Teaching Machines: A Challenging Market for 8mm

By JOHN A. BAYLESS
and JAMES N. BUMPUS

Teaching machines are a relatively new development offering much promise in improving educational practices. Using a variety of presentation modes and immediate reinforcement of appropriate behavior, they can be programed to teach while using the best educational and psychological principles. One estimate of the potential market, including programs and machines, is $100,000,000 for the period through 1965. 8mm film seems to offer the most promise for use in the more advanced teaching machines. An idealized 8mm film system, its functions and its cost are discussed.

THIS PAPER TELLS about the growing market created by the need for a technological base in education. We shall answer the following questions in detail:

What is programed learning and what are teaching machines?
Where did the idea come from?
What has been done so far?
What is in the future?
What are the qualities of an ideal teaching machine?
What are the demands that teaching machines will make on 8mm technology?

Our object is to provide a good understanding of the kind of 8mm equipment that this market needs and to convey a sense of urgency about filling it.

What is programed-learning and what are teaching machines?

Very simply, programed-learning is a new and very effective way of teaching. In this sense, programing is the art of systematically organizing the subject-matter into short, logically sequenced items for presentation to the student. The material is presented in such a way that the student is required to respond frequently by making selections from a set of choices or by writing answers to questions. The student is given immediate knowledge of results after each response. The emphasis here is on individual instruction. A good teaching program is designed so that, as the student proceeds through it, he is automatically exposed to subject-matter that is adapted to his own particular background of strengths and weaknesses. The good program keeps the student's attention focused and provides explicit practice and testing at each step by requiring him to respond and interact with the material to be learned. His right answers are immediately affirmed and his wrong answers are immediately corrected.

As may be imagined, the notion of programed sequencing of the material lends itself to presentation by machine and there are a number of machines on the market at this time, ranging from very simple and restricted types at about twenty dollars each to more complex and versatile models priced at about five thousand dollars. The function of the teaching machine is to present subject-matter to the student, accept his responses and score them, provide him knowledge of results, and select the next presentation.

Where did the idea come from?

Oddly enough, the idea of teaching by machine is not especially new. An early version of a machine to give and score tests and to teach was presented to the American Psychological Association in 1924 by Professor Sidney L. Pressey, then at the Ohio State University and a generation ahead of his time. The device remained a curiosity in the psychology laboratories until 1954 when Professor B. F. Skinner of Harvard University published in the *Harvard Educational Review* a paper, "The Science of Learning and the Art of Teaching." This was the beginning of an intensive series of studies undertaken by Professor Skinner and his students in the Harvard psychology laboratory to develop machines and a method of programing.

Another prominent contributor has been Norman Crowder, who developed a different approach to programed-learning from that of Professor Skinner. This concept, called "intrinsic programing," has received wide publicity since the early 1950's. Since the late fifties an accelerating interest in teaching machines has been shown by public schools, the military services, publishers and industry. Programed-learning was born in the laboratory but has already made a splash in public life.

What has been done thus far?

Some pertinent summarizing statistics are:

(1) As of now, every major university in the country, many smaller colleges, and perhaps 50 public school districts are studying both the theoretical issues and the practical application of programed-learning.

(2) Most of these studies are supported by local financing, but at least 20 organizations are undertaking research in programed-learning that is supported by Federal funds in excess of a total of $1,000,000. This is apart from military expenditure. This level of Federal support is increasing. One study alone, that has been proposed for funding next year, will require Federal funds of $1,000,000 to be spent over a four-year evaluation of programed-learning in the total education context.

(3) There are at least 50 companies in existence with a product line of teaching machines and programs. The machines vary in sophistication and price from about $20 to $5,000. The companies involved range from small, independent outfits to large corporations.

(4) There are over 125 programed courses that are being offered in public and private schools and in military and industrial training programs. They sample almost every branch of knowledge to some degree.

These statements are very general, but nevertheless convey an idea of the level of activity and interest at this time.

What is in the future?*

The amount of money required to support the general use of teaching machines is appalling. Education by whatever method is expensive. Over $13 billion was spend on elementary and secondary schools alone in 1958. These estimates are based on data from the *World Almanac*, some assumptions, some guesses, and on manipulations that could be carried out with equal validity in a number of ways.

The present demand for training is shown in Table I.

