Teaching a single physics module through Problem Based Learning in a lecture-based curriculum

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We report on the design of an introductory thermal physics module taught through Problem Based Learning (PBL) within a lecture-based curriculum and discuss how some of the potential benefits of PBL, in particular, effective mixed-ability teaching and increased student motivation, can be realized within such a framework. We describe how the transition from lecture-based to PBL teaching has taken place and illustrate the development and implementation of our methodology with two problems from the module.

I. INTRODUCTION

Problem Based Learning (PBL) in small groups has attracted much interest since its inception at McMaster University. It has become a popular mode of delivery in medicine, nursing, and engineering, but far less so in physics. Only in the last decade or so has the teaching of physics in this way taken root.2,3

In the course of developing a module on thermal physics and in discussions with colleagues, we found that there often is a gap between traditional instructors and PBL proponents in terms of the language used and the educational concepts familiar to them. We have aimed to bridge this gap by presenting our experience in a format and a language that instructors unfamiliar with PBL and modern educational terminology will find easy to understand. In fact, we have found that designing a PBL module is in itself a form of problem based learning, and this paper is written in the same vein as the written assignments we expect our students to produce.

In this paper we describe the development, implementation, and impact of a single module on thermal physics. PBL enthusiasts and skeptics alike would claim that the introduction of a single module is hardly beneficial at best and confusing to the students at worst, that is, a substantial number of PBL-based modules need to be taught for this approach to be effective.1,4 Although this view is reasonable in theory, in practice, it may often be up to one or two people to introduce this new way of teaching on a pilot basis. Only after they can show that their aims have been met and have had sufficient experience to instruct their colleagues, is problem based learning likely to be implemented on a larger scale.

II. WHY PROBLEM BASED LEARNING IN PHYSICS?

We will first introduce PBL in its pure form, which has been characterized as “active, adult-oriented, problem-centered, student-centered, collaborative, integrated, interdisciplinary, utilizing small groups.” and rooted in real-life problems. Lectures and often formal exams are abandoned and learning centers around tackling problems. Our version of PBL is not integrated, because we have implemented PBL in a single module. It also is not truly interdisciplinary, and the problems are somewhat more well-defined and structured than in pure PBL. Barrows considered PBL to be a “genius for which there are many species and subspecies.”6 The variable factors in PBL are the design and format of the problem and the role of the teacher. Our methodology would be best described as a PBL variant called “problem-centered learning.” The problem is the main focus for learning, as the students acquire the appropriate principles and concepts to arrive at a solution while solving the problem. Information is easily accessible through literature and the internet, but a limited amount of data is given to the students. We choose this compromise to avoid too much time being spent on finding resources that we had found difficult to trace, or where we deemed it too difficult to extract information prior to mastering the vocabulary.

PBL was first introduced in medicine about three decades ago. Camp5 has suggested that the acceptance of PBL in medicine is due to the timeliness of its introduction (it was introduced at a time when many questioned the efficacy of traditional medical curricula), and the fact that it fits in well with current adult learning theory, educational philosophy, and psychological theories of learning. We argue that the time may be right for PBL to make an impact on the teaching of physics. The decreasing enrollment in science in many countries has led many physics educators to look at different ways of teaching physics, and the success of PBL in medicine and engineering, particularly in motivating students, makes PBL a strong candidate. Teaching and learning through PBL is characterized by mutual trust, respect and helpfulness, freedom of expression, acceptance of differences, and learners identifying with the goals of the learning experience, all tenets of adult education.8 In line with constructivist views, the learning process is based on prior knowledge and takes place in the context of the “real world.” PBL students seem to retain knowledge longer and are better equipped to transfer their skills to new situations.10

In contrast, university physics courses are usually content and instructor driven, and structured such that the students are taught all of the basic physics, mathematics, and laboratory skills in the first few years. Only in the final year(s) of the degree are students exposed to applications of the basic theory and exploratory projects. In the meantime little is done to encourage, let alone teach, our students to apply modeling skills and solve anything other than contrived end-of-chapter problems.

Moreover, the traditional methods of teaching physics are not well suited to mixed-ability teaching or developing group work skills. An enticing element of PBL is its potential for...
mixed-ability classes. If the problems are sufficiently complex so that students must work together and rely on each other to solve them, then students take on an active role in constructing knowledge and engaging in inquiry and problem-solving skills.11 The delegation of work in the groups ensures that students remain focused and motivated; weak students don’t trail behind and bright students remain challenged.

