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Interactive Lectures

A new and remarkably simple communication structure is proposed to broaden interaction between teacher and student

One of the most natural ways for a human being to learn is to talk with a knowledgeable person—ask him questions, listen closely to the answers, and carry the conversation into directions which are personally relevant and important. Today, however, most people have few opportunities of this kind, since as knowledge and society have become more complex there are fewer people, proportionately, who can give good answers, and their time is in great demand.

Can we find some new way to extend this interactive experience to a great many more people than at present have access to it?

It would appear that, at least in principle, an interaction with an expert and responsive person might be approximated and made widely available through recording techniques. Yet the trend of technology's contribution to education has been in other areas: development of media and of more directive kinds of structures such as programmed instruction. In part, at least, this has occurred because it has seemed technically very difficult to create a system which would respond to questions and personal inquiry in a satisfyingly rich way.

Five years ago in this journal, Edwin H. Land and I reported an experiment in which a boy—typically about 13 years old—asked questions about atoms into a microphone and received answers which then served as take-off points for the next questions (*see "Education and the Need to Know" in* Technology Review *for January 1967, pp. 29-36*). We wanted to observe and understand the nature of a free-wheeling interaction which are person controlled, guided,—and could terminate—entirely in accordance with his own mind's requirements; and we wanted further to see if a person would engage in such an interaction, not with another person who was physcally present, but instead with a set of responsive tape recordings. To investigate the latter point, we informed the students that the source of answers was a computer which could select from a large bank of tape. Actually, the answers each student received were given "live" by a person at the other end of the line.

The results of the experiment were exciting and encouraging. The sessions turned out to be surprisingly long—over one and a half hours on the average—and the questions were fascinating and often very challenging to answer. In fact, some sessions which ran to three hours or more had to be ended owing simply to the plain fatigue of the person at the other end. It was clear to us that each student valued and enjoyed an interaction of this type. But it was also apparent that the students had no difficulty in working with a system which to them was based on recordings. In fact, the boys' comments suggested that the decoupling between student and teacher which recordings allow had the effect of increasing their freedom to follow their own curiosity and interest.

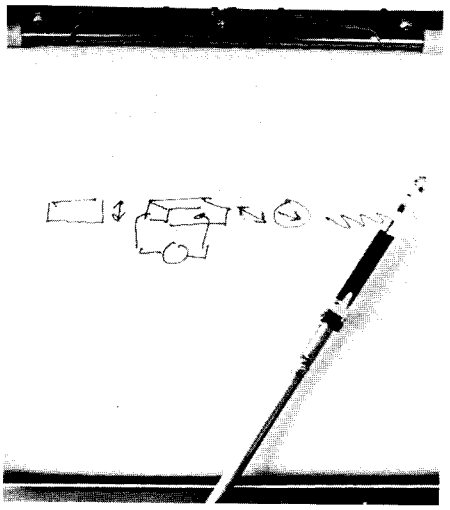
The challenge to me at that point was to find ways of making an interaction with responsive recordings—which of course we had only simulated—work. The problem was to answer a person's questions directly and well but to avoid a system whose stock of tapes tends toward infinity and whose access mechanism gets hopelessly complex. The many experiments since that time would make a long and possibly enlightening article on schemes which turned out not to be practical. But I came eventually to a rather simple recording structure which—as a consequence of the way the recordings are generated—is exceedingly practical and retains much of the variety and responsiveness of the interaction of our early experiment. In this article I describe the new structure, which I call an "interactive lecture," and present the results of experiments in which students tried it out.

Voice and Hand on Tape

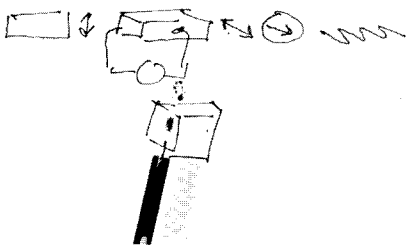
To explain what an interactive lecture is, it is helpful to relate the process by which the five interactive lectures which presently exist were each created. First, a professor was asked to record a talk on a scientific topic of general interest and also personal interest to him. The recording was a high-fidelity audio recording with Electrowriter sketches, made by the professor as he went along, recorded on the second track of the tape. In addition, the professor occasionally referred to photographs. I asked him to think of his talk as directed to an interested individual listener of college age.