Schools run by the military services and industry, elementary and high schools, and colleges and vocational schools train more than 40 million students each year. The length of the school term and the number of hours a day vary somewhat for these six kinds

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* For the material in this section the authors are heavily indebted to "The Teaching Machine: Coming Revolution in Education," by Dr. Robert L. Chapman, presented to the Los Angeles and Santa Barbara Sections of the Institute of Radio En ineers at Santa Barbara, October 7, 1960. It is used with permission of the author.

Table I. The Demand for Training (Based Upon 1958 Student Population Estimate).

Markets	Number of students (millions) in 1958	Present Course Length (academic subjects) Days	Hours/ day	Total hours	Reduced Course Length (hours) To one-half	To one-fourth	No. teaching machines required	Required Course Material* Basic library	Yearly revisions
Military	0.35	360	8	2280	1440	—	268,000	100	40
Industrial	0.80	30	8	240	120	—	32,000	50	10
College	3.00	180	3	540	—	125	125,000	200	50
High School . .	10.00	180	4	720	—	180	600,000	50	10
Elementary . . .	23.00	180	4	720	—	180	1,380,000	100	10
Vocational . . .	3.50	60	2	120	—	30	35,000	50	5
Total	40.65	—	—	—	—	—	2,440,000	550	125

*Total programs needed during 10 years: 550 + 10 (125) = 1800.

of training. But no matter how it is broken down, it adds up to billions of student hours each year.

We cut the estimated course length in half in the military and industrial applications and to one quarter for schools and colleges as the result of using teaching machines.

We assumed that a teaching machine would be available 3,000 hr a year, that is, 10 hr a day, six days a week, 50 weeks a year. This does not mean, of course, that a student would work 3,000 hr a year. A second grader might spend only 250 hr a year at a machine. And although a child might object to going to school on Saturday to be able to sit at an available machine, being able to stay home on Monday might alleviate his pain.

The meager requirement for course material may be a surprise to many. For example, could there possibly be more than 100 academic semester courses for the eight years of elementary school? The basic library for each of these applications could probably stand revision each year. The military would probably have to revise courses and produce new ones more frequently than elementary schools. We tried to take this into account in estimating how many courses would have to be prepared over a ten-year period. Although a total of 1,800 courses for all these schools seems small, we believe we have made a generous estimate.

Now we have to estimate two kinds of costs of using teaching machines, that of the machine itself and that of preparing the course material.

We believe that a fairly well endowed teaching machine could be sold now for military and industrial applications for $4,000 and that with a five-year development program and large-volume production techniques, a better machine could be sold for $2,000 to the remaining markets. To get annual amortized costs, we assumed that a teaching machine would have a ten-year life and could be maintained for $100 a year. So the annual cost for a teaching machine would be $500 for the first two markets and $300 for the others.

We believe the required 1,800 semester courses could be prepared for $25,000 a piece, although the first several hundred might cost a good deal more than that.

Using the previous estimates of training demand, we obtained the cost per student for teaching machines and course preparation. Then we compared the cost of using teaching machines with present costs in Table II. (Only the direct costs are included here, not overhead — which may run as high as 175%.)

While market analysis is an inexact science at best, this particular example is probably shakier than most. We must interpret the results very cautiously. But some relations that deserve our attention are:

(1) The cost of course preparation is small compared to that of the teaching machine.

(2) Because present training costs for the military and industry are so much higher than other schools, the teaching machine is economically more attractive in those markets.

(3) If the teaching machine is to compete as well in the other markets, its costs must be reduced and its effectiveness increased, or both.

(4) Over the long run, it's the annual cost per student that determines the teaching machine's economic value. That cost is influenced by machine life, maintenance expense, the number of hours it is used, and by its effectiveness. It does not follow that just the initial cost of the machine determines its economic value.

These figures do not imply that teachers can be replaced by teaching machines with a saving of 90 to 95% of present costs. What these figures may mean is that teaching machines may take over some teachers' activities, many of their repetitive, routine and tedious duties. A teacher shortage already exists and threatens to become worse. Teaching machines may mean that fewer additional teachers would be needed.

Table III summarizes the annual costs of using teaching machines. These cost figures are the amount of the market. The last column of the table predicts when these markets may open up.

