FaSMEd Position Paper

The use of technology in formative assessment to raise achievement

Annalisa Cusi, Francesca Morselli, Cristina Sabena, University of Torino

1. Introduction

After a brief introduction on the main features of formative assessment and the role played by a good feedback practice, we focus on the possible ways in which technology could support formative assessment, presenting different examples. Because of the fundamental role that teachers could play in developing formative assessment by means of technology, we devote the second part of this paper to this aspect, focusing on the ways in which researchers could enable teachers overcome these difficulties.

2. What is formative assessment?

Black and William (2009) define formative assessment (in the following FA) with these words: *"Practice in a classroom 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).

FA, also in its interrelations with summative assessment (SA), has been a focus of educational research for years, as recent surveys testify (see for instance Bernholt et al. 2013). Comparing SA and FA, Bernholt et al. (2013) stress that, although FA share some similarities with SA, since they both involve the collection, interpretation and use of data, the main peculiarity of FA is related to its purpose, that is assisting learning. This is why FA is also called 'assessment for learning' (Irving 2006).

Enabling teachers to build on learners' prior knowledge and match their teaching to the needs of each learner (Swan, 2005), FA represents a powerful means for meeting goals for high-performance, high-equity of student outcomes, and for providing students with knowledge and skills for lifelong learning (OECD/CERI 2008).

Different research studies have highlighted fundamental elements of effective FA practices:

(1) FA should be planned and practiced systematically, that is, it should be integral to teaching and learning process (Looney 2010, Swan 2005), aligning with valued content standards that range from core principles and practices to basic knowledge and skills (Herman et al. 2005);

(2) Learning intentions and criteria for success should be clarified and shared with students (Black & William 2009) and attention should be focused on students' process of learning and on their progress toward those goals (Looney 2010, OECD/CERI 2008, FAST SCASS 2008);

(3) A range of divergent[1] assessment techniques are proposed (Swan 2005), together with realistic, challenging problems and tasks that elicit evidence of student learning and understanding (Herman et al. 2005, Black & William 2009, Looney 2010, OECD/CERI 2008);

(4) Teachers should engineer effective classroom discussions (Black & William 2009), fostering a classroom culture that encourages interaction and an active involvement of students in the learning process (Looney 2010, OECD/CERI 2008); this could be done, for example, assessing not only individuals but also group work (Swan 2005);

(5) Teachers should take account of the results from the assessment when adapting and changing their teaching (Swan 2005, Herman et al. 2005);

(6) Timely feedback, with a focus on the task at hand instead of marks or grades, should be provided in order to monitor learners' progressive development (Herman et al. 2005), helping them become more aware of where they are going, where their learning currently is and what they can do to move forward (Looney 2010, Swan 2005, OECD/CERI 2008, FAST SCASS 2008, Black & William 2009);

(7) Self-assessment and peer-assessment should be encouraged (Swan 2005, FAST SCASS 2008) to activate students as both instructional resources for one another and owners of their own learning (Black & William 2009).

3. The importance of a good feedback practice

As stressed before and highlighted by Black & William's definition, effective feedback from the different "actors" involved in this process plays a central role in FA. Nicol et al. (2006), who position their research on FA and feedback within a model of self-regulated learning, define feedback as "information about how the student's present state (of learning and performance) relates to goals and standards" (p.2). This is in tune with what Hattie and Timperley (2007) consider the three major questions, posed by the students and the teacher, to which effective feedback should answer: (1) Where am I going? (What are the goals?); (2) How am I going? (What progress is being made toward the goal?); (3) Where to next? (What activities need to be undertaken to make better progress?). Nicol et al. (2006) criticize the idea, widespread in higher education, that feedback can be conceptualised as a transmission process largely controlled by the teacher. They propose a model that distinguishes between *internal feedback*, generated by students' monitoring of their interactions with the task and the internal and external outcomes of their work, and *external feedback*, provided by the teacher, by a peer or by other means; external feedback must be interpreted, constructed and internalized by students to have a significant influence on subsequent learning. Moreover, they propose seven principles of good feedback practice in relation to the development of self-regulation, according to which good feedback practice: (a) helps clarify what good performance is; (b) facilitates the development of self-assessment in learning; (c) delivers high quality information to students about their learning; (d) encourages teacher and peer dialogue around learning; (e) encourages positive