The Electrowriter made it possible for the professor to illustrate what he was saying in much the way he would use a blackboard. The system has two units: a transmitter, on which the speaker writes with a pen on a roll of paper; and a receiver, in which a slender arm having a stylus reproduces the writing in ink on a similar roll of paper. The system is capable of a high degree of detail, and the receiver pen follows in exact synchronism the writing done on the transmitter, including hand gestures and pointing. In making the recordings the professor wrote or drew on the transmitter

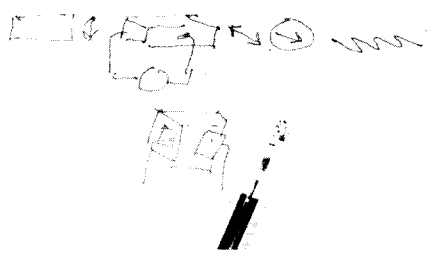
Part of an answer to a question on how laser light can be modulated for communication purposes. From a new interactive lecture on lasers by Stephen A. Benton, Assistant Professor of Applied Optics, Harvard University. *(Photos: Sheldon Lowenthal)*



". . . and then put a second polarizer so that the amount of output energy would depend on the amount of voltage on the crystal. This would be a transverse electro-optical effect."



"There's also a longitudinal electro-optical effect—the Pockels Effect—



"which uses transparent electrodes on the crystal's front and back surfaces and the light shines through them . . ."

whenever he wished; and its signal, together with his voice, was recorded on a stereo tape. On playback, the effect of this combination of voice and evolving drawings is remarkably engrossing and personal.

Next, the professor's talk—including the Electrowriter signals—was transferred to audio cassettes and made available for listening on a playback unit, including an Electrowriter receiver, in a comfortable private room. Duplicate prints of the professor's photographs were provided. A number of M.I.T. students, who took part voluntarily, then listened individually to the talk and in the course of listening wrote down questions which the material of the talk raised. The questions could be of any sort, not limited to those having to do with difficulties of understanding. Requests for background information, questions which took off from a point merely hinted at, challenges to the speaker's explanation, new directions resulting from new crystallizations in the student's mind—all were encouraged.

After several of these sessions the questions were collected and given to the professor for study. At his convenience, the professor returned and recorded individual answers to the questions (using the Electrowriter as appropriate). The style of his answers was direct and personal, as though each question had just been asked of him. The answers were transferred to cassettes, and these were placed with the cassettes containing the main talk. A new listener now had both the main talk and these answers at his disposal. He could have immediate answers to his own questions to the extent that they were similar to those for which answers had been recorded.

To gain access to the available answers, the listener used a 17 × 22 in. "map" of the interactive lecture, consisting of an outline of the main talk and a listing of all the questions, as related to each section of the talk, for which answers had been recorded. Once a particular answer (or section of the main talk) is selected, the listener is able by index numbers to find that answer—in about 10 seconds on the average.

Using the cassettes and the map, listeners continued to add new questions, some related to the main talk as before, and some related to the newly available answers. These questions were again collected, and answers to them were recorded by the professor. In all, five interactive lectures were made; in each case, as the chart shows, the amount of answer material exceeds that of the main talk.

To summarize, the making of an interactive lecture uses recording technology and an empirical method to discover and collect lines of inquiry around a given topic, so as to make them all available, at one time and place, to an interested individual. Though limited in range by comparison with the interaction of our early experiment, I hoped that an interactive lecture would nevertheless be a significant and useful step in the development of practical systems that were genuinely responsive to personal inquiry. I am deeply grateful to the five professors who made the recordings. Their willing interest, the quality of the material they created, and their delight at receiving excellent questions were a constant encouragement to me.

Using Interactive Lectures Interactively

The major experimental period began after the interactive lectures

were completed. Forty-eight M.I.T. students came over a period of four months to try the lectures in response to advertising in the student newspaper. The ad listed the titles and authors of the lectures and briefly mentioned that the recordings included answers to questions. The students who came were approximately equally distributed from freshmen to graduate students. All five interactive lectures were available to a student, and he could spend as much or as little time as he wished in each of as many sessions as he wanted. After a session, he was informally interviewed for his comments. The students were also invited to jot down any new questions which might occur while listening.

Since this was an exploratory experiment, and was necessarily conducted in informal circumstances, the results most naturally take the form of observations on student reactions. A significant quantitative result, however, concerns the length of time each student spent per session with the recordings. For the 48 students, the mean session time was 2.1 hours (averaged over the mean times for each student). Nine students had mean times of 1.5 hours or less; 16 had mean times of 2.5 hours or more. Upon emerging from a session, students occasionally expressed surprise at the amount of time which had passed.

