

Assessment and Collaborative Inquiry: A Review of Assessment-Based Interventions in Technology-Enhanced K-14 Education

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Abstract: We provide a conceptual review of the research on assessment in technology-enhanced collaborative inquiry in K-14 education, published between 1994 and 2013. The 57 studies that satisfied our search criteria were coded using a framework that considered the nature of the assessment intervention, the purposes of the assessment intervention, and the role of technology in student learning. This allowed us to identify four types of assessment interventions. The findings indicated that only interventions in the immersion orientation seemed to help students *learn how to learn*. Such assessment practices enabled students to learn actively and to learn both disciplinary substance and metacognitive/regulative skills. However, relatively few studies clearly integrated assessment and learning. The main contributions of this study are the coding framework and the four patterns of assessment interventions. Together, they provide a new way of thinking about the design of practice. The review provides guidance for the shift of assessment practice to scaffold learning of this field.

Keywords: assessment, learning, technology, collaborative inquiry, scaffolding

Introduction

In the last few decades, collaborative inquiry has emerged as an important research area in computer-supported collaborative learning (Stahl, 2002). Despite substantial development in learning theories, assessment, and the use of educational technology, it remains unclear whether assessment practices have changed in classrooms where educational technology is used to support collaborative inquiry. Theoretical developments suggest that assessment should be used to both measure students' achievements and to scaffold future learning; furthermore, an increased emphasis on collaboration in learning requires assessment procedures that consider both individual and shared achievements (van Aalst, 2013). The role of students in assessment also continues to be neglected. Educational technologies often store large amounts of information about the learning process, which could be used to enhance learning. Thus, assessments that involve educational technology are of particular interest. The use of assessment data to improve learning is gaining some momentum in the policy discourse on education (Datnow & Park, 2014).

Most reviews of the assessment literature have focused on higher education; relatively few have focused on assessment in K-14 education. At the same time, there is a lack of systematic empirical evidence on how assessment practices can be designed to guide learning. This study reviews the latest developments in assessment in technology-enhanced K-14 education, with a view to articulating an agenda for further research and development. The question that drove the review is How are assessment interventions designed to scaffold students' learning? In this study, assessment refers to any evaluative practice that is "part of everyday practice by students, teachers and peers that seeks, reflects upon and responds to information from dialogue, demonstration and observation in ways that enhance ongoing learning" (cited in Klenowski, 2009, p. 268). The definition is used to distinguish this type of assessment practice from others that focus on measuring students' academic achievement through standard tests, or final exams.

In the following section, we present the method and procedures used in the literature review, followed by a detailed analysis of the reviewed studies. We then discuss the key issues and consider the implications of this study for assessment practice and further research.

Methods

Criteria for inclusion

The following five criteria were established to select studies for inclusion in the analysis. (1) *Empirical and peer-reviewed journal articles published in English between 1994 and 2013*. Non-empirical literature, review articles, opinion articles, conference papers, dissertations, book chapters, and books were selected in the initial stages of the literature search to serve as sources of relevant research. However, they were not included in the

final analysis. (2) *Studies conducted in K-14 education, excluding medical education.* We chose K-14 rather than K-12 education because there is considerable variation in when postsecondary education starts. For example, the content of college courses can be similar to that in the final year of high school and many high schools offer university-level courses in the final year. (3) *Studies that focused on educational and formative assessment practices.* Studies that focused on assessment practices that facilitate and transform learning, rather than those used for measurement or educational evaluation purposes were included. (4) *Studies that used technology to enhance student learning and assessment activities.* We only included studies that involved technology in some part of the learning and assessment activities, such as providing information and feedback on performance, creating authentic learning contexts to increase learners' engagement, creating opportunities for collaboration, reflection, and self-regulation, and providing advice before and during the assessment activities. (5) *Studies that provided a clear description of the methodological characteristics necessary for our analysis.* We only included articles with a clear description of the following variables: *the definition of assessment, data source, sample sizes, treatment, research design, and outcome.* If the outcomes were not sufficiently well defined or measured for us to assess the accuracy of the results, then the study was excluded.

