TEACHERS' TREATMENT OF THREE TYPES OF KNOWLEDGE IN THE DESIGN OF PRIMARY SCIENCE INSTRUCTIONAL MATERIALS

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This paper examines teachers' treatment of declarative, conceptual and procedural knowledge in the design of primary science instructional materials. The materials reviewed represent a subset of work done by a group of primary school teachers as part of the requirements for assessment in a short course in materials production. The teachers were participating in this course as part of the professional upgrading exercise being implemented as a result of the establishment of a national Learning Resource Centre in Trinidad and Tobago. The examination of the materials revealed both strengths and weaknesses in the teachers' capability to understand and deal with the knowledge types inherent in the instructional content. The paper concludes by drawing attention to the implications of this exercise for curriculum change, evaluation of instructional design procedures and overall role definition within the context of the Learning Resource Centre.

Rationale

It is often stated that a primary function of the teacher is to initiate the learner into the world of knowledge. Indeed, knowledge is often linked with learning (Bower & Hilgard, 1981; Romiszowski, 1984). Within recent times, concerns have been expressed about the efficiency of knowledge acquisition in the classroom. Beginning in the mid 1980s, the new reform movement developed in the USA sought to re-focus attention on the content of what teachers shared with learners in the classroom. Out of this movement emerged the concept "pedagogical content knowledge" which Shulman (1986) defines as "a second kind of content knowledge which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge of teaching" (p.9). While this concept has been applied to instruction delivered in face-to-face classroom interaction, this writer holds the view that it also has implications for the design of

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instructional materials. For, materials in whatever form, serve the same instructional role as the classroom practitioner in that they are also intended to facilitate learning (Gagne, Briggs, & Wager, 1988).

This paper, therefore, seeks to examine primary school teachers’ approaches to the treatment of knowledge in the design of instructional materials.

Background

The Faculty of Education of the University of the West Indies (UWI), in collaboration with the Ministry of Education of the Government of Trinidad and Tobago mounted a short course in materials production for 24 primary school teachers during the period September 1991 to February 1992. This venture was part of an ongoing professional development programme being undertaken by the Ministry. This teacher-upgrading programme represents a key aspect of the work of the Learning Resource Centre whose overall goal is to improve the quality of teaching and learning in the school system of Trinidad and Tobago. Immediate emphasis is being placed on the primary school, and training of a core of teachers in the design and use of instructional materials constitutes an important component of the programme.

For the main assignments of one part of the short course mentioned above, participants were required to design and produce two small instructional packages, namely, a series of transparencies and a series of slides. For the transparency assignment, participants were required to provide a summary of the content delivered through this medium. In the case of the slides, they were required to supply a shortened version of the oral instruction, whether in the form of statements or questions that would accompany each slide. Each set of materials would provide instruction for one lesson (45 minutes maximum). In addition, each complete package would include a statement of objectives, a brief description of the target audience, an outline of the methodology to be used when delivering the instruction, examples of test items and an instrument for peer evaluation.

Instruction for this sub-course was largely based on the ASSURE model of instructional design as prescribed by Heinich, Molenda and Russell
(1989). The basic model was, however, enhanced by inputs from other areas. For example, there was an introduction on learning and instruction, an overview of the inductive and deductive strategies (Eggen & Kauchak, 1988), a brief exposure to the skill of conducting a task analysis (Davis, Alexander, & Yelon, 1974; Dick & Carey, 1985), and some broad guidelines on the selection and structuring of the instructional content. It also included an examination of different types of knowledge (Romiszowski, 1984).

In developing their packages, teachers were free to select content from any subject matter area and science was one of the areas used. This paper focuses on a subset of packages that were based on science topics. For the purposes of this paper, the terms "teacher" and "instructional designer" will be used interchangeably in light of the writer's view of the expanded role of the classroom practitioner. The terms "content", "instructional content" and "knowledge" will also be used interchangeably. Evidence of this latter usage can be found in the literature (Jones, Li, & Merrill 1990).