There was a rather close correlation between a student's background and interests, as indicated by his major course of study, and the particular interactive lectures which he chose to hear. For instance, students in physics would invariably want the cosmology recordings, while students in biology would usually select the recordings on the symbiotic theory and on the origin of life. Most students did not choose interactive lectures whose topics were relatively unrelated to their major fields. Most of the students who responded to the advertisement (in which the topics were listed) were matched, in the above sense, to at least one of the interactive lecture topics.

Interactive lecture (title and lecturer)	Length of main talk (minutes)	Number of questions	Total length of answer material (minutes)
Cosmology Philip Morrison, Professor of Physics, M.I.T.	166	49	203
Implications of The Apollo 11 Lunar Material John A. Wood, Smithsonian Astrophysical Observatory	45	32	124
The Symbiotic Theory of the Origin of Higher Cells Lynn Margulis, Assistant Professor of Biology, Boston University	59	36	92
Experiments on the Origin of Life Carl Sagan, Professor of Astronomy, Cornell University	62	29	88
Leaf Insects, Birds, and Human Color Vision Jerome Lettvin, Professor of Communications Physiology, M.I.T.	39	21	76

The five interactive lectures listed above were made during the course of the experiment described by the author. The table shows for each lecture the duration of the main talk, the number of questions, and the total duration of answer material available.

From their comments, I found that students generally used the interactive lectures "interactively"; that is, they stopped frequently as they went through the lecture to hear answers to related questions. Twenty-five of the students wrote down new questions. A few students at first used the recordings in a more conventional way: they listened primarily to the main talk and returned to questions only at the end of the session. In later sessions, however, these students said they began to use questions concurrently with the main discussion. It was interesting that students quite frequently remarked on the value of being able to stop the tape and think, or of being able to repeat a passage exactly.

The central matter of practical concern was whether the students felt the sets of questions with the interactive lectures to be sufficiently complete. Since the questions in each set had been generated by a small initial group of students, it was not clear how well they would match the questions of numerous other students. Apparently the sets generalized rather well. Students typically said that "at least 50 per cent" of their own questions could be found on the map and that the absence of the remaining percentage was not limiting. Some students mentioned that it was nice to see

On the two following pages is the "map" (rearranged somewhat for the *Review*'s format) of an interactive lecture on the geological analysis of lunar material prepared by John A. Wood of the Smithsonian Astrophysical Observatory. Questions related to a particular section of the main talk (center column) are grouped together on the "map" next to the corresponding main-talk section. Both main talk and answers are indexed so that the student can easily go to any part of the talk or any answer he seeks; in the typical two-part index number, the first number refers to the cassette, the second to the "band" in that cassette.

The console used by students in the experiment, with cassette deck, speaker, Electrowriter, and an album containing cassettes for one of the interactive lectures. *(Photo: Sheldon Lowenthal)*

interesting questions on the map which might not otherwise have come to mind. There was no difficulty in adjusting to the particular language of a question as stated on the map. However, it became clear that the answer on tape should closely match the question on the map; that is, the question as stated should indeed be answered, and rather directly. Students occasionally expressed annoyance when this was not the case.

There were interesting results on the use of voice plus Electrowriter as the means of communication from professor to student. This is an age of video, yet only a few of the students expressed a desire to view the speaker on a screen. The rest tended to feel that the information gained from seeing the speaker would not be worth the added expense and might even be distracting. The voice/Electrowriter combination, on the other hand, was found by many students to be surprisingly effective —and also personal. This was due, to judge from their comments, to the engaging nature of the Electrowriter drawings, to the fidelity of the voice recording, and to the individual feeling with which the main talk and the answers had been recorded. In fact, several students specifically remarked how, on playing back the answer to a question, they could easily imagine that the professor was present in the room, answering directly. (Conceivably, an image of the speaker might lessen the feeling of personalness, since it would suggest an interposed camera and another location.) About half of the students thought that some additional subject-related visual material (in the form of photographs or film-loops) would be useful in connection with certain sections of the recordings; the other half did not feel an insufficiency in this respect.

A True Course for Educational Technology

I found that students enjoyed using the interactive lectures and valued the experience primarily because they had gained new information and understanding on topics of interest to them. There were numerous suggestions that an easily accessible library of recordings in the interactive format would be a useful resource at school. Some students felt that interactive lectures would be a desirable substitute for regular lectures. But all of them believed that the best use would be in the form of a large and diverse library to which any student could go to learn a lot about a topic of personal interest in a relatively short time, and do so directly from an expert in the field. The students also suggested that an interactive lecture would be good background for personal discussions with the professor who had made it.