Search procedure

The literature search was conducted in a three-step process. First, an exhaustive search of peer-reviewed journals was conducted using the EBSCOhost, ERIC, and PsycINFO databases. The following combinations of descriptors were used: formative assessment, self-assessment, peer-assessment, embedded and transformative assessment, and reflective assessment. This search retrieved 123 studies based on the examination of the titles. Second, to locate other relevant studies, an exhaustive search of the major journals that publish research in the learning sciences, specialize in assessment in education, and specialize in reviews of educational research studies was conducted. The literature search was conducted in learning sciences journals because this is an emerging interdisciplinary field that aims to improve formal and informal education by designing complex learning environments and studying how learning is accomplished in them.

These two steps retrieved 250 studies. After applying the selection criteria to the titles, abstracts, and research designs of these 250 studies, 46 studies were retained. This significant reduction was due to the limited number of studies conducted in K-14 educational contexts and the extended use of the term *formative assessment* to refer to *any* kind of assessment adopted in the learning process. However, in most of these studies, assessment was only used summatively and students did not act as active agents who generated feedback, monitored their learning, and made further plans based on feedback/information to further transform their learning. In the third step of the literature search, ancestral and decendency searches were conducted by reviewing the references in the previously identified 46 articles and in relevant opinion and review articles to identify additional relevant research studies. An additional 11 studies that satisfied the inclusion criteria were identified at this stage, increasing the number of studies to 57.

Emergence of a coding framework

To determine how the design of assessment interventions can encourage guide (scaffold) learning and how scaffolds are used to make assessment practices work in a productive way, it was necessary to consider the detailed documentation of each study and to analyze the core characteristics of the assessments. A three-dimensional framework was developed to capture the core characteristics and features of such practices. By core characteristics we mean the goal/purpose of an intervention, the processes and activities planned to realize the goal, the role of technology in the process and activities, and the evidence collected to demonstrate success in achieving the goal. The three-dimensional framework was determined on the basis of a preliminary analysis of an initial sample of the articles, followed by further refinement after the preliminary analysis was presented to our research team.

The constant comparative method (Strauss, 1987; Strauss & Corbin, 1998) was used to create this coding framework. This is an iterative coding approach (Bogdan & Biklen, 1998; Miles & Huberman, 1994) that usually involves examining each individual article, forming various categories, comparing categories, and achieving category saturation. On the basis of this iterative process, three dimensions with subcategories were identified. The three dimensions were presented to our research team, and researchers with experience of coding provided feedback on the conceptual framework and the coding procedures. The conceptual framework for the review was reconceptualized and reframed accordingly, and the coding process went through a second iterative process. Finally, the following three dimensions with subcategories were identified: the nature of the assessment intervention, the purposes of the assessment intervention, and the role of technology in student learning (see Table 1). Each study received only one code in each of the three dimensions.

Table 1: Coding categories and descriptions

Nature of assessment intervention	Description
Culminating activity	One-time assessment activities that are connected or disconnected from curriculum or activities; the assessment requires student application of pre-determined criteria or construction of assessment criteria to evaluate their own or other's work after initial content instruction or after completing the whole or part of a scientific inquiry.
Continuous assessment	Assessment activities in which students improve their work based on continuous feedback or information from teachers, peers, technologies, or themselves. The feedback or information aims to narrow/close the gap between the present state and the desired goal (Bell & Cowie, 2001a).
Dynamic assessment	Activities in which players (e.g., researcher and student) interact in a guided learning situation in which the more experienced participant selects, focuses, and provides feedback on an environmental experience in such a way as to create appropriate learning sets (Magnusson et al., 1997). Participants' knowledge is assessed in the context of mediated learning situations that attempt to foster conceptual change in a specific domain.
Intrinsic component of learning	Assessment activities are incorporated into a holistic learning and teaching framework, in which learners perform the assessment throughout the inquiry and learning process.
Purpose	
Academic performance	Assessment is used to facilitate content retention and learning, with content as a body of correct information.
Disciplinary substance	Assessment is used to assess and enhance students' domain-specific ideas, thinking, and reasoning.
Learning how to learn	Assessment is used to scaffold students to develop self-regulative and metacognitive skills such as planning, monitoring, evaluation, and reflection.
The role of technology	
Providing/facilitating assessment and feedback	Offering regular and formative online tests, providing rapid and detailed feedback/prompts; supporting teachers/tutors to write assessments and feedback in a timely manner.
Making learning/assessment activities/tasks authentic	Providing an authentic context in which learning and assessment activities are performed; creating an assessment that is authentic to the concepts or competence being assessed or tested.
Creating opportunities/spaces for group work	Creating opportunities/space to facilitate collaboration and peer assessment; encouraging learners to stimulate and scaffold each other's learning; a virtual learning community to enable learners to collaborate with each other.
Providing information/opportunities to encourage learner reflection/self-regulation	Providing learners with information or opportunities that scaffold them to regulate their learning process toward an assessment goal, such as decoding the feedback message, internalising it, and evaluating and modifying their work with it; offering information or opportunities to help students develop reflective skills.

