EDITORIAL

Educating Mechanical Engineering Students in the Art of Noise Control

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Noise control is a key aspect of the discipline of mechanical engineering, since it is associated with a safe workplace and an acceptable environment for communities in the vicinity of industrial facilities. Since mechanical engineers are almost always found in industrial facilities, it makes sense that they would have developed some appreciation and knowledge of noise control during their undergraduate education.

With any noise control project, it is important that we assess whether we have achieved the best solution in the most efficient way and, in some cases, whether existing approaches can be improved by introducing new technology. The same thinking applies to the education of undergraduate students. Students are changing rapidly in the way that they learn and what they expect from an educator. In addition, technologies for enhancing student learning are improving rapidly.

So it is time that new and more effective student teaching and learning methodologies were implemented on a broad scale in universities. The purpose of this editorial is to outline these new approaches and to suggest ways in which they can be implemented in the noise control engineering discipline, as well as what is required of institutions if such approaches are to be successfull.

The aim of any undergraduate mechanical engineering program is to educate students in the fundamental aspects of the discipline, while at the same time developing their problem-solving skills so that on graduation, they can use their knowledge to the benefit of an employer. Acoustics and noise control is one of the disciplines in mechanical engineering where the knowledge and experience that students acquire during a well-structured undergraduate course can be immediately applied to many problems they may encounter during their employment. In fact, this problem-solving skill is one that students expect to develop as a result of undertaking an engineering program.

To enable them to find optimal solutions to noise control problems, it is vitally important that students have a good fundamental understanding of the physical principles underlying the subject as well as a good understanding of how these principles are be applied in practice. Ideally, they should also have access to affordable software and be confident in their ability to interpret and apply the results of any computer-based modeling that they may undertake. Students must fully understand any ethical issues that could arise, such as an obligation to ensure that their actions do not contribute to any negative impact on the health and welfare of any communities.

There are many undergraduate programs (including mechanical engineering programs) throughout the world that include acoustics and noise control as one of the subdisciplines in which students are educated, either via core courses or via one or more elective courses. Typical courses include lectures, in-class demonstrations, in-class problem solving (in some courses), homework assignments and laboratory classes. When designing a new course, it is important that instructors outline in detail (for their own benefit) exactly what is hoped to be achieved by each element and then how the element can be best structured to achieve its aims.

With regard to noise control courses that may be part of a mechanical engineering program, some of the important questions we should be asking when presenting a course include:

- How do we ensure that our mechanical engineering graduates develop the understanding and knowledge required to tackle noise control problems they encounter after graduation?
- How do we equip students with the ability to continue to learn with no instructor after graduation?

Exploring answers to these questions inevitably leads to more questions, including:

- What is wrong, if anything, with the traditional teaching methods that include 50-minute lectures, a few lab classes and a few tutorials?
- Can we improve student-learning outcomes by changing the traditional approach and by using technology, flipped classrooms, active learning and blended learning?
- Can we do everything online?"

I'll begin with the last question. The answer to this is emphatically No! It is well known that students learn better when they engage with an instructor and fellow students than they do by looking at a computer screen. Students also need to develop their technical reading skills, including equations, which is why a textbook is an essential part of any course in mechanical engineering. We may well ask if online delivery has any place in the education of our students. The answer is emphatically Yes! To explain why, it is first necessary to explain the concepts of a flipped classroom, blended learning and active learning, because these labels for new approaches to student learning are widely used in the literature.

A *flipped classroom* is one in which the lecture material is delivered online via a video presentation and/or by required reading of part of a textbook. Classroom time may begin with a short presentation from the lecturer on one or two difficult concepts, and then students can be given problems to work on with the lecturer and tutors (for larger classes) circulating to answer questions and to ensure that any misconceptions held by students are addressed.

Active learning is the process by which students learn through doing rather than by listening. So they are given problems that they first attempt to solve by themselves and then engage in a peer-group discussion. They are also given laboratory classes that require some initiative on their part rather than being required to follow a step-by-step procedure.

Blended learning is really a combination of active learning and the flipped classroom. It means that students learn best when the material is presented in a combination of different ways, so that each mode of instruction blends or interacts seamlessly with all other modes.

Returning to our earlier questions, yes, there is plenty wrong with the traditional university teaching method involving the 50-minute lecture. This method is not focused on student learning; rather, it is focused on teaching. It does little toward instilling lifetime learning skills in students and does even less to ensure that students understand and retain concepts and material that have been presented. And yes, we can improve student-learning outcomes by taking a different approach to learning by implementing such concepts as active learning, blended learning and the flipped classroom.

So how do we implement these new concepts in an engineering noise control class? Before learning noise control concepts, it is necessary for students to learn fundamentals of acoustics, and if engineering acoustics or noise control is a later elective in an engineering program, it is probably best to assume that any acoustics concepts to which students may have been exposed in a freshman physics class have long since been forgotten by most of them.

So the first classroom experience may go something like this: the lecturer explains the blended learning approach that will be taken, what the expectations are of students in terms of the level of engagement required, what students may expect of the lecturer in terms of in-class consultations and out-of-class consultations and how the students will be assessed.

This would be followed by an explanation of the course outline, including reasons for the existence of each topic. By this time, students' attention may be waning so an in-class demonstration using some physical apparatus to illustrate an acoustics concept, which could be as simple as presenting a single tone using a loudspeaker and asking students to vote on what frequency it is. This might be followed by a short five-minute lecture on one or two fundamental concepts, after which students could be given a simple exercise to do that they could work on alone to begin with and then work together in groups with the lecturer circulating to hear what is being discussed and to answer questions and identify misconceptions. One group could then be selected to present the material to the class.