Earlier we commented that teaching machine costs might be halved by a five-year development program. During this first five years the major market will be those buyers who can afford to pay more because their training costs are already high. This reduction in manufacturing cost is necessary to make the machine really attractive to the markets beneath the dashed line in Table III. Unless the experience gained during the first five years is used to lower cost and raise usefulness, we may not be able to exploit the really big market.

What are the qualities of an ideal teaching machine?

There are four major functions that an ideal teaching machine must perform in order to be self-contained:

(1) It must present material to the student in a variety of ways.

(2) It must accept different kinds of student responses.

(3) It must evaluate the student response and select new material to present to the student on the basis of his performance.

(4) It must keep permanent records of the student's performance.

This is a large requirement. These are the things that a teacher in the classroom spends most of his time doing. They sound simple, but the keynote is something that no simple listing can show: the sensitivity and responsiveness of the teacher to the individual needs of the student. The true essence of the teaching role is that of continually probing, testing and sensing the student's capabilities, then adapting the style of instruction to counteract and overcome his weak points. To mechanize this quality of *adaptiveness* is the real goal of the movement towards automated instruction. The four functions are examined with this in mind:

(*1*) *Presentation of Material:* All the earlier machines and most of the present-day machines are very limited in this respect. Typically they show the student only one kind of presentation. Usually this is a paper form that is exposed through a window in the case of the machine. The student sees a few lines of written text and nothing more. This is one of the most disappointing features of current teaching machines. The educator really wants to present a wide variety of experiences to the student. He may draw on all kinds of analogies to illustrate a point in the lesson. He may want to use pictures, color, charts and graphs, animation or a short film clip that demonstrates something. He may want to use the very beauty or esthetic quality of the presentation to capture the student's imagination. To go to extremes, can you imagine trying to teach either a course in great works of art or a course in an experimental science from only a printed page? Even present-day audio visual techniques fall short when it comes to presenting complex information. The essential element of the teaching machine is that the student is not merely exposed to the material, he is made to respond and react to it. The continuous interaction of the student with the material is not provided by merely showing him a movie or a set of slides. The opportunity for explicit practice and testing must be interwoven into the structure of the presentation and the presentation must be capable of adapting to the student.

The ideal media for presenting this rich variety of experience is not a paper form with a few sentences on it, but film, with its enormous versatility for faithfully recording real life and its supporting technology for creating all kinds of special effects; however, it is equally clear that ordinary slides and motion pictures are not sufficient. We need *programed* film presentations that we can change instantly in order to give us the essential quality of adaptiveness.

Table II. Present Costs and Teaching-Machine Costs.

Markets	Present Costs per Student per Year: Student time	Instruction cost	Total	Teaching Machine Costs per Student per Year: Teaching machine	Course preparation	Total
Military	$7500	$5000	$12,500	$240.00	$3.60	$243.60
Industrial	1000	250	1,250	20.00	0.47	20.47
College	—	500	500	12.50	0.58	13.08
High School	—	210	210	18.00	0.04	18.04
Elementary	—	170	170	18.00	0.02	18.02
Vocational	—	30	30	3.00	0.07	3.07

(*2*) *Ability to Accept Student Responses:* Conventional machines typically use one of two techniques for this. The student either writes on a paper record provided for this purpose or he selects one of a set of multiple choices and presses a button. This corresponds to standard practice in testing and presents no difficulties. Some special purpose machines have more elaborate response mechanisms. The student may be asked to operate a set of controls simulating a work situation, for instance. In terms of the machine, the response unit must generate a signal that can be interpreted by the control mechanism.

(*3*) *Evaluation of Student Response and Selection of New Material:* This function comprises the area where wide differences become apparent between machines that are now on the market. The majority of machines now being sold are designed to accept what are called "linear programs" as developed by Professor Skinner and his students. Items in this kind of program are presented in a sequential manner to the student. Some of the linear machines have control features that allow the student either to return to previously viewed material or to skip ahead over a certain number of items. Even with this feature, the control mechanism is quite simple. The cost of machines in this class varies from about $20 to about $250. The degree of control over the presentation and the amount of variety possible in the presentation are minimal.

The rest of the machines on the market are designed to accept the branching programs that were introduced by Norman Crowder and his students. In a branching program an incorrect student response causes the program to choose a line of presentation that is specifically tailored to the individual weaknesses of the student. Machines that accept branching programs are considerably more elaborate both in presentation ability and in control mechanism. Their ability to adapt themselves to the needs of the student is considerably greater than that of the simple linear machines. The cost of the branching machines ranges up to about $5,000.