Results

Our review of the 57 studies indicated that assessment interventions were implemented in a variety of ways to support collaborative inquiry in technology-enhanced K-14 classrooms. The interventions ranged from those that used assessment as an added element of learning and aimed to improve academic performance by providing student feedback to those that emphasized assessment as an integral part of learning that helped students learn how to learn. Within this variation, four orientations were evident: interventions as an instrument to improve students' academic performance (outcome), interventions to facilitate collaboration in learning processes (collaboration), interventions as an instrument to help students learn disciplinary substance (disciplinary substance), and interventions that immerse students in the inquiry process to help them learn how to learn (immersion) (See Appendix).

Interventions to improve academic performance: Outcome-oriented

In eight studies (14%), interventions were used to enhance students' academic achievement. These interventions seemed to be guided by a tacit presumption that learning content consisted of a body of correct information, centered on terminology and measurable skills that was selected in advance as a learning objective. The interventions were used to narrow or close the gap between students' present performance and some targeted outcome. Interventions in this orientation facilitated assessment activities through scaffolds such as *assessment rubric, direct instruction, structuring the tasks, prompts, and assessment strategies*. For example, Hume and Coll (2009) reported on students' use of rubric-referenced assessment to rate peers' work. These assessment rubrics, which had specific evaluating dimensions (e.g., format, timing, and reporting requirements) scaffolded students to quantitatively rate peers' work. Similar directional scaffolds were provided by a Web-based assessment system (Wang, Wang, Wang, & Huang, 2006; Wang, 2007).

Interventions often provided *explicit instruction or* working examples to foster students' active involvement in assessment activities. In the study by Fontana and Fernandes (1994), direct instruction coupled with task structuring was used to facilitate students' assessment activities. For instance, in regular self-assessment activities, students were instructed to understand both the learning objectives and the assessment criteria, and were given opportunities to choose and use the learning tasks that provided them the scope to evaluate their learning outcomes. In Ozogul, Olina, and Sullivan (2006), working examples combined with assessment criteria were used to scaffold students' lesson plan writing.

Facilitating collaboration in assessment activities: Collaboration

The second orientation, collaboration, helped students to develop collaborative skills or to facilitate productive collaboration in assessment activities (eight studies, 14%). The intention was markedly different from the previous orientation's, and could be broadly described as focusing on collaboration rather than academic performance. One strategy used to scaffold student collaboration in peer assessment was *reducing problems such as carelessness and favoritism*. For instance, Lai and Lan (2006) described the "negotiated agreement" approach and the use of computer agents to minimize subjective judgments and unfair assessments. Kao (2013) reported the use of peer assessment with positive interdependence (PAPI) to engage students in productive collaboration. PAPI, which integrates the two approaches of positive interdependence and personal accountability into the assessment process, was designed to reduce or eliminate carelessness and favoritism in peer assessment and to improve the overall quality of peer reviews.

Increasing peer interaction was another strategy used to support collaboration. Kwok and Ma (1999) applied an approach involving collaborative assessment in which GSS supported students and teachers' collaborative construction of evaluating schemes. Lin and Lai (2013) used social network awareness (SNA) to promote the opportunities of peer interaction and collaboration. The social network awareness, visualized in the social network awareness for a formative assessments system (SNAFA) system, enabled students to seek peer online help and supported information sharing and co-construction of knowledge by keeping students aware of peers' social and knowledge context. Roschelle et al. (2010) reported the use of group-level feedback coupled with worked examples of productive collaboration to promote students' collaborative behavior, such as discussion, explanation, cooperative negotiation, and group-level evaluation and feedback, scaffolded by a software program.