A common initial concern of traditionalists and teachers to the PBL method is the loss of subject matter that may occur. They fear that students might overlook vital facts and concepts or spend too much time on less important details. These fears stem from the notion that knowledge is the most important attribute when lecturing. Problem Based Learning prizes not only knowledge acquisition and application; the open-ended problems promote further exploration of the subject matter and provide students with problem-solving skills. Students are taught how to learn and take responsibility for their learning. Perhaps more important, it is true that the instructor covers more material in a lecture-based course; whether the students do, too, is debatable.

Problem Based Learning is not only beneficial to the student, it stimulates the instructor as well. All too often lecturing can be like a spectator sport; students can be unresponsive or not attend at all, one or two students may dominate the class, and little or no discussion of course material occurs outside of the lecture. In PBL, the role of the instructor as a facilitator and the focus on group and individual work can mitigate these problems. As a facilitator, the teacher’s role changes from “sage-on-the-stage” to “guide-by-the-side.”12 The latter role can prove to be satisfying for both parties. The responsibility shift gives students a basis for commitment to the subject and they enjoy owning their work. Due, no doubt, to the responsibility given to the students to make their teams “work,” we have experienced almost 100% attendance. The congenial tone allows for better communication between students and the facilitator, and a relationship of trust is nurtured which improves the working environment. Students who partake in PBL courses generally show higher satisfaction than non-PBL students.13

III. IMPLEMENTATION

A. Preliminaries

One of the authors (PvK) had taught an introductory thermal physics module by lectures for two years and decided to teach the module using PBL for the reasons discussed in Sec. II. He recruited three undergraduate students (CB, MK, EOL) for 8 weeks to work as a team on the development of the PBL problems. This approach helped us appreciate the potential pitfalls of group work and group assessment, ensured that the problems were looked at from many angles, and helped us anticipate the difficulties that students might encounter in solving the problems.

The module was taken by 17 students. Following the experience at McMaster, we divided the students into groups of four or five.13 The groups worked on well-defined open-ended real-life problems, which they were given without any prior instruction. In this sense our version of PBL is quite radical and distinguishes itself from, for example, context-rich written problems encountered in the Cooperative Group Problem Solving approach14 or the Socratic method embraced by Tutorials in Introductory Physics.15 In comparison to Physics by Inquiry,16 our implementation of PBL is entirely classroom based instead of laboratory based.

The entire thermal physics module consists of 75 h of student learning time, of which 40 are contact hours. We had intended to cover the material in about six PBL problems of approximately equal length. We put together a matrix containing all the subtopics and skills on one axis and the problem number on the other axis. We would recommend this exercise, even within the traditional lecturing system, to determine whether all of the aims and objectives are achievable.

The groups were allocated 4–6 contact hours per problem, plus roughly the same amount of time on an individual basis. The groups must be told this time limit in advance: because the problems are open-ended, they could spend an indefinite amount of time at them at the expense of other subjects.

The PBL sessions took place in a dedicated classroom. The room was equipped with movable and reasonably comfortable furniture to ensure learning would take place in a flexible and pleasant environment. Each of the groups had two introductory physics textbooks,17,18 a whiteboard, and one computer with internet access. The use of a dedicated room is probably not necessary, but we would recommend having computer facilities available in the classroom. Outside the classroom, they could use the library.

Two facilitators were present for the four groups. For such a small number of groups one facilitator would almost certainly suffice, although it is an advantage to have two facilitators present in the first PBL session, where everything is new to the students and they need assurances quickly. The overall demands of the PBL module on the staff were somewhat higher than that of a lecture-based module, partly due to the fact that we only learned how to devise PBL problems during the development of the module. In future years time will be saved by revising and reusing existing problems. The development of further modules would be less time consuming, and we estimate that the required preparation time for a second PBL module would be comparable to that of a lecture-based course.

B. Forming the groups

Many people involved in PBL put groups together at random or ensure that strong and weak students are represented in each group. We took a different approach and divided the class in two halves—top and bottom performers in previous physics and math exams—and divided each of these halves into two groups, while ensuring a reasonable gender balance in each group. This approach allowed us to address the problem of mixed ability teaching. The groups were left unchanged throughout the module. We found all groups to be functioning well, and a valuable group dynamic developed where all students played useful and changing roles. We believe that it would be ill advised to break up the groups and have the students create a new dynamic for every problem.