(*4*) *Recording Keeping:* The other major function that needs to be performed by a teaching machine is keeping a record of student performance. This is done in several ways. The simple linear machines provide a roll of adding machine tape on which the student writes his response. Other machines have counters that tally the number of right responses and still others use paper tape punches that provide a machine-readable record.

What are the demands that teaching machines will make on 8mm technology?

We think it is obvious that the ideal presentation device is a projector that can show both still frames and motion pictures, either in color or black-and-white. It must be controllable over a range of speeds ranging from single frame to 30 frames per second or more.

The following is a summary of the features to which some special attention must be paid by designers and engineers.

Simple loading
Central cooling
Film search mode
  frame counting
  rapid deceleration
Optical system
  short focal length
  high resolution
Packaging
Power and shielding
Cost
Reliability

The Ramo-Wooldridge TRW Mentor was developed around a commercially available 16mm projector. We would have preferred to use an 8mm projector for the obvious reasons of cost and simplicity, but the fact is that at its present state of development 8mm does not meet the requirements.

Here, only problems will be discussed, no solutions. We suspect that the solutions may lie both in improvement and

Table III. Annual Cost of Using Teaching Machines.

Market	Number of students (millions) in 1958	Annual Cost (millions of dollars): Teaching machine	Course material	Year market opens
Military	0.35	84	1.3	1961
Industrial	0.80	16	0.4	1963
College	3.00	38	1.7	1965
High School	10.00	180	0.4	1968
Elementary	23.00	414	0.5	1970
Vocational	3.50	10	0.2	1972
Total	40.65	742	4.5	—

innovations in projector design and in an advance in the technology of film manufacture. For each teaching machine there may be as many different filmed programs as there are courses taught by the user. Since each program print must be used many times, it must be durable. But let's take up the problems now, one at a time.

The technical keynote for the projector used in a teaching machine is utterly reliable and simple operation. Class time is closely scheduled. The programs must be loaded into the machine by the teacher or even by the student himself. A minimum of fuss and bother to the loading process is essential. The simplest arrangement we can think of is a plug-in magazine containing the reels and film loops, and with the drive sprockets built in so that no threading is required at the projector. And it must be made so it can't be plugged in upside down!

Single frames must be shown for several minutes at a time with no visible change in the image and without focus drift. This will require special attention to cooling. The projector will be housed in a fairly small cabinet along with other components that are generating some heat. The authors favor a single central blower for the entire teaching machine. Under these circumstances it would be preferable that the projector come from the manufacturer with no blower of its own at all. Instead, the lamphouse should be designed to accept standard duct fittings, one for cool air intake from the central blower manifold and one for exhaust of hot air outside of the cabinet. Another duct fitting should be provided to cool the film gate. The manufacturer should provide information as to the amount of air required for proper operation.

There are some special requirements for moving the film in a teaching machine projector since the pictures on the film are not arranged for straight-through showing. Once the student has begun the program, his responses will determine what the next display should be. This may be the next frame on the film or it may be a thousand frames away in either direction. This means there is a search mode of operation for the projector.

There are two problems here. First, we have to be able to count the film frames to get to the next presentation. The stored program will tell the control unit how many frames to move the film, but the projector must provide an electrical pulse to the control unit as each frame passes the gate aperture. This means that some simple kind of circuit breaker must be an integral part of the projector. For example, it could operate from the pulldown cam of the gating mechanism. In this connection, we advise from bitter experience against the use of either a microswitch or a carbon brush commutator. They just aren't reliable enough. The problem here is to provide the cleanest possible signal to the control unit.

The second problem in searching the film is to transport the film as fast as possible without getting into an expensive method for protecting it against tearing or scratching. This probably means something not much faster than 30 frames/sec; but nevertheless, some design effort on this problem seems essential. Long search times are really undesirable; and we are sure that occasions will arise when there will be long jumps forward or backward to special program sections.

Along with fast film travel, we have the corollary problem of fast stopping. We want to stop on one specific frame; not just near this frame, but *on* it. The reels are heavy and there is quite a bit of inertia to overcome. We need some means to insure a constant fast deceleration time from search speed or operate speed down to zero. This is one of those areas where some joint work is needed by both the film manufacturers and the projector designers.

