Chapter 1
Formative Assessment: A Critical Component in the Teaching-Learning Process

Denisse R. Thompson, Megan Burton, Annalisa Cusi and David Wright

Abstract This introductory paper to the volume contrasts formative assessment with summative assessment and describes the importance of formative assessment to classroom instruction. In particular, it argues that a task is formative to the extent that data from the task are used to enhance and inform further instruction rather than simply to provide an evaluation of a student or of instruction. The use of design research as a mechanism to develop sound classroom assessment is outlined because a design science framework provides a means to tie together varied exemplars of innovations in assessment. A cycle of task implementation and revision can lead to improved assessment practices.

Keywords Design research · Formative assessment · Summative assessment Evaluation

D. R. Thompson (✉)
University of South Florida, Tampa, FL 33620, USA
e-mail: denisse@usf.edu

D. R. Thompson
College of Education, EDU105, Tampa, FL 33620, USA

M. Burton
Auburn University, 5020 Haley Center, Auburn, AL 36849, USA
e-mail: megan.burton@auburn.edu

A. Cusi
University of Turin, Via Tamburini 45, 42122 Reggio Emilia, Italy
e-mail: annalo@tin.it

D. Wright
Research Center for Learning & Teaching, Newcastle University, Newcastle upon Tyne NE1 7RU, UK
e-mail: wrightdavidg@gmail.com

D. R. Thompson et al. (eds.), *Classroom Assessment in Mathematics*, ICME-13 Monographs, https://doi.org/10.1007/978-3-319-73748-5_1

1.1 Introduction

For much of the general public, including parents and politicians, assessment is often synonymous with tests. But assessment can and should be much more than just a test. In fact, one way to define *assessment* in mathematics is "as the process of gathering evidence about a student's knowledge of, ability to use, and disposition toward, mathematics and of making inferences from that evidence for a variety of purposes" (National Council of Teachers of Mathematics [NCTM] 1995, p. 3). In contrast, *evaluation* is "the process of determining the worth of, or assigning a value to, something on the basis of careful examination and judgment" (NCTM 1995, p. 3). Tests, then, are a means of evaluation, and evaluation is just one aspect of assessment.

The tension implicit in the previous paragraph reflects the fact that assessment has both formative and summative perspectives. A given assessment task can be either formative or summative, depending on how the information gathered from that task is used. If an assessment task is used for accountability purposes, at the individual student level or to make value judgments about the quality of education in a school or country, then that assessment task is *summative*; most large-scale external assessments or classrooms assessments used at the end of a unit of study fit within this category. However, when assessment tasks are used to collect insight into students' thinking that can inform the teacher or the students about their learning which is then used to guide further instruction, the assessment task is *formative*; tasks and activities that help move students' thinking forward and help guide teachers as they make instructional decisions fit within this side of the assessment coin.

Too often, assessment is viewed as something that occurs at the end of a unit of study or a specific time period. However, assessment "that enhances mathematics learning becomes a routine part of ongoing classroom activity rather than an interruption. … [and is] an integral part of instruction that encourages and supports further learning" (NCTM 1995, p. 13). The papers in this volume take this view of assessment—as an ongoing and integral part of instruction to enhance the learning of students.

1.2 The Role of Formative Assessment in the Classroom

Black and Wiliam (2009) describe formative assessment in terms of decisions made based on the assessment rather than on the actual collection of information from the assessment. Assessment is formative

> to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded than the decisions they would have taken in the absence of the evidence that was elicited. (p. 9)

As noted by Wiliam, this definition means that formative assessment necessitates "that one is clear about what it is that students are to learn, but it does not impose a particular view of the mathematics curriculum, nor does it entail any particular view of what happens when learning takes place" (2015, p. 250). That is, a determination of the nature of an assessment depends on how information from that assessment is used. A given task, even an end-of-unit test, could be formative if it is used to guide instruction or help teachers determine how to move students' learning forward, but could be summative if it is used solely to provide a grade.

The definition of formative assessment posited by Black and Wiliam poses a challenge for teachers, educators, and researchers. To gain the type of information needed to make effective instructional decisions, cognitively demanding tasks are needed that focus on conceptual understanding rather than just surface knowledge. Identifying and developing such tasks is not only a challenge for teachers, but is also a challenge for students who are asked to think mathematically in ways that involve more than just procedures and to explain their thinking in multiple ways—via pictures, words, symbols, or in some other format. Students and their teachers need many opportunities to engage with such tasks to develop an appreciation for the extent to which they can facilitate the learning process.