C. A first problem: How to convince the students?

It is important to start with a problem that serves to convince the students that PBL is worth their while. We thought it would be an opportunity lost, if not counterproductive, to give an overview lecture extolling the virtues of PBL. Because the module was taught to science education students who are studying to become secondary school teachers, we
were able to devise a real-life introductory problem for them, which essentially asked them to explain why PBL is worthwhile:

As part of your second year teaching practice you discover that it just seems impossible to make certain lessons interesting to your students. You decide that it’s time to try some other method, and think that perhaps things would be better if the students got actively involved in the teaching process.

Part 1. You read up on the subject and get particularly interested in the area of PBL in small groups. After a lot of humming and hawing you decide to give PBL a real go. How would you go about convincing your students that PBL can be a much more exciting way of learning science? What difficulties do you anticipate and how would you try to avoid these?

Part 2. You believe that assessing the groups is a potential minefield. For example, you don’t want one person to dominate the group (either by dominating the discussions or by doing all the work) nor do you want any hangers-on. What is your strategy to prevent this and what role can assessment play in this?

Assessment. Prepare a 10 minute talk in which you present your ideas.

This problem illustrates how the students are given responsibility for their own learning—in fact, the class and the facilitators together decided on a policy based on the four groups’ answers. The problem is open-ended, in that there is no correct answer. We also wish to stress the use of everyday language for example “hangers-on” instead of “students who are essentially inactive”.

It is probably significant that the module was taught to science education students. On the one hand, we might reasonably expect them to be more open to a different educational environment than physics students; on the other hand, many students might have enrolled with a greater interest in chemistry than in physics. Regardless of their initial attitude, we deem it crucial that the students believe from the very start that they can complete their first assignment—otherwise they may well reject PBL. This risk was even more relevant in our case, where just a single module was taught in this manner. Even with a positive attitude toward PBL, the groups need much encouragement for the first few assignments until they get used to the methodology.

D. Physics problems

What constitutes a good physics PBL problem? It is important to link the question to the students’ existing knowledge, whether acquired formally or not. The criterion of relevance, however, is only a necessary, not a sufficient condition. A question like “Explain why double glazing keeps the energy bill down” is not a good PBL problem. Although it may seem open-ended by virtue of its loose formulation, it is still an end-of-chapter question with a right or wrong answer. Instead, we formulated the following problem. Students were given part 2 only after submission of part 1, etc.

Part 1. Bob and Martha are physicists who live in a house that was built in the 1960s. The house has a central heating system and is generally in good condition, but there is no form of insulation in the house. On a cold winter’s day, the heating system breaks down suddenly. While they’re waiting for the plumbers to arrive, they monitor the temperature in the living room. What factors determine how quickly the temperature will decrease?

This problem is based in real life, and the students were able to come up with answers based on knowledge obtained outside a formal learning environment. In this problem, as in all other problems we developed, we deliberately got the students used to thinking about the parameters that determine heat loss before any calculation was requested. Experts solve problems by looking at the physics of the situation before jotting down any equations.

We give part 2 of the problem in two forms—one that we used this year, the other that we will use next year. When a new methodology is introduced, an evaluation often focuses on the successes and may mention only in passing some pitfalls encountered along the way. We deem it important to discuss in detail an imperfect example to illustrate the ongoing development of the PBL problems.

Part 2 (old). When the heating system gave up the ghost, Bob and Martha’s detached two-story brick house was a cozy 22°C, while the outside temperature was 5°C. They measure that after only an hour the temperature has dropped to 18°C. Bob is getting really worried about his beloved goldfish. On the one hand, he doesn’t want to leave Martha on her own in the house; on the other hand, he knows that once the temperature drops below 12°C, the goldfish will probably die. How long does he have before the situation becomes critical?

