Pertanika J. Soc. Sci. & Hum. 24 (S): 33 – 42 (2016)

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Challenges of Transforming Introductory Science Classes to Learner-Centered Teaching

Chantima Pathamathamakul

King Mongkut's University of Technology Thonburi, Learning Institute, 126 Pracha-Uthit rd., Bangmod, Thung krue, Bangkok, Thailand

ABSTRACT

In introductory level courses, the learning environment of the large class makes it difficult for teachers to implement methods that facilitate and engage students through interactive pedagogies. In addition, assessment methods tend to align with the mainstream teacher-centred approach. This paper presents an analysis of qualitative data from in-depth interviews with science faculty members at King Mongkut's University of Technology Thonburi (KMUTT), who provided insightful perspectives on teaching improvements. The reflections of these teachers indicated the constraints of department, faculty and course level that challenged the transformation of science education at the university. The discussion proposed that professional learning development was highly required for any initiatives towards change in teaching and assessment practices that would result in meaningful learning by students.

Keywords: Large class, learner-centred teaching, introductory college science courses

INTRODUCTION

In introductory level courses, the learning environment of the large class makes it difficult for teachers to implement methods that facilitate and engage students in the learning process. Even though many higher education institutes have been trying to initiate and promote student learning through interactive pedagogies, centring classes around dialogue and discussions still encounters challenges (Nicol & Boyle, 2003). Teaching non-science major freshman students for whom learning science is unlikely to be the ultimate learning goal seems to deepen such difficulty (Henderson & Dancy, 2007).

Over the past decades, reform in science education has continued to find better answers in teaching that enables

ARTICLE INFO

Article history:
Received: 29 September 2015
Accepted: 4 January 2016

E-mail address:
chantima.pat@kmutt.ac.th (Chantima Pathamathamakul)

ISSN: 0128-7702

student to solve contemporary problems with cognitive flexibility, adaptability and creativity rather than by using strict information and rules-based logic (Udovic, Morris, Dickman, Postlethwait, & Wetherwax, 2002). However, most introductory science courses tend to rely on the traditional, old-fashioned approach in delivering the authoritarian presentation of the material. Unfortunately, the learning process that is normally designed with such organised ways of didactic teaching does not effectively foster conceptual understanding or scientific reasoning. It is also unlikely to foster a scientific attitude among students and may even develop students' dislike for science (Shamsudin, Abdullah, & Yaamat, 2013). This concerns not only the quality of cognitive achievement of students but also the development of a positive attitude towards the subject knowledge.

Research Purpose

This paper aimed to identify the current practice of the teaching strategies in introductory college science courses at King Mongkut's University of Technology Thonburi (KMUTT) and to analyse the challenges to transforming instruction to align with outcome-based education.

METHODOLOGY

This research took the format of qualitative research. Data collection was conducted during the year 2014 using the in-depth interview method using the semi-structured questionnaire. The 18 interviewees were purposively selected based on their experience in teaching introductory science courses for non-science major students. Key informants were teachers of the departments of Physics, Mathematics and Chemistry at the Faculty of Science, KMUTT. The sampling did not include teachers from the department of Microbiology because of the difference in the course structure, the smaller class size of lectures and the nature of the subject, which largely requires students to participate in laboratory activities. The data were coded according to the objective of the study, using both data-driven and the inductive reasoning in analysis.

LITERATURE REVIEW

Most large science class teaching reconstructs the course design by following the science education reform pathway. According to Hobson (2001), three significant elements of science education reform include: introducing "conceptual changes" by directly confronting student misconceptions through concrete experiences; integrating "science as inquiry" so that the students view science as a way of knowing; and introducing science in context to make a clear linkage between science and society. Of course, all the elements are based on quality teaching. Currently, there have been initiatives that align with the teaching reconstruction and yield prospective improvements. For example, a three-term, lab-based introductory sequence for non-science majors of the Workshop Biology project (Udovic, Morris, Dickman, Postlethwait, & Wetherwax, 2002), peer instruction (Crouch & Mazur, 2001; Mazur, 2009), and SCALE-UP project (Beichner *et al.*, 2007).

