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INTRODUCTION

Evaluation is indispensable to the teaching and learning of mathematics. The National Council of Teachers of Mathematics [NCTM] (1989, 1991, 1995) recommends that evaluation should be an integral aspect of the teaching of mathematics and should be used to inform instructional procedures. Hoosain and Naraine (1995) listed evaluation as a component of effective mathematics teaching. In this paper we illustrate how the various types of evaluation can be used advantageously in classroom practice. We use the term evaluation as defined by Webb (1992) and NCTM (1995); that is, as a broader and more inclusive concept than assessment.

Evaluation may be defined as a systematic process of obtaining information for the purpose of making decisions. Thus the ultimate purpose of evaluation is decision-making. In education we conduct evaluation to make decisions about students, teachers, curricula and teaching methods and strategies. There is consensus that good teachers should be thoughtful decision makers (Carpenter & Fennema, 1988; Clark & Peterson, 1986). For example, we decide what grade to give to a student, whether to reteach a lesson or not, and so on. Good decisions depend on valid evidence (obtained from evaluation). Therefore, it is important to conduct evaluation objectively.

TYPES OF EVALUATION

There are three broad types of evaluation: (a) diagnostic, (b) formative, and (c) summative. These are not independent types because aspects of one type of evaluation may be found and used in another. However, there are differences among them, and these differences relate to the purpose for which each is conducted.

Diagnostic evaluation is usually done at the beginning of a course of study or a series of lessons to ascertain students' entry behaviors. This can be achieved by written or oral tests, teacher-made or otherwise. This is to facilitate a close fit between new material to be taught and students' cognitive level of development and current achievement. The assumption is that the closer the fit, the more likely learning will take place. This type of evaluation may also be useful during a program of instruction to identify the specific difficulties that students may be experiencing and to determine why they are having these difficulties. The information obtained can be used to design appropriate remediation, differentiated, and follow-up programs. By accurately diagnosing students' problems, teachers are in a better position to help the students. Diagnosis may be done through written and oral tests, written work, and interviews or one-on-one conferences involving the teacher and students. A combination of different sources of information about students (written work, interviews, observations, etc.) is likely to result in a more accurate diagnosis.

An example of diagnostic evaluation in mathematics is the use of a written test to determine students' readiness for a formal course in geometry. Respondents to the Priorities in School Mathematics survey (NCTM, 1981) believed that geometry is taught primarily to develop logical thinking abilities. These include the ability to understand and construct formal proofs. However, Usiskin (1982) reported that of all U.S. high school students, 60 percent did not study proof, and of those who did, only 13 percent were successful with proof. One reason for this poor performance is an apparent mismatch between teacher instruction and student readiness: the teacher is presenting information at one level while the student is functioning at a different (and usually lower) level. Research supports the existence of five levels of learning (the van Hiele levels) in geometry (Burger & Shaughnessy, 1986; Fuys, Geddes, & Tischler, 1988). It is believed that a student can be helped to progress through this hierarchical system of levels if appropriate level-specific instruction is provided.

If a teacher is to provide instruction at a level that matches the student's current van Hiele level, that teacher must first determine the student's current van Hiele level. Usiskin (1982) found that as many as 90 percent of a sample of almost 3000 high school stu-

dents could be assigned a van Hiele level based on a multiple-choice geometry test. Using such a test to provide information on students' entry behaviors is an example of diagnostic evaluation.

Formative evaluation may be done during a program of work: for example, during a lesson. Its primary objective is to provide feedback to students and teachers who will then decide in what direction to proceed. For example, if during a lesson evaluation indicates that students are grasping what is being taught, the teacher may decide to continue as planned. On the other hand, if the evaluation indicates that students are not following the lesson, the teacher wisely deviates from his/her plan. The teacher may do additional and different examples, reteach part(s) of the lesson, use a different strategy or method, and so on. In other words, formative evaluation is intended to help the teacher to improve his/her instructional practices so as to promote better learning by the students. Some element of diagnosis is involved here, too.

The teacher can also use formative evaluation to keep students informed about their individual progress toward a goal so that the students can take the necessary measures to improve their performance. In a wider sense, formative evaluation may direct a reexamination of the appropriateness of objectives, materials, content, teaching methods and evaluation procedures related to a program of work.

Formative evaluation requires that the teacher monitor the students' progress closely. An examination of students' written work could reveal whether they are following the lesson or not. Therefore, it is necessary for the teacher to assign written activities during a lesson and to move around the class to spot check students' work. However, written work alone is inadequate (NCTM, 1991). Oral work could also be helpful (Buschman, 1995; NCTM, 1989; 1991). Asking students How? What? and Why? questions could help to identify students' specific misconceptions. For example, the teacher could ask students to explain how an answer was obtained or why a particular method was used. In this way the teacher can ascertain how students are thinking.

Observations by the teacher and self and peer evaluations are relevant in this context. Self and peer evaluations provide students with opportunities to identify their own mistakes and those of their peers. These forms of evaluations help students to develop their 'self-correcting' abilities, something we should aim at in mathematics teaching because in this way students become more independent learners.

As part of formative evaluation, instead of asking students 'Do you understand?' (a common practice among teachers), students could be asked specific questions relating to what was taught. The answers to these questions would be more helpful to the teacher and students because in many cases students claim they understand when in fact they do not.

One of the authors used the strategy of returning college students' assignments with comments, suggestions, and directions for improvement. These, coupled with the opportunity for further research, enabled the students to produce better work. There are at least two problems associated with this practice. First, although it worked very well with a small class, it would be more difficult to implement with much larger classes which are common in high and middle schools. Second, students may be reluctant to do an assignment twice.

Summative evaluation, the most common and most frequently used of the three types of evaluation, is usually done at the end of a program of work or a series of lessons. For example, it is done at the end of a month, quarter, semester, grading period or academic year. Its main intention is to obtain and report information about students. Based on this information a final grade (or certificate/diploma in some cases) is awarded. This final grade could be a combination of several grades. Generally, summative evaluation is not used often to provide feedback information. However, we do not see why it cannot be used for this purpose. The practice of providing students with the opportunity to redo their assignments with the objective of improving them (as well as their grades) as explained earlier in this paper is also relevant to summative evaluation. Summative evaluation usually takes the form of quizzes, tests, examinations, portfolios, individual and group projects, and presentations, or any combination of these. Based on the recommendation of NCTM (1989), an objective evaluation of the student is likely if several sources of information are used.

CONCLUSION

A critical question for the teacher is: What relative emphasis is to be placed on these three types of evaluation? This is difficult to answer. The answer may be related to the type of school: elementary, middle, or high. Much emphasis is usually placed on summative evaluation. This is understandable because parents, administrators, colleges, employers, and so forth, want to see what grades a student has. Unfortunately, the same emphasis has not been placed on diagnostic and formative evaluations. Since final grades depend to some extent on diagnostic and formative evaluation, greater emphasis on these types of evaluation is likely to result in improved as well as more accurate final grades. We, therefore, recommend that teachers emphasize diagnostic and formative evaluations more than they currently do. Another important concern of the teacher is the evaluation of aspects of the affective domain. Admittedly this is difficult for various reasons, but one cannot help observing that traditionally school evaluations have been exclusively concerned with the cognitive domain. We think that the time has come for teachers to begin to evaluate students' interests in and their attitudes toward mathematics, as part of diagnostic and formative evaluations.

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"No amount of experimentation can ever prove me right; a single experiment can prove me wrong."
--Albert Einstein