The results of this experiment may perhaps be summarized and interpreted by the following model. The students who came did so out of intellectual interest in one or more of the topics offered. The sessions were long as a consequence of this basic interest and also because the interaction permitted a student to tailor his use of the recordings to the things of greatest particular interest, and had a personal quality. Because the recordings were responsive to the students' intellectual requirements, a large amount of visual material—beyond that needed for informative purposes—was not essential.

Implications of the Apollo 11 Lunar Material

by John A. Wood
Smithsonian Astrophysical Observatory

Dr. Wood tells how his group has worked with sixteen grams of Mare Tranquillitatis *and come up with a new hypothesis about the structure and early history of the moon:*

You seem to be skeptical about the value of the quarantine procedure. Would you explain why? (7 minutes) 3/1

What is the present schedule of future Apollo missions? 3/2

How would you assess the value of the Apollo program in relation to its cost? 3/3

How is the age of a rock calculated from its radioactivity? 3/4

Was there actually any significant probability of finding fossils or organic compounds on the Moon? 3/5

You mentioned that some people were looking for diamonds in the sample. Where would they have come from and how would they have been formed? 6/4

What is "petrology"? 6/3

Introduction; distribution of the lunar sample to various groups 1/1

The terrain at Tranquillity Base; diffusion of impact debris 1/2

How is the depth of the regolith determined? 3/6

Why is it believed that the regolith is deeper in the highlands than in the maria? 3/7

Why does the Moon's escape velocity set a lower limit to the speed of incoming meteorites? 3/8

Why did the fine lunar dust stick to the rocks? 4/4

Appearance of the sample material: preparation of thin sections 1/3

The four basic types of rock present:

Basalt 1/4

Anorthosite, glass, soil breccia 1/5

What might be the meaning of the high titanium content of the lunar material? 4/5

How does the chemical analysis of the sample compare with analyses of Earth material and material from meteorites? What questions is one trying to answer, and what do the results tend to say? (7 minutes) 8/1

it was mentioned in the newspapers that the glass which was found might be the result of some special astronomical event. Do you think so? 4/6

What was it about the glassy layer that led most people to conclude that Prof. Gold's idea was probably not correct? 7/2

What is a "degradation product"? 6/5

The sample as a key to lunar structure and thermal history:

Significance of the anorthosites **2/1**

How did the Surveyor 7 alpha-particle backscattering experiment work, and what composition did it find? 4/1

Would you show the calculation by which it is estimated that the Moon's crust is 25 km thick? 4/2

How is the overall density of the Moon determined? (7 minutes) 4/3

Can you really be sure that the highlands are composed *mostly* of anorthosite? That seems a critical step in the discussion. 8/4

A structural model of the Moon; formation of the maria **2/2**

What can one say about the fact that all the maria are on one face of the Moon? 4/7

If the maria were made by huge meteorite impacts, where are those meteorites now? They were certainly too big to have been annihilated. 8/5

What do the results of Apollo 11 and 12 imply about the way the Moon formed, and what, in general, are the major theories? (10 minutes) 6/2

You said that the great density difference between the Earth and Moon was pretty decisive evidence against the accretion hypothesis. But it seems to me just the opposite, namely, that the iron would tend toward the central body, leaving the lighter material to form the Moon. Why would this not be the case? 7/3

Would you comment on particle accretion in general? Does the theoretical problem lie in getting the particles to come together in the first place, or in their staying together, or in their ultimately fusing, or what? (5 minutes) 8/3

In several places you speak of "tidal interactions" between the Earth and Moon. Just how does one body twist or flex the other? (15 minutes) 7/1

If you could be placed on the moon with a complete lab, what would you do first? 7/4

Formation of the crust by magmatic fractionation; implication that the Moon was once very hot **2/3**

What do you mean by "refractory"? 4/8

Did the radioactive dating give any indication of when this molten or volcanic period of the Moon ended and is there any indication that there is still some volcanic action going on? 8/2

What is the basis for Professor Urey's belief that the Moon has always been cold? (5 minutes) 5/1

If the Moon was once hot, what was the source of heat? (8 minutes) 5/2

What do your results on early heating say about the Moon's origin? 6/1

If this interpretation is correct, the experiment with interactive lectures suggests that technology's deepest contribution to education should occur not so much in the programming of instruction, or even the further development of media, but instead in the creation of individually responsive systems. From a practical point of view, such systems, to be useful and satisfying to people, have been thought—at one time by me, as well—to require large information networks and the consequent use of computers. But the present experiment indicates that size is not so important if the material is generated by the right technique. Although each interactive lecture had only a finite set of answers to questions, the students did not find this finiteness limiting; nor did they find the listed questions inappropriate. The essence of creating a responsive system of deep fascination may lie in finding knowledgeable speakers, applying good initial questioners, capturing the results on tape, and then providing good maps.