Types of Knowledge

Regardless of subject matter area, instructional content is often classified according to certain basic attributes that are applicable to all knowledge. As a result of this classification, four types of knowledge are commonly recognized by most theorists, and the labels normally ascribed to them are facts, procedures, concepts and principles. Whether using these labels or others, instructional designers need to approach the treatment of instructional content based on an awareness of the type of knowledge involved. This writer takes the view that such an awareness constitutes an important dimension of the instructional designer’s task of constructing "subject matter knowledge for teaching." This paper seeks to address some key considerations related to the teachers' treatment of three knowledge types in the design of their packages.

Declarative (Factual) Knowledge and Meaningful Learning

While one would want to emphasize the higher levels of learning in the cognitive domain, the reality is that a fair amount of school learning is at
the level of declarative (factual) knowledge. Tennyson and Rasch (1988) describe this type of knowledge as "knowing that." Romiszowski (1984), in his schema, establishes the broad category called "factual information" under which is subsumed "facts." Facts are further divided into other units including concrete facts (knowledge gained by direct experience) and verbal information (knowledge of a factual nature that has been gained by means of a symbolic language).

This type of knowledge is particularly evident in the area of the biological sciences, and there is a tendency within the classroom setting to adopt rote memorization strategies for this area of knowledge acquisition. In the face of such a situation, one is reminded of the Gestalt theory of learning which emphasizes wholeness and meaningfulness, and in the context, opposes the practice of rote memorization (Hergenhahn, 1988). One is also reminded of Ausubel's (1968) emphasis on the need to relate new material to the learner's cognitive structure. The task of the instructional designer, therefore, is to establish meaningful contexts for the learning of new content particularly where such content is largely factual.

Teachers A and B both designed transparencies on the parts of a flower. Teacher A's objective was that pupils should be able to identify the parts of a flower. Teacher B went one step further. Her objective was that pupils should be able to identify the parts of a flowering plant and state their uses. Both chose to use the hibiscus as a prototype of a flowering plant.

Teacher A's package included a set of eight transparencies targeted to Standard II pupils (7-8 years). The first transparency presented a drawing of the whole flower while the other seven each focused on one part, namely, the sepals, petals, pistil, stamen, pollen grains and style. The methodology, outlined by the teacher, would require that each pupil have a live hibiscus flower. As the teacher presents each transparency, the pupils would identify the part in their specimen, remove it from the main flower and stick and label it in their workbook. Simultaneously, the teacher would provide a description/explanation of the relevant part. In keeping with this instructional approach, test items were designed to test recall. Examples included:
(a) What part of the flower are the sepals?
(b) Briefly describe the stamen.

Teacher B’s package included nine transparencies targeted to Standard IV pupils (9-10 years). It assumed previous knowledge of the parts. The first transparency presented a branch with a large flower and bud, to be used mainly for revision of the previous lesson on the parts of a flower. Some of the structure/function relationships highlighted in the subsequent transparencies were:

(a) the calyx protecting the young flower and preventing it from falling off;
(b) the petals whose beauty and bright colour serve to attract insects and birds (a butterfly was included in the drawing);
(c) the style which links the stigma to the ovary.

One of the test items was a matching exercise. Pupils, working in groups of five, would be given two sets of cards, one set naming parts and the other describing functions. They would be required to match correctly.

Teacher A’s approach could have been improved with the inclusion of strategies to facilitate greater pupil participation. Given the use of clear drawings, along with the live specimen itself, pupils could have been led, with appropriate questioning, to share in describing the various parts. Nonetheless, the approach, as outlined, reflects some thought and innovation and it is very likely that it would generate interest among her pupils. In spite of its positive features, however, this instruction is mainly a rote memorization exercise that largely rests on pupils’ ability to remember strange sounding words. Even though the description of the part is a key aspect of the instruction, there was little in the descriptive statements that could act as a cue to trigger the name of the appropriate part.

Teacher B’s approach reflects a greater sensitivity to the Gestalt concern for wholeness and meaningfulness in learning (Hergenhahn, 1988). With the use of illustrations that visually demonstrate the part performing its function, it is likely that pupils would be able to build more efficient schemata connecting parts with functions. Based on Gestalt theory, one could assume that a statement that relates name of part with function,
reinforced by a visual image that pictorially represents the same relationship, can be expected to act as a more efficient cueing device to activate the name of the part than a statement which only describes the part.