Among those practices that refocus the concept of learning in science, the main components are active participation in lectures, where students transform into active learners instead of being passive recipients. The continuum of being an active learner could range from simple strategies (think-pair-share, short write, minute paper) to more complex strategies including concept mapping, in-class discussions, peer instruction, role playing and inquiry or problem-based learning. However, among the increasing effort to make a large lecture hall of introductory science classes more interactive, there is a widespread norm that science is delivered as a body of knowledge in a lecture-based format. Such persistence exists even though many research-based instructions find that giving lectures is helpful only for short-term and surface learning and only when the teaching goal is to emphasise on mastery of content knowledge, and not the development of scientific skills (Ebert-May, Brewer, & Allred, 1997).

However, successful lectures are possible with all the essential qualities of good university teaching. Nevertheless, the quality lecture that achieves student learning might work only under certain conditions. Lectures might be considered the best teaching method for learning content and new skills unless the teachers possess a strong working knowledge of scientific content and pedagogy. According to Bain (2004), lectures from highly effective teachers have features of natural critical learning that stimulate students to engage the question critically and generate argument. The effective lecture enables student learning by providing opportunities for interaction and student participation. Also, the well-structured lecture could provide the students with feedback about their learning. For example, even chalk and talk could be considered as a mathematics specific genre of teaching that involves interactive modelling of the solution development process (Wilson & Maclaren, 2013). Artemeva and Fox (2011) described chalk talk as a "situated disciplinary practice" and contended that it can be pedagogically interactive, meaningful and engaging as a way to disciplinary doing and being.

However, based upon student learning, no matter how good the teacher, typical students in a traditionally taught course tend to learn by memorising facts and recipes for problem solving; they do not gain a true understanding (Wieman, Perkins, & Gilbert, 2010). In addition to that, for non-science major students (e.g. engineering students), learning science is unlikely to be their ultimate learning goal and this might result in their engagement. This is especially challenging in large enrollment classes where the teachers are exposed to more diversity of student learning styles and student background.

In response to such a learning environment, teachers require a variety of teaching techniques to elicit student engagement. However, in some courses, building student attitudes and beliefs was possible only after the courses were specially designed for this purpose and the results have proved to be inconsistent in some cases. For example, little change in students' positive incoming attitudes occurred in reformed classroom practices and in classes that were successful at improving student conceptual learning of Physics (Redish & Steinberg, 1999; Handelsman *et al.*, 2004).

RESULTS AND DISCUSSION

The context of teaching introductory science courses at KMUTT as mentioned by these key informants concerns the effective management of a large class teaching. The common experiences involved the enrolment, which could reach hundreds of students; even the smaller sessions varied between 80 and 120 students. Some of the classes served the students of one department, while others had students from two or more departments/faculties (e.g. a mix of students from Civil Engineering and Electrical Engineering or a mix of Civil Engineering students and Industrial Education and Technology students). The mix of student populations was caused by the class schedule management under the registration system of the university.

Some courses divided the large lecture classroom into smaller ones and had several faculty members teaching those parallel sessions. In this paper, the faculty members are referred as a teaching team. The team shared teaching responsibilities and predetermined the teaching plans in order to keep the scope of the subject content manageable and teachable in the given time.

According to the interview, all the teachers spent over 80% of their class time lecturing the subject content. The lecture notes were simply presented using PowerPoint slides projected from a personal computer (PC) or visualiser. More explanations were written to show the thinking process or detail in steps (algorithm). High technology-driven pedagogy was not what the teachers depend on.

The repertoire of content were done by showing examples of objects, simulating and demonstrating experiments. Only a few of the teachers conducted live demonstrations in class. In cases of Physics and Chemistry, most of the informants would present YouTube video demonstrations followed by pair or small-group discussions. Asking the large numbers of students to perform conceptual understanding was only done from time to time but a variety of methods was not used.

Here are the selected responses of the 18 teachers.

