Acoustics Teaching and Manfred Heckl

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Abstract: Manfred Heckl, like all outstanding teachers of acoustics, wrote and lectured with great clarity. In addition, he had a sense of humor and understanding of his students. He used demonstration experiments and films to illustrate his lectures. The author argues that the best place to learn acoustics is in the laboratory.

Teaching is a challenging task, indeed. As teachers, we attempt to convey to our students some of the excitement of our discipline, to share some of the passion we have for the subject at hand, to stimulate their curiosity, and to help motivate them to probe the field and to develop their own ideas. Sometimes we are successful in this endeavor, sometimes we are not. As teachers, we are constantly looking for ways to help our students learn, new ideas for presenting material, new approaches to teaching. Good teachers are always trying to improve their effectiveness as mentors. We share ideas for teaching our subject; frequently we try out techniques that have been successful for other teachers, always remembering that they may or may not work for us. Teaching is a very individual activity.

I greatly admire the work of Manfred Heckl, although I never knew him well. My acquaintance came mainly as a result of reading his papers and his celebrated book *Structure-Borne Sound,* which resulted from a collaboration with Lothar Cremer and Eric Ungar. This book, which is the epitome of clarity, could only be written by skilled acousticians who are also great teachers. The Foreword tells us that the chapters on Damping, Impedance, and Radiation were written by Professor Heckl. He also animated several of the figures from the chapter on Radiation for a classroom video he created.

While the other papers in this session describe some of Heckl's many contributions to acoustics, it seems appropriate to include one paper that focuses mainly on his contributions to teaching the subject. I believe that Professor Heckl would approve of that. I am very grateful to his daughter Maria, his colleague Helmut Müller, and others who have shared their recollections and anecdotes about this great teacher. Of course, I will include a few of my own thoughts about teaching acoustics, as well.

ACOUSTICS, THE SCIENCE OF SOUND

The science of sound, which is called acoustics, has become a broad interdisciplinary field encompassing the academic disciplines of physics, engineering, psychology, speech, audiology, music architecture, physiology, oceanography, and others. It is not surprising that in various universities acoustics is taught in departments of physics, electrical engineering, mechanical engineering, speech and hearing, architecture, ocean science, and even music. In some universities, it is taught in more than one department; in many universities, unfortunately, it is not taught at all.

I have had the privilege of teaching acoustics to students on several different levels. Sound and light are subjects that have great appeal to young and old, alike, yet we too often neglect them in our science curricula, I am sorry to say. I would never think of teaching an introductory physics course that didn't include the behavior of sound and light waves. Understanding these everyday phenomena contributes so much to our appreciation of the music and visual arts as well as to our appreciation of modern technology that no person should be ignorant of their physical nature. On a more advanced level, the study of sound and vibration is an ideal way to learn about the nature of wave propagation. When I was a graduate student, an acoustics course from Morse's *Vibration and Sound* was considered a logical prerequisite to the study of quantum mechanics.

HECKL, THE TEACHER

The most important attributes of a good teacher are probably an understanding of his/her students and skill in presenting and explaining the material clearly. Manfred Heckl possessed both of these skills, his colleagues and former students agree. In addition to these necessary skills, it helps to have a good sense of humor and to be a bit of a character. Professor Heckl apparently fulfilled these criteria as well. His daughter Maria passes on a couple of anecdotes about her father:

1. He liked to demonstrate the correspondence between sound pressure and rate of volume change with an experiment involving champagne bottles. First, he would open a bottle very gently so as to produce very little sound; then he would open another bottle by letting the cork shoot out, producing the well-known bang. He would then share the champagne with his

students.
2. At the end of a course, he would make cookies for his students that had formulas written in sugar icing. He handed out these cookies with the comment, "I want to be sure that you have digested at least one formula from my course."

At a conference on teaching acoustics in Gdansk, Poland in 1987, Professor Heckl showed two animated films for teaching acoustics: "Visualisation of some structure borne sound phenomena" and "Some aspects of sound radiation." Both are based on his book on his book *Structure-Borne Sound*." For a reasonable fee, he granted me permission to translate the videotape to the NTSC format, add a sound track, and make copies for my students and teaching colleagues. It is an excellent film, and I use it every time I teach an advanced undergraduate or graduate course in acoustics.

A demonstration experiment often associated with Professor Heckl is the Rijke tube, which demonstrates heat-maintained feedback oscillation (1). A Rijke tube is typically a vertical cylinder, about 1 to 2 meters long and 10 cm in diameter with a wire mesh screen in the lower half of the tube. The screen is heated with a Bunsen burner, and after removal of the burner, a strong tone is emitted at the fundamental frequency of the tube. It is observed that a tone is produced only if the screen is located in the lower half of the tube.

Although a detailed explanation of the oscillations is rather complicated, Ingard (2) offers a rather simple qualitative explanation. The heating of the air in the tube by the screen creates a convected flow up through the tube. Superimposed on this steady flow is the oscillatory gas flow in the sound field in the tube, which can be considered to be initiated by an unavoidable fluctuation. In the fundamental acoustic mode, the oscillatory flow goes in and out of the ends of the tube in counter motion, the velocity at the center of the tube being zero. When the flow is inwards, the sound pressure p in the tube increases; when it is outwards, p decreases with time. At a time when the flow in inward, the oscillatory flow velocity u is in the same direction as the convection flow velocity U in the lower half of the tube. Thus with the heated screen located in the lower half of the tube, the rate of heat transfer to the gas from the screen will be increased through the cooling action of the air motion in the sound field, increasing the pressure in the tube so that feedback oscillations occur. Similar explanations are offered by Rayleigh (3) and by Dowling and Ffowcs Williams (4). Maria Heckl discusses non-linear acoustic effects in the Rijke tube in a very interesting paper in *Acustica* dedicated to her father (5).

The Rijke tube is a popular demonstration in many introductory physics courses, although often no attempt is made to explain the acoustic feedback process, either qualitatively or quantitatively. The demonstrator amazes students by turning the pipe horizontal, "pouring out the sound into a bucket," then pouring it back into the tube to make it sound again.

THE ACOUSTICS LABORATORY

I hear: I forget; I see: I remember; I do: I understand

The best place to learn science is in the laboratory. This is almost certainly true of acoustics. One cannot learn to play the piano by hearing lectures on the subject (however brilliant they are). One must practice! And so it is with learning acoustics; the laboratory is the practice room. Yet how often we try to teach acoustics without providing for the needed practice facility.

In our Acoustics Laboratory at Northern Illinois University, we have developed experiments for learning acoustics at several different levels of sophistication. Many of them are borrowed or adapted from experiments done at other universities; some of them resulted from hearing presentations at Acoustical Society meetings. We have, in fact, assembled 52 of them into a laboratory manual entitled *Acoustics Laboratory Experiments*, which we are happy to make available to others. Some of these experiments are intended for students without any previous experience in a physics laboratory, and are appropriate for introductory courses in acoustics, such as our course in Acoustics, Music, and Hearing. Other more sophisticated experiments are intended for advanced undergraduates and graduate students. Some experiments are appropriate for students interested in audio and electroacoustics.

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