Interventions to facilitate disciplinary substance learning: Disciplinary substance

Twenty-three (40%) interventions adopted the disciplinary substance orientation, which seemed to be guided by the notion that assessment involves genuine engagement with disciplinary ideas, thinking, and reasoning. These interventions engaged students in progressively constructing scientific theories (explanations) and/or developing disciplinary thinking and reasoning skills in investigative and collaborative contexts. They facilitated students' engagement with ideas through scaffolds such as assessment rubric/assessment worksheets, prompts, creation of inquiry contexts/tasks, and structuring learning tasks/activity.

Interventions that used scaffolds such as *assessment rubrics, assessment worksheets, and assessment instruments* were used to enhance students' development of disciplinary ideas, thinking, and reasoning. For example, Lin, Hong, and Lee (2011) described the use of worked examples of scientific explanations, and a reflective peer assessment instrument containing six open-ended questions with competing theories, to support students' collaborative argumentation and conceptual understanding. Similar interventions were reported in Li, Liu, and Steckelberg (2010) and Toth, Suthers, and Lesgold (2002). *Creating inquiry context or tasks* was another strategy used to support student learning. For example, Chin and Teou (2009) used concept cartoons to create an inquiry situation to encourage students to discuss, articulate, question, evaluate, and reflect on their own and their peers' ideas, and to elicit their ideas, including misconceptions and argumentation, about the

scientific concepts. Etkina et al. (2010) designed conceptual design tasks, supported by the Investigative Science Learning Environment, which integrated cognitive apprenticeship and ongoing assessment supplemented by reflection to help students develop their scientific abilities. Students used assessment rubrics to self-assess their inquiry process and guide their experimental design and report writing.

Provision of *working examples and prompts* was a third strategy. For example, Woo, Chu, and Li (2013) used online writing prompts to guide students' group writing. Treagust, Jacobowitz, Gallagher, and Parker (2001) engaged students in learning by asking them to respond to various questions during the activities. *Structuring learning activities or tasks* was a fourth strategy, used to direct students' attention to disciplinary substance. For instance, in Taasobshirazi, Zuiker, Anderson, and Hickey (2006) and Anderson, Zuiker, Taasobshirazi, and Hickey (2007), a four-step review routine was used to foster students' understanding of astronomy and to develop their reasoning skills. The four-step review routine asked students to explain and compare each answer, reach an initial consensus, review the explanation of the answer, and then confirm the group's understanding. Students were encouraged to provide claims and use data to justify them.

Immersion in inquiry process to help students learn how to learn: Immersion

The final type of orientation (15 studies, 26%) used assessment to help students learn how to learn by improving their metacognitive/self-regulative awareness and their abilities to monitor, evaluate, reflect, and re-plan. In this orientation, assessment interventions were an intrinsic component of students' inquiries; assessment was embedded in the inquiry process and further transformed their learning. Interventions in this orientation facilitated assessment activities using scaffolds such as assessment rubrics/principles/forms, models/examples, and prompts.

The interventions that used *assessment rubrics, assessment principles, and assessment forms* were designed to help students learn how to learn. In a series of studies, Chang (2008) and Chang and Tseng (2009, 2011) reported on the use of assessment forms embedded in a Web-portfolio system to foster students' metacognitive activities, such as self-/peer-assessment and reflection. The Web-based portfolio assessment system itself provided students with a metacognitive model that fostered their engagement in a series of metacognitive activities, such as setting learning goals, writing reflections, creating their own portfolios, viewing and emulating peer projects, conducting self-/peer assessment, providing feedback, and continuously improving their work. In another series of studies, Lee, Chan, and van Aalst (2006) and van Aalst and Chan (2007) described the use of a set of principles combined with e-portfolios to help students learn how to learn. These principles worked both as a conceptual framework to scaffold students' inquiry, and as assessment criteria to guide their reflections on the quality of their work in preparing and reflecting on the e-portfolios. Through assessment, the students monitored, evaluated, and re-planned their inquiry processes and products.