The problem of moving the film in the projector presents another area where there are probably several solutions. All available film sources must be used to generate motion-picture clips that go in the master programs. Some of the sources are filmed at 16 frames/sec, and some are filmed at 24 frames/sec. From our position it is most economical in program construction to use the slower speed because the clip takes less room on the film. If in the 8mm format the 24-frames/sec clips can be printed by a dropout process that will convert them to 16 frames/sec, then the only movie speed we need is 16 frames/sec. If not, then we need both 16 and 24 frames/sec as well as the single-frame feature.

Now the optical system should be considered. The projector will be used in a console designed for rear projection. The screen can be hooded, but the room will not necessarily be darkened. The front throw will be between 2 and 3 ft, and we do not want to use a folded light path. The screen will be about 12 by 14 in. This calls for a short focal length projection lens with a flat field. The lens ought to be capable of resolving something like 80 to 100 lines/mm. There must be flickerless projection at all speeds.

Since the student should not see the film during searches, a lens blanking arrangement of some kind is required. This needs to be controllable independently of the state of the projector, perhaps a simple shutter in front of the lens. All controls must be remotely operated by relay contacts. These include the lens blanking shutter, all operating speeds, and direction of film travel. Depending on how well focus drift can be controlled by cooling, a separate manual control may be needed to focus the projection lens from the front of the cabinet.

Since the projector is to be housed inside a cabinet, an absolute minimum of fancy packaging and styling is required. Black painted metal stampings with all the welds showing will do just fine.

Power requirements are the standard 117-volt, 60-cycle a-c service. And here is a note of warning. The motor and relays need to be shielded against transients in the audio frequencies because these can very seriously disrupt electronic control devices.

Now as to the cost: such a projector in quantities of a thousand or more should wholesale between $150 and $300, in order to keep its proportional contribution to the overall cost of manufacturing the teaching machine at a reasonable level.

The teaching-machine challenge demands good technical ideas and good products competitively priced. There will be a premium on good management, some judicious risk-taking, the effective use of creative and productive people, and educating the customer to try new ideas. The compensation is that rarest of opportunities, a large market limited only by the ambition of those who wish to enter it.

The authors hope that they have managed, in some way, to share their vision and to stimulate enthusiasm to invest in the necessary research and development to give education the technological base that it so badly needs.

Discussion

David Anderson (*Yale University*): Why do you believe that film will be needed in teaching machines instead of printed material. Would you give an example of a subject matter that is helped out by film?

Mr. Bumpus: We've had a little bit of experience with this in doing some programing of our own. One of the subject matters that we tried to tackle was a short bit of physics having to do with the laws of motion and I can't imagine being able to effectively put this across without a motion-picture capability. I think the same holds for a number of other areas.

Mr. Anderson: If you are using the branching system to go back to review material, wouldn't it be easier on the mechanism to repeat some footage that could be run forward?

Mr. Bumpus: If a jump were excessively long and required a long waiting time I think we would certainly do this. Of course there is a trade off that depends on how much capacity you have in a reel for duplication of footage.

Dr. John G. Frayne (*Consultant*): Of the various fields you listed, military, industrial, college, high school, etc., which do you think will be the first to take up this method of teaching?

Mr. Bumpus: Military, I believe; however, it is hard to tell. There's been a persistent comment in the military to the effect that there is no research and development money for teaching machines. There are a number of companies that are accepting this at face value. They produce commercial products and sell them off the shelf to the military for research installations. There's wide interest in industry — the American Management Association, for example, has sponsored two conferences and exhibits on teaching machines and program learning already and we are getting ready to do a third one out on the West Coast in November; so the interest is quite broad in both the military and industry. As far as the academic fields go, it's a little slower. We need to get the products more reliable and less costly.

Mr. Anderson: How would the teacher unions react to this proposal?

Mr. Bumpus: Somebody once made the remark and I won't say that I necessarily agree, that any teacher who could be replaced by a machine deserves to be.

8mm Sound and the Distribution Bottleneck

By JIM CAMPBELL

Two related problems effectively bottleneck expansion of film use in the church—the number of rental prints available from primary sources and the cost of release prints. Evidence that the cost of release prints in 8mm sound may be considerably reduced has led to an optimistic belief that these two related problems may be solved. But at the same time, 8mm raises the problem of how to introduce a new medium into a market (the church) that has no equipment for its use.