[1] Divergent assessment (Swan 2005) is "characterized by open questions that allow learners opportunities to describe and explain what they know, understand or can do".

motivational beliefs and self-esteem; (f) provides opportunities to close the gap between current and desired performance; (g) provides information to teachers that can be used to help shape the teaching.

Focusing specifically on the content of feedback, Sadler (1989) identifies three conditions necessary for students to benefit from feedback: students must know what good performance is, how current performance relates to good performance, how to act to close the gap between current and good performance.

4. The role of technology in formative assessment

4.1 Different ways in which technology can give support

In order to develop effective systems for formative assessment supporting adaptive and/or differentiated instruction, teachers need diagnostically useful and actionable information, not just classification data such as numeric test scores (Foshayla et al., 2012). For this reason, in the last decade different research projects have focused on the role played by technology in fostering FA (see, for instance, the CCMS Project: *Classroom Connectivity in Promoting Mathematics and Science Achievement*; the ITEAM Project: *Integrating Technology-Enhanced Assessment Methods*; the WHIRL Project: *Wireless Handhelds In Reflection on Learning*; the FANC Project: *Formative assessment in a networked classroom*; the TLT Project: *Teacher learning of technology-enhanced formative assessment;* eVIVA Project: *Electronic virtual ipsative valid assessment*[2]).

Quellmalz (2013) introduces different ways in which technology could support FA: (a) it enables the collection of resources, by offering online databases that link curriculum, district, state, and national standards; (b) it can make available to teachers pools of assessment tasks and items that they can embed within lessons and units; (c) it enables the assessment of those aspects of cognition and performance that are complex and dynamic, through technology-based systems characterized by rich, complex, authentic contexts; interactive, dynamic responses; individualized feedback and coaching; diagnostic progress reporting (Quellmalz et al., 2012). In relation to this last point, Looney (2010) observes that different ways to assess student performance are incorporated by several new technologies, designed to support rapid assessment of student understanding, timely and targeted feedback, interactive learning and assessment of higher-order skills, tracking of students' learning in different contexts and over time. Van den Heuvel-Panhuizen et al. (2011) add that that ICT-based assessment could enable to: (a) use high-demanding tasks; (b) make tasks more accessible for students; (c) reveal students' thinking and solution processes.

---

[2] CCMS Project - Institute of Education Sciences, funded by U.S. Department of Education (Grant n. R305K050045); ITEAM Project - University of Hertfordshire, JISC funded project funded under their Assessment and Feedback programme; WHIRL Project - SRI International, funded by the National Science Foundation (Grant n. REC-0126197); FANC Project - funded by National Science Research and Evaluation on Education in Science and Engineering program (Grant n. DRL 0723953); TLT Project - funded by US National Science Foundation (grant n. TPC-0456124); eVIVA - Ultralab, a learning and technology research unit at Anglia Polytechnic University, funded by the Qualifications and Curriculum Authority (QCA).

4.2 Examples of technology use in formative assessment

In the following sections we explore, in particular, two ranges of technologies that have been developed to integrate technological development and FA: the Computer aided assessment and the Connected classroom technologies.