The provision of *metacognitive models/working examples* was another strategy used to help students learn how to learn. For example, Kostons, van Gog, and Paas (2012) used modeling examples to help students acquire self-assessment and task selection skills and further used the obtained skills to support students' self-regulated learning. White and Frederiksen (1998) used a metacognitive model of research (the Inquiry Cycle) and a metacognitive process (reflective assessment) in a computer-supported curriculum to engage middle school students in learning about and reflecting on their inquiry process as they constructed and applied increasingly complex causal models of force and motion. *Prompts* were a third strategy for engaging students in learning how to learn. For instance, Wang (2011) described the use of five strategies (adding answer notes, stating confidence, reading peer answer notes, recommending peer answer notes, and querying peers' recommendations on personal answer notes) provided by a peer assessment system to help students foster self-regulated awareness and skills.

The assessment orientations were derived from the nature of the interventions. The outcome orientation emphasized the improvement of students' academic performance, as the assessment interventions were used as instruments to narrow or close the gap between actual results and expected goals. The collaboration orientation tended to foster productive collaboration in assessment activities and to help students develop collaborative capacity. The disciplinary substance orientation engaged students in the development of disciplinary substance in collaborative and investigative environments that mediated their learning. The immersion orientation included assessment activities that facilitated students' development of metacognitive/self-regulative awareness and skills for learning how to learn such as monitoring, evaluation, reflection, and re-planning. Three studies (5%) could not clearly be grouped into any of the four orientations.

Discussion and conclusions

This review explored how assessment practices in K-14 education are currently used to scaffold students' learning, with a view to articulating an agenda for research and development. We reviewed technology-

enhanced, cognitively oriented research on assessment in K-14 classrooms published between 1994 and 2013. The selected articles were coded using a three-dimensional coding framework that considered the nature of the assessment intervention, the purposes of the assessment intervention, and the role of technology in student learning. This framework was developed to capture the characteristics of the assessment interventions, and to provide data for further analysis of how assessment interventions scaffolded student learning and which strategies made assessment activities work to scaffold learning.

Documenting the core characteristics of each intervention in this way clarified how the outcome of each study was determined by its overall design rather than by a single core characteristic. The documented characteristics also revealed how scaffolds, strategies, and methods were used to make a particular assessment practice work in a productive way in each study. This method differed from that of previous reviews (e.g., Black and William, 1998), which reported either the results or the effect size of the assessment interventions, with little description of the assessment processes or assessment activities that the students were involved in. Furthermore, most of the previous reviews focused on higher education, whereas this review focused on the K-14 educational context, which has received little attention. In addition, previous reviews of the literature have generally focused on interventions in which teachers played a central role in initiating assessment tasks and providing feedback. However, this review analyzed a body of research dealing with assessment practices in which students, with technological support, assessed (through peer- or self-assessment), managed, evaluated, monitored, and reflected on their own collaborative inquiry.

The review found that assessment interventions ranged from those that used assessment to provide feedback that could improve academic performance to those that helped students learn how to learn using an inquiry process focused on learning disciplinary substance; others used technology to provide information or feedback and some integrated technology into the inquiry process. All of the interventions to some extent scaffolded students' learning. However, only interventions in the immersion orientation seemed to fully help students to *learn how to learn*. This approach seems the most promising for facilitating students' agency in the inquiry process and to further transform their learning. The review also found that requiring students to monitor, evaluate, and reflect on their progress in light of criteria and principles related to learning goals had positive effects on their ability to learn actively, and to learn both disciplinary substance and metacognitive/regulative skills. However, not many assessment interventions engaged students in metacognitive activities.

The review should facilitate further research on the use of assessment to scaffold students' learning. The findings provide evidence suggesting that some promising features (e.g., students' engagement in metacognitive activities in assessment practice) contribute to both students' disciplinary substance learning and learning how to learn. However, the limited assessment designs and findings may not be sufficient for researchers and teachers to design strong and successful assessment activities to scaffold students' learning. We hope that more educational researchers will work toward this goal.

References

* References marked with an asterisk indicate studies included in the review (Not a full list of all of the reviewed studies).