My class was lecture-based. My teaching style was simply chalk-and- talk. The only tool used was visualizer. The students were supposed to have class materials in hands and making a note only if they would like to. (Physics)

While lecturing, using visualizer to show how probing Mathematics solutions by steps was hugely more practical. Writing the calculation in paper and visualize it might sound very traditional but it better helped the students to understand its meaning. PowerPoint was not as useful as visualizer in my case. (Mathematics)

My teaching approach was certainly deductive. I usually give lecture to make sure that the students would have a solid understanding of concepts. The given examples were provided to help illustrate the phenomenon. (Mathematics)

My class was lecture-based, demonstration was done from time to time. Examples and case studies were occasionally used to explain the rigid content. (Physics)

Teaching chemistry at an introductory level, for me, was obviously lecture-based, the chemical demonstration kits were sometimes used. There were small-group discussions once in a while. (Chemistry)

Demonstration was used from time to time to give a picture of concepts of Chemistry. (Chemistry)

The objects used in demonstration were simply small and ponderable. (Mathematics)

I used pair discussion-let the students who passed quizzes explain their understanding to their peers. This worked quite well. (Chemistry)

I showed YouTube video, let students discussed in groups and randomly asked students to answer questions. (Physics)

Questions were raised to check whether the students had misconceptions. The voluntary students just handed-up and answered. Sometimes they were randomly called to probe solutions in front of the class. (Chemistry)

In spite of lecture-based teaching, some indicated effort to mix other teaching strategies to help the student understanding. One of the Physics teachers set up the tutorial session apart from the lecture class time (lecture for two hours, tutorial for an hour). The small groups of 8-10 students would practise solving problems with the guidance of the graduate teaching assistants who were available for help. Another tutorial session of the mathematics class was also run but only the teacher himself was in charge of guiding student thinking for the whole class.

Two of the mathematics teachers mentioned the supplementary use of technology to encourage student self-directed learning. The assistive technology included Sketch Pad, a programme that helped students review content and practise solving problems and Peer Wise, a Learning Management System that provides different levels of task difficulty.

Assigning hands-on learning experience was also found in introductory science courses. One of the mathematics teachers mentioned an attempt to include in-class activities based on Plearn (play and learn) to encourage hands-on experience by allowing the students to work in teams and self-construct their knowledge through the object-to-think-with. One of the Physics and Chemistry teachers assigned hands-on group projects. However, due to the limit of available class sessions of each individual instructor among the teaching team, the student project was flexibly managed outside class time.

I provided tutorial sessions in which the students practise solving Physics problems intensively. The small groups of 8-10 students would practise solving problems with the guidance of the graduate teaching assistants. (Physics)

I usually spent most of the class time lecturing. I tried to conduct group activities to involve students practice in abstract thinking. I applied the concept of Plearn based learning; the students play, have fun and learn through hands-on activities. Sometimes I set up group discussion (up to 10 students), gave them guidelines and had them mark each other's assignment. This way, they would learn that solving mathematics problems sometimes require no rigid single method. (Mathematics)

My lecture was quite content-laden. Besides lecturing, I tried to use Sketch Pad to support the students' learning outside classroom. This would particularly help the students review the course content and practise solving problems according to their pace of learning at the different difficulty levels. (Mathematics)

I assigned the different level of task difficulty in Peer Wise - the Learning Management System of Oakland University. (Mathematics)

Besides lecture time, I presented video demonstration from YouTube, which provided tons of resourceful reference in Physics from distinguished university. Both lecture and demonstration focused on the conceptual knowledge. Showing small objects on visualizer was basically used while giving a talk in certain topics. (Physics)

Only one project was assigned. The purpose of given projects were primarily to train students the teamwork skills. The ability to link the subject knowledge with real-life application was also the main objective. The students must do a piece of work, written report and presentation video. (Physics)

According to their teaching experience, similar reasons were found as factors that promoted the current teaching practice of direct instruction. The factors included the scope of the subject content, the teaching team (in certain courses) and student prior knowledge. These factors formed the teaching environment that maintained traditional lecture-based pedagogies rather than active learning approaches.

Being the introductory and prerequisite subjects for non-science major students, the scope of the content was designated in accordance with the requirements of the specific academic discipline it served. The teachers were unauthorised to design the subject content but had to follow the rule-based scope of the prerequisites. This is similar to any professional courses in which 'must-know' content can predominate the subject area. Consequently, the introductory science courses tended to focus on the breadth of the content and student learning was widely emphasised at the level of understanding. In order to cover the breadth of the curriculum under the time constraint, the teachers felt that involving the students in activities or discussions in class was a secondary priority to giving a direct lecture. Even though the class activities were ideally good for deeper learning in an authentic way, they were possible only if there was time left over after the lecture proper.