4.2.1 Computer aided assessment

Computer aided assessment (CAA) is widespread especially within higher education and it is used as a diagnostic, formative and summative tool (Jenkins, 2004). Referring to FA, Jenkins observes that, although a multiple-choice questions approach exploits some of the strengths of using computers, focusing only on multiple choice-questions limits the possibilities of use of ICT. He therefore suggests looking at web technologies to promote the use of different assessment methods within a range of approaches, including peer-assessment, self-assessment, and group-based assessment. In this way CAA can encourage collaborative and reflective styles of learning and could also become adaptive, in that the outcomes of an assessment can be used to determine further questions or information that the student needs to address. This is in tune with Bernholt et al.'s (2013) observation about the key areas relevant for the design of e-assessments: self-assessment, peer assessment, diagnostic assessment, adaptive assessments and interaction between the teacher, learner and computer.

Charman (1999) has identified different advantages of using CAA for FA in higher education. Among them: repeatability; immediacy of response to the student; immediacy of assessment's results to teachers for monitoring and adaptation; increasing the diversity of assessment; potential for assessments to be used at the most appropriate time; flexibility of access; student interest and motivation; student-centered skills and learning.

Wang (2008) suggests a way of using CAA as a formative tool also with young students, presenting the design of a Web-based quiz-game-like formative assessment (GAM-WATA) based on seven key strategies aimed at activating both a challenge mechanism and a game mechanism: the strategies 'repeat the test', 'timely feedback', 'query scores' enable to track learning status anytime and anywhere; the 'ask questions' strategy encourages students to discuss the questions with peers or teachers; 'all pass and then reward' and 'monitor answering history' let students query their own answering history after all items have been passed; finally 'Ask-Hint' strategy provides the info about how their peers answer each question for the less-competent students.

Wang's analysis shows that if the administering of FA only involves changing paper-and-pencil test into Web-based test without offering assessment strategies, this change will not necessarily improve the effectiveness of FA. Using more than one strategy in a Web-based FA system to provide feedback and enhance the human–computer interaction, instead, would have a positive influence on the effectiveness of the system.

4.2.2 Connected classroom technology

Connected classroom technology refers to a networked system of personal computers or handheld devices specifically designed to be used in a classroom for interactive teaching and learning (Irving, 2006). These technologies, defined WILDs (wireless internet learning devices) by Roschelle and Pea (2002), include *classroom response systems*, *networked graphing calculators* and *participatory simulations*. Connected classroom technologies are considered effective in enabling forms of participation in classrooms in which elements of online learning are integrated fully into face-to-face instruction (DeBarger et al., 2010).

A first example of these technologies is the so-called *Classroom response system* (CRS), that consists of a set of input devices for students, communicating with the software running on the instructor's computer, enabling the instructor to pose questions to students and take a follow-up poll (Beatty & Gerace 2009, Looney 2010). The devices usually allow students to respond to yes/no or multiple-choice questions, but some of them also accept free text or numeric answers. After the instructor has posed a question, typically students beam answers to a receiving station with an accompanying anonymous display of histograms of students' answers. A subsequent public examination of the solutions and of the subtended alternative conceptions helps students understand their role as critical listeners and thinkers in the classroom (Irving, 2006) and guide teachers to adapt instruction depending on the results of the poll (Roschelle et al., 2007). Beatty and Gerace (2009) observe that one crucial feature of CRSs is that they simultaneously provide anonymity and accountability, support collecting answers from all students in a class, rather than just the few who speak up or are called upon and enable recording the data of students' individual and collective responses for subsequent analysis.

Additional names have been given to this class of systems: clickers, classroom communication system (CCS), audience response system (ARS), voting machine system, audience feedback system. Roschelle et al. (2004) have introduced the term CATAALYST to refer to these systems, as an acronym for "Classroom Aggregation Technology for Activating and Assessing Your Students' Thinking".