Over the last three decades, in particular, there has been a recognition around the globe of the need to engage many more students in mathematics, and to ensure that all students have an opportunity to be successful. As a consequence, mathematics educators in many countries have emphasized the importance of a student-centered classroom rather than just a teacher-centered or teacher-directed one. Formative assessment is a critical component of shifting to a student-centered perspective because it places the student at the center of the assessment process, through having students assess their own learning as well as supporting the learning of classmates. Black and Wiliam stress that, together with the teacher and the learner himself, fundamental agents in the assessment processes are the peers. Peers can challenge learners to reflect on their own thinking, helping them "to make unconscious processes overt and explicit and so making these more available for future use" (2009, p. 19). As Leinwand and colleagues note, "an important goal of assessment should be to make students effective self-assessors, teaching them how to recognize the strengths and weaknesses of past performance and use them to improve their future work" (2014, p. 95). Through both self-assessment and peer assessment of present and past performance, students become the center of the instruction and assessment cycle.

1.3 Design Research in Classroom Assessment

The report *Knowing What Students Know* (Pellegrino et al. 2001) identifies progress in the science of designing assessments as a key factor in enhancing classroom assessment. The report provides a range of assessment examples and steers the analysis of them towards a science of design:

> while it is important to carefully analyze each of the examples as a separate instance of innovative design, they also need to be analyzed as a collective set of instances within a complex 'design space.' The latter can be thought of as a multivariate environment expressing the important features that make specific instances simultaneously similar and different. (Pellegrino et al. 2001, p. 304)

Developments in design science in recent years (Barab and Squire 2004; Bereiter 2002; Burkhardt 2006; Cobb et al. 2003; DBRC 2003; Kelly 2003; van den Akker et al. 2006) provide a clearer view of what might be required for the design of effective assessments. The principles of design research can be described as:

> a formative approach in which a product or process (or 'tool') is envisaged, designed, developed and refined through cycles of enactment, observation, analysis and redesign, with systematic feedback from end-users. Educational theory is used to inform the design and refinement of the tools, and is itself refined during the research process. Its goals are to create innovative tools for others to use, to describe and explain how these tools function, account for the range of implementations that occur, and develop principles and theories that may guide future designs. Ultimately, the goal is transformative; we seek to create new teaching and learning possibilities and study their impact on end-users. (Wright et al. 2017, this volume as adapted from Swan 2014)

Examples within the papers in this volume provide windows into the different perspectives of the design process as researchers attempt to develop innovations in assessment occupying the complex design space identified in *Knowing What Students Know*. Teaching itself has also been characterized as a design science (Laurillard 2012) with technology and assessment playing crucial roles in improving practice. Hence, design research appears to provide a guiding framework for the development of assessment tasks and resources and might be adopted as a strategic approach for further research into assessment practices. A design framework provides one means to tie together different papers in this volume with their varied perspectives on formative assessment. As teachers take small steps in changing their assessment practice, reflect on the benefits and challenges of those changes, and then try again, they are actually engaging in aspects of design science (Suurtamm et al. 2016).

1.4 The Ongoing Nature of Formative Assessment

As noted in Suurtamm et al. (2016), the current climate in mathematics education encourages teachers to focus students' learning on both content and process and to ensure that students have robust mathematical proficiency consisting of appropriate skill proficiency, understanding of concepts, ability to reason, and productive attitudes towards learning mathematics. Research with Canadian teachers as well as with Finnish teachers has found that a focus on the use of formative assessment has encouraged teachers to view assessment as a social practice that becomes a natural part of the daily life of the classroom. As teachers move toward ongoing assessment practices that engage students in demonstrating robust mathematical proficiency,

they often face a number of dilemmas: conceptual dilemmas relate to viewing assessment as more than an end-of-unit result; pedagogical dilemmas focus on how to develop and implement ongoing assessment opportunities; cultural dilemmas address challenges faced by teachers and students when assessment practices change from the established practices in a schooling environment; and political dilemmas arise as teachers' assessment practices interact with district or national assessment practices (Suurtamm and Koch 2014). Although not characterized as such, the papers in this volume reflect various ways in which teachers and researchers have addressed one or more of these dilemmas.