The content seemed overstuffed that breaking down the lecture meant leaving some of the content under the students' responsibility. (Physics)

The topics of subject contents were defined under the requirement of the (engineering or other programs) curriculum and our teaching needed to cover all the basic concepts. (Mathematics)

Pair discussion was used only when there were times left enough. (Chemistry)

I would rather demonstrate live experiment if I had a smaller class and more class time. It was no use to demonstrate without the student participation. (Physics)

The fact that every learner had individual learning styles multiplied the challenge for the teachers when teaching large numbers of students from different programmes. The diversity of these populations was a deep concern among the teachers, who could not be sure of each student's prior knowledge and the teachers indicated this concern as one of the reasons why the direct lecture still dominated most of class time. Even though some of the topic areas in the introductory science courses had already been taught in high school, too many students were not adequately prepared to further their learning in these subjects at the university level. From the teachers' perspective, even though the direct lecture ought to be questioned on its effectiveness, providing step-by-step transmission of knowledge is still a better response to the needs of students with such difficulties.

The prior knowledge of the students whose backgrounds were from vocational education was found insufficient in most cases. The classes that mixed the students from faculties also meant that the wide range of student learning difficulty was more likely to occur. While some students thought the teacher had not taught them anything new, others were struggling to understand those same lessons. (Chemistry)

Even though giving lecture might not sound appealing, it suited the learning situations where wide learning gaps among the students existed. The students with poor or lower knowledge background slowly got information and typically did not respond to the questions and discussions. I tried to give lecture at a moderate pace so that these students were not left behind. However, as I tried to support the needs of at-risk students, the outperform students might feel unnecessary to attend the classes. (Mathematics)

It was hard for many students to participate in classroom discussions. Only a few of more advanced students were likely to raise their hands to answer questions. (Chemistry)

Team teaching mattered because it concerned the justification issue. Individual teachers assumed the responsibility that their students were fairly well-prepared for the exam. Accordingly, teaching in the structured and organised ways of the didactic approach better ensured that all/most of the subject content tested in the exam would be covered in class. The standardisation particularly mattered because the assessment of lessons still emphasised on the measurement of cognitive achievement. Moreover, as the institution and faculty imposed formal examination conditions, each session was subjected to use the same exam as well as the same marking and grading criteria to make sure that the necessary rule-based commitment was fairly adhered to across the team.

I needed to ensure that the students were adequately prepared with basic knowledge once they finished my sessions and transfer their learning to the next topics taught by other teachers. (Physics)

When teaching as a team, each instructor had teaching commitments which mostly concerned the coverage of subject content to be tested. (Mathematics)

What we taught must align with what the students were going to be measured by test. (Chemistry)

As the teaching team, we shared the teaching topics and had to manage the individual class time according to our standard setting. (Mathematics)

Even though the subject was very much content laden, each instructor needed to cover it within his/her session so that the students would not miss what they were going to find in the exam. (Chemistry)

CONCLUSION AND IMPLICATIONS

The current teaching practices of these faculty members reflected that student learning in introductory science courses is emphasised in the breadth of the content. The dominant teaching practice found was lecture-based instruction. The teachers' perspective indicated the pattern of beliefs that included the scope of subject content, team teaching and student prior knowledge, all of which fostered the existence of the teacher-centred didactic lecture. To criticise this persistence, Wieman, Perkins and Gilbert (2010) pointed out that one of the major problems in shifting to learner-centred teaching was the existing norms that were already established, limiting how science could be taught and what it meant to learn science. In this case, the pattern of beliefs among the teachers could arguably be considered as so-called norms. The teaching environment was claimed as the condition that fostered lecture-based pedagogies rather than active learning approaches. In other words, such contexts strengthened the teachers' belief and hindered their efforts to transform student learning experience.

However, the weak points of lecturing should not be taken for granted. Enabling the students to develop higher order thinking during lectures in class is possible. According to Bain (2004), lectures did not always promote ineffective student learning. Lectures could have features of natural critical learning which stimulated student thinking e.g. to question critically and generate argument. However, such effective lecturing required a certain quality of instructional strategy and was possible when lecturing did not focus on transmitting content knowledge to serve exam-orientated assessment. In order to transform this habit of mind of the teachers, teaching development at not only the individual level but also the institutional level must be addressed.