Another example of connected classroom technologies are *Networked graphing calculator systems*, which enable information to be aggregated and mutually exchanged and accessed, as well as being displayed visually for all to see. Among them is the TI-Navigator, which enables teachers to select one of the handheld screens to be shared, to send immediate polls to the students, to collect students' answers and add them to the class portfolio. These supports could foster the development of a collaborative classroom environment by enhancing student interactions, focusing students' attention on multiple responses, and providing opportunities for students to peer- and self-assess student work (Clark-Wilson, 2010). Clark-Wilson highlights the opportunities, given to teachers and students by TI-Navigator, to engage in a range of FA practices: providing teachers with additional insight into their students' sense-making processes; promoting purposeful classroom discourse, prompted by shared responses and screens; developing strategies for students' peer assessment and self-assessment. Robutti (2010) stresses that this connectivity software enables to work together, share the products of problem-solving strategies, discuss on a theme and give or receive feedback in real time. She highlights that an important feature of this kind of activity is that the class discussion can be deeply intertwined with the group work, because at any moment the public screen gives information on what students do on their private screens.

A third example of connected classroom technologies are *Participatory simulations*, which involve graphing calculators that are connected to hubs that have a wireless connection to a computer that acts as a central server. Students are asked to “act out the roles of individual system elements and then see how the behavior of the system as a whole can emerge from these individual behaviors. The emergent behavior of the system and its relation to individual participant actions and strategies can then become the object of collective discussion and analysis” (Wilensky & Stroup 2000, p.2). Ares (2007) observes that these systems enable students to deal with multiple modes of contribution (language, text, physical and electronic gestures), engage with multiple representations of phenomena (texts, graphs, visual displays of emergent systems, language), and be involved in inquiry-oriented discussions.

A final example of connected classroom technology developed in the last years is *Group Scribbles*, a software platform designed by Roschelle et al. (2007) to support teachers in inventing and enacting new forms of collaboration and coordination in their classroom and “maximize the power of ink, improvisation, and interactive engagement in a wireless, tablet-based learning environment” (p.39). The Scribble Sheets are small squares of virtual paper through which students can express their thoughts via a quick sketch or a few words, which can be posted to public boards, visible to all participants, or to a private board on which to create and arrange Scribble Sheets. According to Roschelle et al. (2007), FA and adaptive instruction are possible throughout the lesson with Group Scribbles because both the teachers and students receive rich and continuous feedback on what students know and have the possibility to act more like a community than they would in a conventional classroom.

Summing up, these are the innovative features of connected classroom technologies that, as outlined by researchers, make them effective tools to develop FA:

(1) they give immediate information to teachers, enabling them to monitor students’ incremental progress and keep them oriented on the path to deep conceptual understanding, providing appropriate remediation to address student needs (Irving 2006, Shirley et al. 2011);

(2) they support positive student’s thinking habits, such as arguing for their point of view (Roschelle et al. 2007), seeking alternative representations for problems, comparing and contrasting different solution strategies, explaining and describing problem solving strategies (Irving 2006);

(3) they create immersive learning environments that highlight problem-solving processes and make student thinking visible (Looney 2010);

(4) they enable most or all of the students contribute to the activities and work toward the classroom performance, taking a more active role in the discussions (Shirley et al. 2011, Roschelle & Pea 2002);

(5) displaying the aggregated student results, they can give powerful clues to what students are doing, thinking, and understanding (Roschelle et al. 2004) and enable teachers "take the pulse" of learning progress for the classroom as a whole (Roschelle & Pea 2002);
(6) they provide students with immediate private feedback, encouraging them to reflect and monitor their own progress (Roschelle et al. 2007, Looney 2010);
(7) they provide opportunities for independent and collaborative learning (Looney 2010), fostering classroom discourse (Abrahamson et al. 2002; Dufresne et al. 1996; Shirley et al. 2011; Roschelle et al. 2007);
(8) they offer potentially important avenues for enlarging the types of cultural practices used as resources for learning and foster students' dynamic engagement in conceptual, collective activities which are more akin to practices of professional communities, making them become knowledge producers rather that consumers (Ares 2008);
(9) they enable to carry out a multi-level analysis of patterns of interactions and outcomes thanks to their potential to instrument the learning space to collect the content of students' interaction over longer timespans and over multiple sets of classroom participants (Roschelle & Pea 2002).