References

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1–14.

Bereiter, C. (2002). Design research for sustained innovation. *Cognitive Studies, Bulletin of the Japanese Cognitive Science Society, 9*(3), 321–327.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability, 21*(1), 5–31.

Burkhardt, H. (2006). From design research to large-scale impact: Engineering research in education. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 121–150). London, UK: Routledge.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9–13.

DBRC [The Design-Based Research Collective]. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8.

Kelly, A. (2003). The role of design in educational research. *Educational Researcher, 32*(1), 3–4.

Laurillard, D. (2012). *Teaching as a design science*. London, UK: Routledge.

Leinwand, S., Brahier, D. J., Huinker, D., Berry, R. Q., III, Dillon, F. L., Larson, M. R., et al. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics*. Reston, VA: Author.

Pellegrino, J., Chudowsky, N., & Glaser, R. (Eds.). (2001). *Knowing what students know: The science and design of educational assessment*. Washington, DC: National Research Council, National Academy Press.

Suurtamm, C., & Koch, M. J. (2014). Navigating dilemmas in transforming assessment practices: Experiences of mathematics teachers in Ontario, Canada. *Educational Assessment, Evaluation and Accountability, 26*(3), 263–287.

Suurtamm, C., Thompson, D. R., Kim, R. Y., Moreno, L. D., Sayac, N., Schukajlow, S., et al. (2016). *Assessment in mathematics education: Large-scale assessment and classroom assessment*, ICME-13 Topical Surveys. SpringerOpen.

Swan, M. (2014). Design research in mathematics education. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 148–152). Dordrecht, The Netherlands: Springer.

van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (Eds.). (2006). *Educational design research*. London, UK: Routledge.

Wiliam, D. (2015). Assessment: A powerful focus for the improvement of mathematics instruction. In C. Suurtamm & A. Roth McDuffie (Eds.), *Assessment to enhance teaching and learning* (pp. 247–254). Reston, VA: National Council of Teachers of Mathematics.

Wright, D., Clark, J., & Tiplady, L. (2017, this volume). Designing for formative assessment: A toolkit for teachers. In D. R. Thompson, M. Burton, A. Cusi, & D. Wright (Eds.), *Classroom assessment in mathematics: Perspectives from around the globe* (pp. 207–228). Cham, Switzerland: Springer International Publishing AG.

Author Biographies

Denisse R. Thompson is Professor Emeritus of Mathematics Education at the University of South Florida in the U.S., having retired in 2015 after 24.5 years on the faculty. Her research interests include curriculum development and evaluation, with over thirty years of involvement with the University of Chicago School Mathematics Project. She is also interested in mathematical literacy, in the use of children's literature in the teaching of mathematics, and in issues related to assessment in mathematics education. She served as co-chair of Topic Study Group 40 on classroom assessment at ICME 13. In addition, she is a co-editor of the series *Research in Mathematics Education*, published by Information Age Publishing.

Megan E. Burton is an Associate Professor and the elementary education program coordinator at Auburn University, Alabama (USA). She teaches and advises undergraduate and graduate students in elementary education and conducts research related to elementary mathematics education, with focus on elementary teacher change, inclusion, and rural education. As a former elementary teacher with experience in inclusion and English Language Learners, Burton is committed to classrooms that allow all students to encounter strong mathematics instruction in meaningful, differentiated ways.

Annalisa Cusi graduated in Mathematics at Modena and Reggio Emilia University in 2001, where she obtained a Ph.D. in Mathematics in 2009. She's been teaching mathematics and physics in upper secondary school since 2001. She worked as a research fellow at the University of Turin from 2014 to 2016 within the European Project FaSMEd. Her main research interests are innovation in the didactics of algebra; the analysis of teaching/learning processes, with a focus on the role played by the teacher; methods to promote early algebraic thinking in young students; teacher professional development; and formative assessment processes in mathematics.

David Wright is Senior Research Associate: Research Centre for Learning and Teaching, Newcastle University (United Kingdom) (now retired). David has fifteen years' experience teaching mathematics at secondary, further and higher education as an associate lecturer with the Open University. He was Subject Officer for Mathematics for the British Educational Communications and Technology Agency (Becta) for four years and ten years in initial teacher education and research at Newcastle University. He is the Scientific Director of the European Union research project: Formative Assessment in Science and Mathematics Education (FaSMEd).