Toward Interactive Learning Centers

What might be the meaning of this experiment for universities? I suggest that the experiment responds to two increasingly felt needs: for closer individual relationships between students and faculty; and for new opportunities and resources through which a student can do a significant part of his learning on his own. The two aims are connected, since the more effective a student can be in teaching himself, the more time both he and a professor will have for the kinds of relationships in which personal contact is most fruitful. A library of interactive recordings should offer important new opportunities for independent learning, but at the same time it should have the perhaps unexpected effect of increasing in both degree and dimensions the direct contact between student and professor.

I can envision a conveniently located center where interactive recordings on a great many topics are readily available to all students at any hour. A freshman, for instance, who was curious about lasers could come during two free hours and learn from an interactive recording which would link him, in effect, with one of the institution's foremost teachers in the subject. Or a senior, interested in a new field whose results were still scattered in journal articles, could connect with a person who knew and had assimilated those articles—perhaps also written some of them—and could put the results, and their relative importance, in perspective. Another student might choose an interactive recording on an older but never easy theoretical subject such as relativity and he would learn through the clarity, expression, and responsiveness to questions of a teacher who, having lived with those questions, understood the subject deeply. The first activity of the center, then, would be to act as an impedance-matcher between a student who desires to learn a certain thing and an expert and responsive person who knows that thing well.

But the very fact that the impedance match was a good one would lead quite naturally, I believe, to the student's seeking out the professor and talking further to him personally. The door of a professor's office is always open, but part of a student's problem in crossing its threshold is that he often has had little previous interaction with the professor and it is hard to know where to start. The discussion usually begins with the last quiz, because that is something the two have in common. But if instead they had the common experience of an interactive recording, I think this kind of obstacle would disappear. The student would, in a very important sense, know the professor; and the discussion could begin with the new directions and unanswered questions the recordings had inspired.

The center's second activity would be the creation of new interactive recordings. In this, the participation and contribution of students would be essential. New topics and speakers would be chosen according to students' expressed interests, and small groups of students would associate with each professor in the generation of each set of recordings. This would seem to me a participatory experience of a high human and intellectual order. The students' responsibility would be independently to discover in themselves questions which even as they led to new understanding also brought out the professor's talent and power—indeed, his inherent greatness—as a teacher. And the professor's complementary responsibility would be to put his knowledge and experience, in the subjects he knows best, at these students' disposal. This special kind of interaction would be an exciting and rewarding enterprise in itself. But it would have special reward because it would have a creative product—a set of recordings—that many others will use and enjoy.

The third activity of the center would be research. I have used the term interactive recordings in the last few paragraphs because I sense that there must be a whole family of

To illustrate what he is saying during recording, the speaker—in this photo the author—picks up the Electrowriter transmitter's pen and writes. (*Photo: Sheldon Lowenthal*)

useful formats of which the interactive lecture is just one member. As an example, one might consider generating recordings by beginning with a small set of fundamental questions, letting their answers lead to further questions, and building a kind of mosaic. Differences in topic and degree of formality should probably lead naturally to differences in form. The research would also include developing new interactive technology and testing new devices experimentally with students to find those that make the interaction work best. For example, it is possible that an interactive recording implies a basically new kind of storage and play-back design.

All these activities would take place concurrently in the center, in an atmosphere of participation and intellectual enterprise. Because it would be fundamentally concerned with questions—with discovering real questions and responding excellently to them—I believe the center would enjoy a fresh, unifying, and constantly revitalizing spirit. It would have questions as its focus, and it would bring the talents of many people directly to bear on understanding and exploring this most basic expression of the need to know.

My work began with and has been sustained by the belief that the question-answer mechanism is intuitive to the human mind and must therefore flourish and find continual response in our society if that society is to continue to consist of capable, creative, and responsive individuals. We cannot afford to forget, as society ages and becomes more complex, that every civilized advance and every increment of personal growth begins with a question. In my work I have attempted to understand the dimensions of the question-answer mechanism and to discover structures which, in harmony with the nature of that mechanism, would permit its exercise to be real and wide-spread. I offer for consideration one such structure which, to me and to the students who have tried it, works and feels right. Its value and promise are far from fully explored, and to do so will require the interest, competence, and energy of many people. But this enterprise, in which culture and technology converge, should be a joyful and refreshing one because the goal and the need are so deeply human.