Notwithstanding the potential of these tools, many researchers have stressed that the effectiveness of connected classroom technology depends on the skill of the instructor (Irving, 2006) and on his/her ability to incorporate procedures such as tracking students' progress, keeping students motivated and enhancing reflection with technologies (DeBarger et al., 2010). For this reason the last paragraph will be devoted to the research on the role played by the teacher in developing FA activities by means of technological tools.

5. The role of the teacher in using technology to develop FA

Different studies have highlighted that connected classrooms technologies (CCT) have increased the complexity of the teacher's role with respect to 'orchestrating' the lesson (Clark-Wilson 2010, Roschelle & Pea 2002). As a "conductor-of-performances", in fact, he/she has responsibility for choosing and sequencing the material to be performed, interpreting the performance, and guiding it toward its desired forms (Roschelle & Pea 2002). Therefore, in order to bring about improvements to student participation in class and achievement, technology must be used in conjunction with particular kinds of teaching strategies (Penuel et al. 2007, DeBarger et al. 2010).

Some studies have stressed that it takes a considerable amount of time for teachers to change their beliefs about teaching and learning, classroom culture and the teacher's role (Foshayla et al., 2012) and their ways of being so that FA with technology becomes an integral part of their practice (Feldman & Capobianco, 2008). It is, in fact, possible to be expert in various combinations of the technologies without having expertise in FA (Feldman & Capobianco, 2008).

Foshayla et al. (2012) introduce a three-level developmental progression for teachers' full transition to the highest level of expertise: (1) the *Immediate level*, which describes many teachers at the beginning of their use of technology for FA, who usually examine students' feedback after class and take decisions about "what to do next" from day to day, informed by this feedback; (2) the *Expert* *level*, typical of teachers who feel comfortable with the mechanism of obtaining frequent student data and are able to use these data to make "real time" decisions about skill steps or concepts needing re-teaching; and (3) the *Master level*, which is characterized by the teacher's command of the full range of advanced interactive capabilities that technology offers, and his/her ability to use them in an innovative way in classroom teaching to deepen student understanding and to differentiate instruction to support all learners.

Penuel et al. (2007) have identified similar profiles of teachers' use of classroom performance systems related to the frequency of use and the breadth of instructional strategies employed: (1) *Infrequent user*, who rarely uses CPS and tends not to use the full range of capabilities of the system; (2) *Teaching self-evaluator*, who often uses the CPS, but usually only for summative assessment purposes, to gain feedback on the effectiveness of his/her own teaching; (3) *Broad but infrequent user*, who uses the CPS less frequently than self-evaluators, but for both formative and summative assessment purposes, to adjust instruction and to make judgments about what their students had learned; (4) *Broad and frequent user*, who uses the CPS frequently and for a wide range of purposes, often involving students in peer and whole-class discussions.

Shirley et al. (2011) have analysed the costs and benefits of implementing CCT in middle and high school Mathematics and Science classrooms. With regard to the teachers' difficult evolution toward the highest level of expertise in the use of technology, they highlight that all the teachers experience initial challenges in setting up computer equipment and that initially the lack of familiarity with the technology sometimes could even impede instruction. Many of the costs associated with this implementation are therefore connected to factors related to instrumentality.

Therefore teachers need support for the design of these strategies (DeBarger et al., 2010). DeBarger et al. (2010) propose a frame aimed at providing teachers with different possible sequences of movement across public and private workspaces and between computer-mediated and face-to-face communication to make student thinking transparent (*IFAs - Interactive formative assessments*). Specifically, they have identified a collection of seven (science) teaching routines that describe a sequence of instructional moves for creating a particular kind of interactive FA opportunity: concept mapping, test design, data creating and sharing, question posing and categorizing, constructing a model, interpreting and using a model, designing tests, predicting with reasons.