In this form, the question does not meet our own criteria; it is essentially an end-of-chapter problem set in context. When we were developing the problems, we had envisaged that this question would make the students think about the relationship between heat loss and temperature as a function of time. An approximate graphical solution would have sufficed, although we would have guided the students toward setting up a differential equation. We feared that without any of the data given, the question would prove too difficult. What happened instead is that all four groups not only discovered Newton’s law of cooling,

$$\frac{dT}{dt} = -\alpha(T - T_s),$$  \hspace{1cm} (1)

but also its solution,

$$\Delta T = \Delta T_0 e^{-\alpha t},$$  \hspace{1cm} (2)

where \( T \) is the temperature of the object, \( T_s \) the temperature of its surroundings, \( \Delta T = T - T_s \), \( \Delta T_0 \) the temperature difference at \( t = 0 \), and \( \alpha \) a constant. They then started plugging numbers into Eq. (2) without thinking about the assumption that underpins Newton’s law of cooling. This process is just what one would expect from an end-of-chapter problem, and just what we wanted to avoid.

This unexpected development—students using the solution to Newton’s law of cooling without bothering to find out the assumption that justifies its use—presented us with a problem that occurs often in PBL: the freedom given to the groups to solve problems in their own way may result in
them not exploring the intended topics or skills. In this specific case, we had to decide whether our original idea of guiding the groups to setting up a differential equation was so important that we would have to impose it on the groups. In addition, due to our poor formulation of Part 2, we had to undertake corrective action to ensure that the students learned some thermal physics and that their modeling skills were honed.

We got the students to realize that Newton’s law of cooling is not a fundamental law like Newton’s laws of motion, but an empirical relationship. We asked the groups to develop a model that would relate heat loss to the temperature drop in the house. The students could have modeled the heat loss from the house by considering any one of the mechanisms of convection, radiation, and conduction. Newton discovered his law in an experiment where he cooled down a piece of red hot iron through forced convection. Provided \( \Delta T \) is small, Eq. (1) can be derived for radiative heat loss analogous to the procedure given below which applies when conduction is assumed to be the main heat loss mechanism. As it turned out, all groups independently adopted the latter approach.

Thus the groups set off to find equations to link heat loss and change in temperature. It is hard to see how one could prevent the students from doing so, given that it is their first encounter with PBL, and probably the first time that such a strategy does not pay off. They all discovered the equation relating heat and temperature change,

\[
Q = mc \Delta T,
\]

and the equation for heat flow by conduction,

\[
\frac{dQ}{dt} = -\frac{kA}{d} \Delta T,
\]

where \( Q \) is the heat lost, \( m \) the mass, \( c \) the specific heat, \( k \) the thermal conductivity, \( A \) the surface area, and \( d \) the thickness. It is important that the groups are not allowed to just define the variables in the equations, notably the different quantities represented by \( \Delta T \) in Eqs. (2)–(4). They must also explain the physics contained in each equation and discuss, for example, what mass or area they are referring to. The groups then discussed the heat loss and temperature inside the house as a function of time.

At this juncture the separation of groups into different levels of ability paid dividends. Because the mathematically weaker groups found it difficult to obtain a numerical answer to Eq. (2), we concentrated on developing a strategy for solving this type of equation after informing them that it is possible to solve Eqs. (3) and (4) to yield Eq. (2). The stronger groups were encouraged to think about a mathematical manipulation that would link Eqs. (3) and (4). Students who are mathematically more advanced than ours could set up and solve the differential equation

\[
\frac{dQ}{dt} = -mc \frac{dT_{\text{house}}}{dt} = \frac{kA(T_{\text{house}} - T_{\text{outside}})}{d},
\]

which reduces to Eq. (1) with \( \alpha = kA/mcd \).

To avoid students unjustifiably using Newton’s law of cooling in the future, we have reformulated the question. We have retained the positives outlined above, but have left more to the students’ research skills:

Part 2 (new). With the heating system no longer functional, the temperature in the house is drop-

The students now have to estimate the indoor and outdoor temperature and the rate of heat loss, and look up the temperature below which goldfish will struggle. Although these determinations might seem like an unnecessary distraction from “the real physics,” such an easily obtained success often is an encouragement and motivation for the students to tackle the physics aspect of the problem. It also makes the use of Newton’s law of cooling a less obvious choice, and hence the groups will have to understand more of the physics that justifies the use of this law.

Part 3 of the problem introduces the concept of thermal transmittance and its relation to thermal conductivity:

Part 3. The plumbers arrive in time and get the heating system going in no time. With his goldfish swimming happily in his bowl, Bob and Martha now realize that this episode has given them a good if unwanted opportunity to see if insulating the house is economically viable. After estimating the surface area of their house they estimate its overall thermal transmittance. To see what kind of insulation is most useful, they consider two options: insulating the walls and roof with Styrofoam or replacing the windows with double-glazing. After a bit of research they collect some data that is tabulated below. They probably don’t have enough money in the bank to pursue both options at once. Through a friend they know that they can get either at roughly the same price. Their decision will therefore be based on how much they save on the heating bill. Which option should they go for?