Later lectures would require students to review preparatory material before attending the lecture, which could be an online video presentation or required reading from a textbook. Narrated PowerPoint slides for the online material are not ideal, but many lecturers use them. At least they allow students to pause them to think about the material just presented before moving on, and they allow replay of the material in case the student didn't get it the first time (quite common).

However, narrated slides have been shown to be less engaging than online presentations, where the lecturer is using a whiteboard to develop the material as it is being presented. However, this requires considerably more effort by the lecturer and is currently not widely used.

In either case, it is important that students are instructed in their very first lecture to take notes when viewing online presentations or reading the textbook. The lecture may begin with 10 minutes of explaining some of the more difficult concepts in the online material. This may be followed by an interesting hardware demonstration of an acoustics concept, which could be followed by one or two problems that students can work on alone for 10 minutes and then work together collaboratively in groups. Each group could be required to hand in a single assignment or each student could be required to do so. These could be graded by peers toward the end of the class session and count as a small proportion of the overall assessment. (It is important for classroom assessment to count toward the final grade for students, because it encourages them to attend class, which is an important component of the learning process.)

When discussing ethics concepts, the hardware demonstration of an acoustics concept could be replaced with a short video on an engineering ethics example (quite a few of these are commercially available), and this could be followed by an in-class discussion of various aspects of the video, including who acted unethically and why, as well as whether they could act ethically and keep their job and what they could do to ensure that they did not breach the engineering code example video of ethical behavior.

Between lectures, students would be given online course material in the form of a video presentation and some reading from a textbook. They would be required to answer a quiz on the material prior to attending the next lecture. In addition, students could be given regular homework assignments that count toward their final grade. These problems could be discussed in a limited way in class prior to the final submission date so that students are encouraged to maximize their effort. Students could also have access to some engineering noise control software so that they could explore the effect of various parameters on the solution of more complex problems.

An important question is, How do we get students to engage with the process? That is, How do we get students to do the required reading prior to coming to the lecture or lab class? How do we get them to ask questions in class, especially when some international students are from a culture where the teacher is never questioned in a public forum? How do we get all students to engage and contribute to collaborative problem solving? What types of laboratory classes are suitable? How do we ensure that students develop a good understanding of ethical issues? How do we ensure that the staff is implementing the active learning process conscientiously. And most importantly, How do we know this new approach is improving student learning outcomes?

The best way to ensure that students complete required tasks is to make them count toward their overall grade or to require that a task be completed before students can undertake a further task that counts toward their overall grade. Implementing these ideas may involve a mini quiz on the material that is assessed. Or in the case of a lab class, there may be a required minimum grade before the student is permitted to participate in the lab class, as well as assessment of student engagement during the class and a lab report.

Quizzes can be easily set up to be marked automatically online, and together all quizzes and class exercises should count toward somewhere between 20% and 40% of the final grade. Lab class participation and report should count another 20%, with the final exam counting between 40% and 60%. Good lab classes are those that encourage student engagement by requiring them to show some initiative, while at the same time, working with tools with which they are somewhat familiar.

So a beginning lab class may involve students downloading an octave-band frequency analysis app on their phones and then proceeding to measure a noise environment somewhere. This could include measurements near a noise source such as a refrigeration compressor or a bus leaving a bus stop. Students could be asked to undertake a frequency analysis and then comment on likely sources of particular frequency components in the spectrum. A second lab class may involve them calibrating their phone analyzer as a function of frequency using a precision mic setup in the lab. The number of engaging lab classes is only limited by the imagination of the lecturer.

Getting students to be engaged and ask questions can be difficult in some cases. However, one way of beginning the process is for the lecturer to walk around the class while students are working alone or in groups and ask them if they have any questions. If not, then perhaps the students could be asked to explain their understanding of one of the concepts that form the basis of the class exercise.

In recent years, universities have been subjected to large changes in the way in which they are administered and the way in which the academic staff is treated by their institutions. The academic staff is being subjected to ever increasing administrative burdens by the introduction of online administration systems that are designed to make life easier for senior administrators but impose additional burdens on the time of the staff. It is in this unfortunate environment that we would seek to introduce new learning approaches that have been proven to work but which require additional effort from the staff.

From an institutional perspective, it is tempting to force a staff to adopt an active or blended learning approach when it is well known that such an approach achieves better student outcomes. However, the outstanding positive results reported so far where these new methods have been implemented need to be tempered somewhat with the knowledge that all staff at the leading edge of these new methods is extremely dedicated and put in an enormous effort to maximize the learning outcomes for students.

One can imagine that a less enthusiastic staff that is forced by an institution to implement active and blended learning methods, including the flipped classroom, may not be so dedicated. And after putting all their material online, they may not spend much effort in designing and implementing learning activities for the classroom time that is freed up, preferring instead to spend more time on research.

So changing student-learning approaches at an institutional level must be done slowly and cautiously with continuing student evaluations, as well as assessments of student-learning outcomes. As more and more staff in a particular institution voluntarily adopts the methods, momentum will build on its own, with no forcing by the institution. Students will come to demand and expect blended and active learning, and student evaluations of teaching will reflect these expectations, which will result in an increasing number of a teaching staff adopting the new approaches. However, it is important that institutions provide academic staff with sufficient resources and support in developing online material and managing online assessment so that excessive staff time is not spent learning new software tools. SV

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