Similarly, Beatty and Gerace (2009) developed *technology-enhanced formative assessment (TEFA)*, a pedagogical approach for teaching science and mathematics with the aid of a classroom response system (CRS). To help teachers implement FA, the TEFA approach introduces an iterative cycle of question posing, answering, and discussing, which forms a scaffold for structuring whole-class interaction. The essential phases of the cycle are: 1) pose a challenging question or problem to the students; 2) have students wrestle with the question and decide upon a response; 3) use a CRS to collect responses and display a chart of the aggregated responses; 4) elicit from students as many different reasons and justifications for the chosen responses as possible; 5) develop a student-dominated discussion of the assumptions, perceptions, ideas, and arguments involved; 6) Provide a summary, micro-lecture, meta-level comments.

6. Final remarks

In this paper we have outlined some aspects related to the development of FA by means of digital technology, analyzing the main features of FA, the potentials of widespread digital technologies as tools to foster FA, the teaching practices that have been identified as "effective" by research and the challenges for teachers. A research aimed at fostering students' achievement through technology-enhanced FA needs to consider all these aspects. In particular, the fundamental and complex role played by teachers suggests focusing on teacher professional development activities in order to foster teacher transition to a high level of expertise.

References

Abrahamson, L., Davidian, A., and Lippai, A. (2002). *Wireless calculator networks –Why they work, where they came from, and where they're going.* Paper presented at the 13th Annual International Conference on Technology in Collegiate Mathematics. Atlanta, Georgia.

Ares, N. (2007). Challenges in operationalizing cultural practices in classroom and peer communities. *International Journal of Educational Research*, 45(6), 404–419.

Ares, N. (2008). Cultural practices in networked classroom learning environments. *Computer-Supported Collaborative Learning*, 3, 301–326.

Bernholt, S., Ronnebeck, S., Ropohl, M., Koller, O. and Parchmann, I (2013). ASSIST ME. Report on current state of the art in formative and summative assessment in IBE in STM. ASSIST-ME Report Series Number 1-2.

Beatty, I.D, and Gerace, W.J. (2009). Technology-Enhanced Formative Assessment: A Research-Based Pedagogy for Teaching Science with Classroom Response Technology. *Journal of Science Education and Technology*, 18, 146–162.

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

Charman, D. (1999). Issues and impacts of using computer-based assessments (CBAs) for formative assessment. In S. Brown, P. Race & J. Bull (eds.), *Computer-assisted Assessment of Students* (pp. 85-94). London: Kogan Page.

Clark-Wilson, A. (2010). Emergent pedagogies and the changing role of the teacher in the TI-Nspire Navigator-networked mathematics classroom. *ZDM Mathematics Education*, 42, 747–761.

DeBarger, A., Penuel, W. R., Harris, C. J., & Schank, P. (2010). Teaching routines to enhance collaboration using classroom network technology. In F. Pozzi & D. Persico (Eds.), *Techniques for fostering collaboration in online learning communities: Theoretical and practical perspectives* (pp. 224-244). Hershey, PA: IGI Global.

Dufresne, R. J., Gerace, W. J., Mestre, J. P., & Leonard, W. J. (2000). ASK-IT/A2L: Assessing student knowledge with instructional technology (technical report No. UMPERG-2000-09). Amherst: University of Massachusetts Physics Education Research Group.

FAST SCASS (2008). Attributes of effective formative assessment: A work product coordinated by Sarah McManus, NC Department of Public Instruction, for the Formative Assessment for Students and Teachers (FAST) Collaborative. Washington, DC: Council of Chief State School Officers.

Feldman, A. and Capobianco, B.M. (2008). Teacher Learning of Technology Enhanced Formative Assessment. *Journal of Science Education and Technology*, 17, 82–99.

Foshayla, W.R., and Bellman, A. (2012). A Developmental Model for Adaptive and Differentiated Instruction Using Classroom Networking Technology. *2nd International Conference on Future Computers in Education. Lecture Notes in Information Technology*, Vols. 23-24 (pp.90-95).