This question illustrates that we occasionally preferred to provide the groups with some data when we anticipated that too much time would have to be devoted to information gathering. In this instance the parameters were not as readily available as we had expected, and when available, often in Imperial units or without any units. Depending on how much time is available and how important it is for the students to practice these skills, the values of the parameters could just as easily have been withheld.

We conclude the discussion of our PBL developments with a discussion of the last part of the problem:

Part 4. There is a grandfather clock in the living room of the house. After a couple of weeks they notice that the clock is running slow. Bob and Martha suspect this is because the room is hotter than before they insulated the house. Carry out calculations to check if this is a likely cause. Could the pendulum be used as a thermometer?

This question barely qualifies as a PBL problem and is much like an end-of-chapter problem. However, there is an element of flexibility: do the groups assume that all heat previously lost is retained, or do they assume that Bob and Martha will have the house hotter by a degree or two? (It is interesting to note that, even though the problem explicitly stated that the aim was not to raise the temperature in the
house but to use less fuel, no group suggested that the temperature would remain constant as their answer.) Also, this question really brought home the notion of what thermometry is, and all groups tied the problem to the physics of the pendulum they had learned in a previous mechanics course.

E. Guiding the students

The role of the instructor as facilitator is discussed extensively in almost every book on PBL, and we will not discuss it in depth. The instructor plays a crucial role in determining the success or failure of PBL. The facilitator guides students in the right direction without giving too much away and not frustrating them by withholding vital information. There is some merit in letting students go down a blind alley for awhile, because one sometimes learns most from one’s mistakes. However, the facilitator must build up a relationship with the students based on trust. We experienced far less problems with our roles in practice than we had anticipated.

It is essential that all students contribute, and believe that they contribute, to tackling the problems. We strongly believe that the groups’ involvement through part 2 of the introductory problem was beneficial in this regard. With three of the four groups, this involvement was never an issue; only in one group did two people believe that they were overshadowed by the other two. Sitting down with such a group and getting them to discuss these issues openly can be a frightening prospect for student and facilitator alike, but the outcome was very positive in this case. The ability to discuss such issues is a valuable team working skill to acquire.

In some PBL implementations students are formally assigned different roles within a group, with students taking on a new role for each problem. To give the groups more autonomy, we did not encourage this approach, although we would not have discouraged it. We found that the group members tended to change roles continuously without any formal assignment of duties.

F. Assessment

As in any teaching methodology, it is crucial that the assessment matches the learning outcomes. Among the main learning outcomes of a PBL module we list the ability to communicate results, the acquisition of in-depth knowledge that the students can apply to problems not previously encountered (“operational” or “conditional” knowledge), and the acquisition of the means to learn physics; the emphasis is placed on the process of obtaining a reasonable answer, not on the answer itself.

Many PBL proponents maintain that students should only be assessed within a PBL environment. However, if we are to convince our colleagues that PBL is a viable methodology, it is essential to demonstrate that students can perform in a standard exam setting. Thus the final grade consisted of 50% continuous assessment (5 physics problems, of which the house insulation problem discussed in this paper was the first) and 50% examination. The continuous assessment focused mainly on rewarding the process (and not the answers obtained), while the exam was designed to test the students’ operational knowledge.

The continuous assessment consisted of a mix of reports and class presentations. The facilitators must insist that the report details where the information was obtained, how it was evaluated, used, or discarded, and that all the failed attempts at obtaining an answer are discussed. In a sense the reports resembled a lab book more than an answer sheet. Following the presentations or the grading of their reports, the students were given a brief overview of all the items that we had wanted the students to cover.

Assessing a group process is intrinsically a subjective exercise, and hence it is crucial that the groups receive feedback promptly. We did not let the groups grade their own work, but the facilitators were open to adjusting the grades somewhat based on feedback sessions with the groups. Discussion of the grades awarded is essential in reducing and making acceptable the element of subjectivity that accompanies grading the learning process.

