covered in class, and they went ahead to study some further algebraic properties of those numbers. In particular, they studied the ordering of fuzzy numbers.

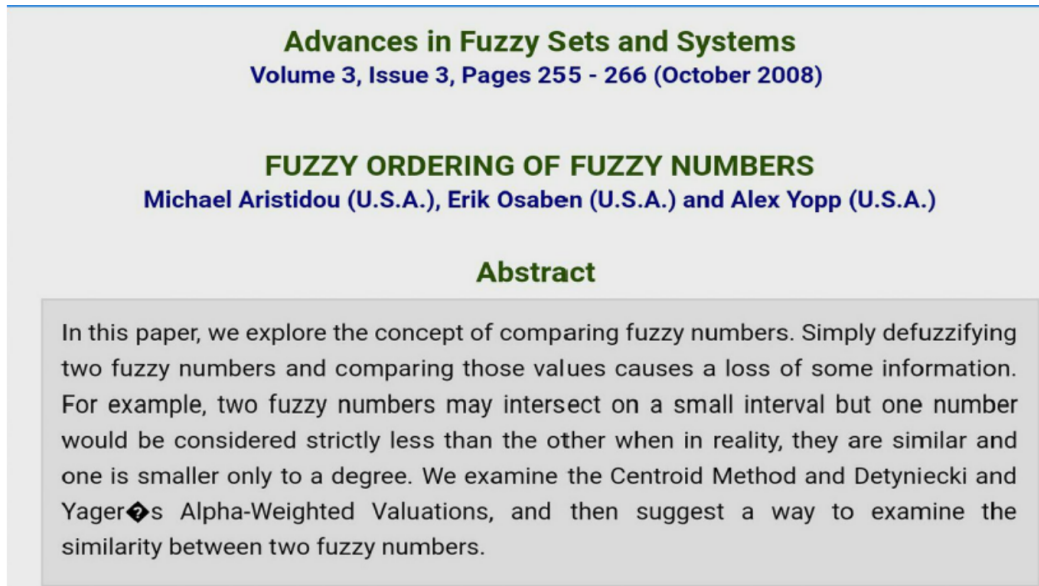


Figure 2: Another paper from a student project.

The students naturally encountered some difficulties with some of the proofs, but with the help of their teacher they managed to polish the project into a paper which was published jointly with the teacher the following semester. As the students expressed to the teacher, their project experience was most interesting and most valuable.

Now, what could have sustained the student's motivation in devoting an extra semester on this project? There could be a variety of reasons, but certainly the possibility of publishing their article, and hence enhancing their academic and professional development, was one of those reasons.

6. Some Objections

One might claim that it is not clear specifically which PBL methodology is criticized in this article, as apparently the definition of PBL is not unique and certain differences exist between different PBL models. And, furthermore, this could be seen by some as an advantage of the PBL method in virtue of its flexibility. Indeed, as I also explained in Footnote 2, PBL's definition is not unique. Nevertheless, most PBL models agree on certain key points, such as: student centered method, real-life projects, use of technology, minimal instruction, etc.

It is some of those key points of PBL that I was examining, and whether they are applicable or beneficial to a mathematics course in college. And in this essay I tried to provide reasons that they are not. PBL is not simply implementing a project in a course, but the project is a means for students to learn, collaborate, etc. In terms of academic benefits for teachers and students in a college setting, these attributes are of course desirable but not the only goal. Projects in college are not only about teaching certain concepts; they should whenever possible also provide the kinds of specific academic benefits I have focused on here.

There might also be some confusion regarding my use of the term: “academic benefits”. With “academic benefits for the teacher” I do not only mean things such as job satisfaction, feeling of fulfillment, etc. And with “academic benefits for the student” I am not restricting myself to only things such as learning, creativity, collaboration, etc. These I take for granted. There are valuable outcomes we should target in addition to these fundamental ones. I tried to define what I mean with the term “academic benefits” in Footnote 3. Namely, I use the term to refer to outcomes that could enhance the teacher’s or the student’s academic and professional development. For example, a publication in a scientific journal would definitely count. Academically it enhances research, creativity, knowledge, etc., and professionally it improves one’s C.V., opening opportunities for scholarships, funding, promotions, etc. These kinds of benefits are also benefits that could be sought and motivate the teaching/learning process. I pointed out that, unfortunately, PBL is not conducive to these kinds of benefits. Other methods, such as the one I implemented in my mathematics courses, seem to do much better. Thus I offer my experience as a case study of how an intentionally non-PBL approach to projects in teaching can provide concrete academic benefits, for both the teacher and the students.

7. Conclusion

PBL is a student-oriented teaching approach with limited academic benefits for the teacher or the students. In a college environment this could have detrimental effects as both teaching and research are important aspects of academic practice. Engaging in projects that would academically benefit the teacher and the students is an important motivating factor. PBL seems to ignore this crucial aspect of academic practice. Together with PBL’s other drawbacks discussed above, these convince me that more “traditional” practices seem to work just as well if not better, and so I see little reason for an across-the-board implementation of PBL in the college mathematics classroom.

PBL could be successful for certain college courses and some students. However, it seems to me that we can conclude that it is not optimal for all courses, all classrooms, and all students. Certainly, there are several objectives for a college mathematics course and teacher or student research is not the only objective. But, in college, teacher and student research is an important objective, at least for some courses, and instruction methods that encourage (not discourage) it should be promoted.

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