One notices, though, that Teacher B felt the need to precede this segment of instruction with one similar to the one developed by Teacher A. What one can infer from this is that both teachers probably feel some security in the rote memorization approach. Whether their sense of security is matched by an equal degree of learning on the part of the pupils is debatable. This writer holds that the issue of wholeness and meaningfulness, particularly in the area of the biological sciences, deserves greater consideration. Consequently, thought should be given to devising strategies to facilitate this for both face-to-face and mediated instruction.

Integrating Conceptual and Procedural Knowledge

Tennyson and Cocchiarella (1986), supported later by Peterson, Ridenour and Somers (1990) suggest that there is an interactive relationship between conceptual and procedural knowledge. The former writers define conceptual knowledge as "the integrated storage of meaningful dimensions selected from known examples and the connecting of this entity in a given domain of information" (p. 41). Procedural knowledge, they state, "is developed by using conceptual knowledge to solve domain-specific problems" (p. 44).

In discussing the relationship between these two types of knowledge, Peterson et al. (1990) suggest that in the acquisition of procedural knowledge, learners are also able to build conceptual knowledge even when overt instruction is not provided for the latter type. This writer is of the view that, in the design of instruction, this implicit relationship as recognized by Peterson et al. in particular, could be highlighted in a more explicit manner in the interest of the learner. Such a strategy can be expected to benefit the learning of real-world procedural tasks inherent in which is the application of scientific conceptual knowledge.
Some of the slide packages were developed to introduce pupils to procedural tasks that involve the application of scientific concepts and principles. Two are discussed here.

From a unit on electricity, Teacher C designed a series of slides with the combined objectives that pupils would be able to:

(a) construct a simple electrical circuit;
(b) test the electrical circuit for its functional capabilities by activating the electrical switch;
(c) troubleshoot the electrical system if the electrical circuit is non-functional.

The intended methodology would involve pupils working in groups, each group being provided with the necessary equipment. The entire slide series would be presented once to provide an overview of the whole procedure, then it would be repeated in short segments to allow pupils to perform each step of the procedure as it is demonstrated. Accompanying the slides were clear instructions. For example, the following instructions accompanied slide #9:

Use the two long screws to secure the switch to the correct position on the base. As you may have realized by now, tightening is only possible by turning the screws in a clockwise direction.

The testing and troubleshooting aspects of the objective would be performed on completion of the construction phase.

This package was clearly geared towards maximum accuracy in task performance. The slides would serve to enhance efficiency in a learning environment which seemed designed to function in a manner similar to that of the expert craftsman and apprentice. The clarity and precision of the instructions to accompany the respective slides reinforce this point of view. Given the efficiency in both the sequencing of the slides and the accompanying verbal instruction, it is very likely that pupils would attain the intended objectives. Further, if one is to accept the findings of Peterson et al. (1990), it is also likely that some incidental learning could occur. Thus, when pupils follow the instructions to "attach one end of the red wire to the large nail that represents the positive terminal of the
power supply," the meaning of the concepts "positive," "terminal" and "power supply" would begin to emerge as well as the relationship among them.

While not denying the likely potential of the package or the significance of the Peterson et al. findings, this writer is of the view that more overt interventions could have been made to ensure acquisition of conceptual knowledge. Such an approach can be expected to clarify the concepts and principles themselves, strengthen the learning of the procedure and facilitate learning transfer. One recognizes that it might be difficult to incorporate this aspect in the instruction under review, given the methodology of combining demonstration with learner performance of task. Probably, however, instruction for concept learning could immediately follow this activity session to reinforce and/or enhance any incidental learning that could have taken place.

The second slide series was extracted from a unit on food preservation designed by Teacher D, with the objective that pupils would describe the process of making papaw jam and explain the main principles involved. It was envisaged that this lesson would precede another where pupils would actually be involved in the preparation of the jam. Teacher D began the series with visuals showing fruit that were both suitable and unsuitable for jam making. After an overview of equipment used, it continued with a well-sequenced set of steps including cutting, peeling, washing, parboiling, grating and measuring of the fruit, followed by the measuring and mixing in of the sugar, and the preparation and storage of the bottles. Built into this sequence, was an attempt by Teacher D to draw attention to underlying principles. For example, reasons for adding lime juice, grating the papaw, and cooking the mixture rapidly after sugar is dissolved were all highlighted. The series also included a segment showing fungal growth on jam and improperly set jam to demonstrate the likely effects of incorrect procedure.