THE GOAL of the church film producer is to get the maximum use of his product. He prices it with this in mind. As a rule he must also include in his price the cost of production amortized over expected sales and rentals.

Maximum film use occurs when the film is included as an integral part of some on-going church program such as the discussion stimulator for a specific Sunday church school lesson or the main resource for a church-wide mission study. But this cannot be done as long as films are distributed primarily on a rental basis. If, for instance, the curriculum writers made it necessary for a certain film to be used in all churches on the fourth Sunday in October, how many copies would be needed to service over forty-five thousand Methodist churches? (Surveys indicate about two-thirds have 16mm projectors.)

The present rental system of films, and to some extent the design of church films, is based on precedents carried over from theatrical exhibition. The fact that educational films can and often should be re-used is rendered impotent when they must be ordered from some area depository and rent paid for each use. The high rental rates virtually rule out small group use where most effective learning takes place. Consequently, we must think in terms of sale.

Four things influence the quantity of a product sold to the church: (1) how closely it is tied to a church program (2) how well it is promoted, (3) how it is priced, and (4) how good the quality is. In the case of films we have found that all of the above factors are under control, to some extent, except that of price.

8mm Economy

The curves of Fig. 1 show the relation of unit cost to number of units. The unit price of a typical 16mm twenty-minute film is charted as a solid line. It is supposed that the production cost was $20,000 and that an additional $10,000 was needed for promotion, packaging and other merchandising costs. The total film cost of $30,000 is spread over the number of units indicated in the ordinate. The abcissa charts the cost in dollars of individual units.

It is evident that if we were to turn away from a 16mm rental economy we would have to think in terms of sales in the neighborhood of two to four thousand copies to take advantage of the obvious price break that occurs in larger quantities. It theoretically ought to be possible to sell this large amount with good promotion. But it has never been done—never have such large sales of films even been approached despite isolated experiences of high promotion and subsidized pricing.

Numbers of sales to churches are not only inversely related to price, but there are price levels beyond which churches will not go. We do not know for sure where these psychological price

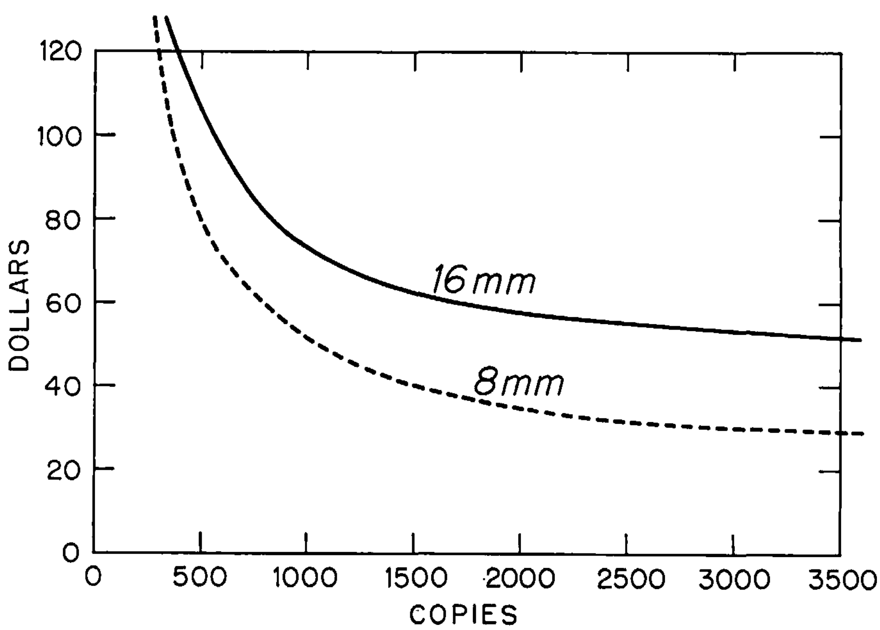

Figure 1

Presented on October 3, 1961, at the Society's Convention at Lake Placid, N. Y., by Jim Campbell, Dept. Audio-Visual Resources, Television, Radio and Film Commission, Methodist Church, Nashville, Tenn.

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