Hattie, J. and Timperley, H. (2007). The Power of Feedback. *Review of Educational Research* 77(1): 81–112.

Herman, J. L., Osmundson, E., Ayalya, C., Schneider, S., & Timms, M. (2005). The nature and impact of teachers' formative assessment practices. *Paper presented at the Annual meeting of the American Educational Research Association*. Montreal, Quebec, Canada.

Irving, K.I. (2006). The Impact of Educational Technology on Student Achievement: Assessment of and for Learning. *Science Educator*, 15(1), pp. 13-20.

Jenkins, M. (2004). Unfulfilled Promise: formative assessment using computer-aided assessment. *Learning and Teaching in Higher Education*, Issue 1, 67-80.

Looney, J. (2010). Making it Happen: Formative Assessment and Educational Technologies. *Thinking Deeper Research Paper n.1*, *part 3*. Promethean Education Strategy Group.

Nicol, D.J., and Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, 31(2), 199-218.

OECD/CERI (2008). Assessment for learning. The case of formative assessment. OECD/CERI International Conference "Learning in the 21st Century: Research, Innovation and Policy"

Penuel, W.R., Boscardin, C.K., Masyn, K. and Crawford, V.M. (2007). Teaching with student response systems in elementary and secondary education settings: A survey study. Educational *Technology Research and Development*, 55, pp. 315–346.

Quellmalz, E. S. (2013). Technology to Support Next-Generation Classroom Formative Assessment for Learning. http://www.wested.org/resources/technology-to-support-next-generation-classroom-formative-assessment-for-learning/

Quellmalz, E. S., Timms, M. J., Buckley, B. C., Davenport, J., Loveland, M., & Silberglitt, M. D. (2012). 21st century dynamic assessment. In J. Clarke-Midura, M. Mayrath, & C. Dede (Eds.), *Technology-based assessments for 21st century skills: Theoretical and practical implications from modern research* (pp. 55–89). Charlotte, NC: Information Age Publishing.

Robutti, O. (2010). Graphic calculators and connectivity software to be a community of mathematics practitioners. *ZDM* 42, pp. 77–89.

Roschelle, J., and Pea, R. (2002). A walk on the WILD side. How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology*, 1(1), 145-168.

Roschelle, J., Penuel, W.R. and Abrahamson, L. (2004). The networked classroom. *Educational Leadership*, 61(5), 50-54.

Roschelle, J., Tatar, D., Chaudhury, S.R., Dimitriadis, Y. and Patton, C. (2007). Ink, Improvisation, and Interactive Engagement: Learning with Tablets. *Computer*, 40 (9), 42-48. Published by the IEEE Computer Society.

Sadler, D.R. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, 18, 119-144.

Shirley, M., Irving, K.E., Sanalan, V.A., Pape, S.J. and Owens, D. (2011). The practicality of implementing connected classroom technology in secondary mathematics and science classrooms. *International Journal of Science and Mathematics Education*, 9, 459-481.

Swan, M. (2005). *Standards Unit. Improving learning in mathematics: challenges and strategies*. Produced by the Department for Education and Skills Standards Unit.

Van den Heuvel-Panhuizen, M., Kolovou, A., & Peltenburg, M. (2011). Using ICT to improve assessment. In B. Kaur, & W.K. Yoong (Eds), Assessment in the mathematics classroom: Yearbook 2011, Association of Mathematics Educators (pp. 165 -185). Singapore: World Scientific and AME.

Wang, T. (2008) Web-based quiz-game-like formative assessment: Development and evaluation. *Computers & Education*, 51, 1247–1263.

Wilensky, U., & Stroup, W. (2000). Networked gridlock: Students enacting complex dynamic phenomena with the HubNet architecture. *Paper presented at the Fourth Annual International Conference of them Learning Sciences*, Ann Arbor, MI.