As the institution and faculty imposed the rules and standards that faculty members were to follow, the change initiatives towards teaching improvement must involve support from the institutional and departmental levels. For example, the redesign of the scope of content and the revision of formal examination conditions, marking and grading criteria must all be revisited. For the individual teacher, each should be able to customise classroom management to facilitate the expected learning outcomes.

Teachers are experts of subject content but academic expertise does not ensure successful pedagogy. To come up with productive pedagogy, teachers should possess qualified teaching skills aligned with a new paradigm of assessment. The supportive mechanism to foster such faculty development is crucial in creating a culture that encourages a growth mindset among teachers as adult learners.

Good teaching is not only about cognitive achievement; it also requires a positive attitude and inspiring learning experiences. In large science courses, the high enrolment of non-science majors means teachers must handle a diverse student population with different prior knowledge. It is even more challenging to create meaningful learning for students for whom learning science is unlikely to be the ultimate learning goal. Introductory science courses which are usually designed with a rigid scope of content and involve the measurement of cognitive achievement can easily distract from student engagement. This leads to basic questions about expected learning outcomes. Teachers must design course working backwards from expected outcomes in order to orientate themselves and students to the focus of each lesson as well as the entire module. Besides the cognitive dimension of outcome, according to Isaacs (2001), the major focus should not ignore the affective domain. How students perceive and give value to a subject can strongly impact their approaches to learning for both application in their chosen field as well as in everyday life.

ACKNOWLEDGEMENT

The author would like to thank the informants for sharing their experiences and insights.

REFERENCES

Artemeva, N., & Fox, J. (2011). The writings on the board: The global and the local in teaching undergraduate mathematics through chalk talk. *Written Communication, 28*(4), 345–379.

Bain, K. (2004). Effective classroom teaching. In L. Hunt, & D. Chalmers (Eds.), *University teaching in focus: A learning-centred approach* (pp. 106–107). London: Routledge.

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J., Deardorff, D., Allain, R., & Risley, J. S. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project. *Research-based reform of university physics, 1*(1), 2–39.

Crouch, C. H., & M. E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics, 69*(9), 970–977.

Ebert-May, D., Brewer, C., & Allred, S. (1997). Innovation in large lectures-Teaching for active learning. *Bioscience, 47*(9), 601–607.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., C. A., D. R., & Wood, W. B. (2004). Scientific teaching. *Science, 304*, 521–522.

Henderson, C., & Dancy, M. H. (2007). Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics. *Physical Review Special Topics-Physics Education Research, 3*(2), 020102-1-020102-14.

Hobson, A. (2001). Teaching relevant science for science literacy. *Journal of College Science Teaching, 30*, 238–243.

Isaacs, G. (2001). *Assessment for learning.* Queensland, Australia: Teaching and Educational Development Institute, The University of Queensland.

Mazur, E. (2009). Farewell, lecture? *Science, 323*, 50–51.

Nicol, D., & Boyle, J. (2003). Peer instruction versus class-wide discussion in large classes: A comparison of two interaction methods in the wired classroom. *Studies in Higher Education, 28*(4), 457–473.

Redish, E. F., & Steinberg, R. N. (1999). Teaching physics: Figuring out what works. *Physics Today, 52*, 24–31.

Shamsudin, N. M., Abdullah, N., & Yaamat, N. (2013). Strategies of teaching science using an inquiry based science education (IBSE) by novice chemistry teachers. *Procedia-Social and Behavioral Sciences, 90*, 583–592.

Udovic, D., Morris, D., Dickman, A., Postlethwait, J., & Wetherwax, P. (2002). Workshop biology: Demonstrating the effectiveness of active learning in an introductory biology course. *Bioscience, 52*(3), 272–281.

Wieman, C., Perkins, K., & Gilbert, S. (2010). Transforming science education at large research universities: A case study in progress. *Change, 42*(2), 7–14.

Wilson, D. I., & Maclaren, P. (2013). From chalk talk to tablet talk: Pedagogies for control engineering. In *10th IFAC Symposium Advances in Control Education*, pp.144–149.