In this package, there is evidence of overt attempts to focus learning attention on underlying concepts and principles. Questions such as, "Can anyone say why we are grating the papaw?"; "Can anyone say why the mixture must cook rapidly after the sugar is dissolved?", are clearly intended to enhance conceptual knowledge. It is also evident that this teacher is aware of the value of eliciting the information from the learners and intends to use the inductive approach for this purpose. However,
her questioning techniques may not be entirely adequate in the circumstances. The appropriate response to either of these questions would require pupils to perform a series of subordinate intellectual operations which, in turn, would be dependent on prior storage of relevant units of information.

In the case of the first question, this writer suggests that pupils would need to perform the following intellectual skills:

- identify the features of the grated papaw;
- identify the ingredients that must be added in order to make the jam;
- determine how these additives are intended to behave so that good quality jam is produced;
- compare the likely effect of adding these ingredients to the fruit in a grated rather than cut-up state;
- formulate the principle.

On the basis of this task analysis, one can generate a series of questions that are more likely to guide the learners in the intended direction than the single omnibus question mentioned above. In providing instruction for a procedure, therefore, one needs to address the issue of appropriate strategies to facilitate the learning of related conceptual knowledge.

Discussion

In spite of some of the comments made in the preceding discussion, a very satisfactory standard was attained, both in the materials reviewed as well as in all the assignments taken as a whole. However, given the limitations noted, this writer suggests that, in the thrust towards enhancing the professional competence of primary school teachers and engaging a subset of these teachers in developing materials for use in the classroom, the following areas are worthy of further consideration.

First, one may need to review existing curricula to assess the weighting of different types of knowledge within the respective content areas. Specifically, one may need to rationalize the amount of factual knowledge that is included in relation to other types of knowledge. One acknowledges that teachers ought to explore alternative strategies for
rendering the learning of factual knowledge meaningful, whether in face-to-face or mediated instruction. However, one cannot ignore the situation where, faced with a large body of factual data, teachers may consider it necessary to resort to rote memorization techniques in an attempt to satisfy themselves that they have taught it all.

A second issue arises out of the current trend of bridging the gap between the classroom and the real world, one that is particularly evident in the science curriculum. Knowledge of real world procedures such as the two discussed above is regarded as an integral part of science instruction. In this regard, the critical issue to be addressed is the nature of the factors which should be taken into consideration in determining the relative weighting that should be given to the performance of the steps in the procedure, and to the exploration of the concepts and principles inherent in the procedure. Resolving this issue is important for the teacher whether functioning as a classroom practitioner or designer of instructional materials.

A third area relates to the nature and function of questions in the development of instructional materials. It is significant that little or no emphasis is placed on this aspect in the more widely used instructional design models. This is probably the case because most of these models focus primarily on the learner as a recipient of knowledge (rather than as a generator of knowledge), hence the need for efficient transmission from the source, the instructional agent, to the receiver, the learner. The view of the learner as participant in the generation of knowledge would require an identification of appropriate question types and an assessment of how these could be adequately built into the instruction being designed. This writer suggests that this area deserves the attention of those having the responsibility for initiating teachers into this additional role of instructional designer.

Finally, at a broader level, this new teacher-role has implications for other roles within the education system. Traditionally, it has been the responsibility of the curriculum officer to supervise and monitor the work of the teacher as classroom practitioner. With the introduction of the Learning Resource Centre and its broader vision of the role of the teacher, it is evident that there should be a re-defining of the type of supervision that is provided for the instructional designer/teacher.
One is aware of the need to be sensitive, not only to the potential but also to the obstacles to the adoption of an instructional design perspective within the school system (Martin & Clemente, 1990). Nonetheless, this writer contends that instructional design, with its emphasis on clarity and precision in the stating of intended learner outcomes and on specifying the process for achieving those outcomes, can be expected to provide an appropriate theoretical framework for the professional development function that is envisaged for the Learning Resource Centre (See Burkman, 1987 and Snelbecker, 1987 for additional perspectives on instructional design and the school system).

What is evident from the above discussion is that the exposure of classroom practitioners to instructional design techniques has the potential of bringing about significant qualitative change, at both the micro level of the design and delivery of instruction and at the macro level of policy formulation and role definition.

REFERENCES