We insisted that we would give the same grade to all members of the group to enforce proper functioning groups. An open discussion on this matter formed a natural part of the introductory problem discussed in Sec. III C. Once teamwork was accepted as a valuable learning outcome, the students agreed on this measure as a logical implementation.

As an example of difficulties with assessing groups, we discuss the following example. Group A, mathematically the most gifted, found it very difficult to cope with all the factors they had suggested in part 1; their initial model was so complicated that it would challenge most final year students. Group A’s learning process was mostly about making sensible simplifications; they acquitted themselves well and received a high grade. In contrast, Group C, mathematically the weakest, eliminated most of the minor effects straight away. Initially they were almost embarrassed to discuss their model, thinking it too simplistic, whereas in reality it was pitched exactly at the right level of difficulty. However, they still struggled with the mathematics, which therefore constituted the most important learning process for them. Their grade was based on their ability to identify and deal with their difficulties, and they were not penalized for struggling to manipulate a relatively simple equation.

The students performed remarkably better in the exam than students in previous years where lateral thinking was required to solve the exam problem, and marginally better in standard problems. For example, in one of the exam questions the students were asked a question on soup cooling in a pot. The last sub-question asked the students:

Somebody suggests that you can estimate the heat flow through the walls of the pot as follows. You measure the surface area $A$ and the thickness $L$ of the walls, and knowing the thermal conductivity of aluminum $k$ you can work out the heat flow $H$ using

$$H = \frac{kA(T_{\text{soup}} - T_{\text{kitchen}})}{L}. \tag{6}$$

Do you think this is a valid method? Explain your answer briefly.

Under the pressure of an exam, less than a quarter of the students did not show any evidence of an ability to apply the knowledge and understanding they gained from the PBL module to this particular question. More than half the students commented on the incorrect use of the temperature of the kitchen as the “outside” temperature, using arguments such as “because you would get burnt when you touch the pot” or “like when we did the insulation problem, a layer of air builds up near the pot.” Such answers clearly demonstrate an operational understanding of Newton’s law of cooling. In previous exams, similarly probing questions would be an-
answered satisfactorily by a far smaller fraction of students. For example, in a previous year students were given the following question:

A cylindrical vessel, with its axis vertical, contains 0.100 mol of an ideal gas initially at thermodynamic equilibrium with its surroundings which is at standard pressure and at 20.0°C. This cylinder is closed off by a piston with a mass of 800 g which can move freely in the direction of the cylinder axis. What are the temperature, pressure and volume inside the vessel? Explain your answer briefly.

Only one of the 17 students taking the module that year recognized that the pressure of the gas would exceed standard pressure due to the weight of the piston—despite the fact that this effect was pointed out to them in the lectures.

IV. STUDENT FEEDBACK AND CONCLUSION

None of the 17 students gave negative feedback on the PBL methodology. Almost all of them found thermal physics significantly more interesting and relevant: on a scale from 1 (very uninteresting and irrelevant) to 5 (highly interesting and relevant), surveys showed an increase from 3.0 and 2.7 to 3.9 and 4.1, respectively. Student attendance rose to almost 100%, and the students performed more strongly in the exams than before: from 49±13 out of 100, with 4 people failing, to 58±15 out of 100 with no people failing. The only common complaint was the amount of time taken up by the module. On probing the students, it emerged that this complaint stemmed in part from inexperience with time management, and partly from front loading the time spent on the module during the semester (in contrast to the week before the exam). We stress that the amount of time formally allocated to the module was unchanged from previous years.

Most encouragingly, in the next semester there was evidence that the students took more responsibility for their learning and were able to apply the skills acquired in subsequent lectures and laboratories. To give an example, in lectures the following semester many of the students asked for learning outcomes. While discussing end-of-chapter problems in tutorials, we observed that about half of the students tackled these by thinking about the physics before looking for a suitable formula—a considerable improvement over the one or two students who would do so without prior exposure to PBL. In laboratories, they wanted to see the experiments in the context of science, and their science education degree.

Can we conclude that the introduction of PBL has been a success? In many ways, certainly, but we must make a few provisos. First, we had no control group (because a group of 17 students is too small to divide into a PBL and a non-PBL group). It is possible that all the good practice that accompanied the development of PBL (such as openness on learning outcomes, matching assessment, prompt feedback), was more important than the PBL methodology itself. However, it is difficult to imagine that the same enthusiasm would be generated among students and staff with a traditional lecture module.

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