- * Anderson, K. T., Zuiker, S. J., Taasobshirazi, G., & Hickey, D. T. (2007). Classroom discourse as a tool to enhance formative assessment and practise in science. *International Journal of Science Education*, 29, 1721-1744. doi:10.1080/09500690701217295
- Bogdan, R. E., & Biklen, S. K. (1998). *Qualitative research for education: An introduction to theory and methods*. Boston: Allyn & Bacon.
- * Chang, C.-C., & Tseng, K.-H. (2011). Using a web-based portfolio assessment system to elevate project-based learning performances. *Interactive Learning Environments*, 19, 211-230. doi:10.1080/10494820902809063
- * Chin, C., & Teou, L. Y. (2009). Using concept cartoons in formative assessment: Scaffolding students' argumentation. *International Journal of Science Education*, 31, 1307-1332. doi:10.1080/09500690801953179
- Datnow, A., & Park, V. (2014). *Data-driven leadership*. San Francisco, CA: Jossey-Bass.
- * Etkina, E., Karelina, A., Ruibal-Villasenor, M., Rosengrant, D., Jordan, R., & Hmelo-Silver, C. E. (2010). Design and reflection help students develop scientific abilities: Learning in introductory physics laboratories. *Journal of the Learning Sciences*, 19, 54-98. doi:10.1080/10508400903452876
- * Fontana, D., & Fernandes, M. (1994). Improvements in mathematics performance as a consequence of self-assessment in Portuguese primary school pupils. *British Journal of Educational Psychology*, 64, 407-417. doi:10.1111/j.2044-8279.1994.tb01112.x

- * Kim, M., & Ryu, J. (2013). The development and implementation of a web-based formative peer assessment system for enhancing students' metacognitive awareness and performance in ill-structured tasks. *Educational Technology Research and Development*, 61, 549-561. doi:10.1007/s11423-012-9266-1
- Klenowski, V. (2009). Assessment for learning revisited: An Asia-Pacific perspective. *Assessment in Education: Principles, Policy and Practice*, 16, 263-268.
- * Lee, E. Y. C., Chan, C. K. K., & van Aalst, J. (2006). Students assessing their own collaborative knowledge building. *International Journal of Computer-Supported Collaborative Learning*, 1, 57-87. doi:10.1007/s11412-006-6844-4
- * Lin, H. S., Hong, Z. R., & Lee, S. T. (2011). Using reflective peer assessment to promote students' conceptual understanding through asynchronous discussions. *Educational Technology & Society*, 14, 178-189.
- * Magnusson, S. J., Templin, M., & Boyle, R. A. (1997). Dynamic science assessment: A new approach for investigating conceptual change. *Journal of the Learning Sciences*, 6, 91-142. doi:10.1207/s15327809jls0601_5
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook (2nd ed.)*. Thousand Oaks, CA: Sage Publications.
- * Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, B., Nussbaum, M., & Claro, S. (2010). Scaffolding group explanation and feedback with handheld technology: Impact on students' mathematics learning. *Educational Technology Research and Development*, 58, 399-419. doi:10.1007/s11423-009-9142-9
- Stahl, G. (2002). *Computer support for collaborative learning: Foundation for a CSCL community*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Strauss, A. L. (1987). *Qualitative analysis for social scientists*. London: Cambridge University Press.
- Strauss, A. L., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks, CA: Sage Publications.
- * Toth, E. E., Suthers, D. D., & Lesgold, A. M. (2002). "Mapping to know": The effects of representational guidance and reflective assessment on scientific inquiry. *Science Education*, 86, 264-286. doi:10.1002/sce.10004
- * Trautmann, N. M. (2009). Interactive learning through web-mediated peer review of student science reports. *Educational Technology Research and Development*, 57, 685-704. doi:10.1007/s11423-007-9077-y
- * Tseng, S. C., & Tsai, C. C. (2007). On-line peer assessment and the role of the peer feedback: A study of high school computer course. *Computers & Education*, 49, 1161-1174. doi:10.1016/j.compedu.2006.01.007
- van Aalst, J. (2013). Assessment in collaborative learning. In A. O'Donnell, C. A. Chinn, C. K. K. Chan & C. Hmelo-Silver (Eds.), *International Handbook of Collaborative Learning* (pp. 280-296). New York, NY: FalmerRoutledge.
- * van Aalst, J., & Chan, C. K. K. (2007). Student-directed assessment of knowledge building using electronic portfolios. *Journal of the Learning Sciences*, 16, 175-220. doi:10.1080/10508400701193697
- * White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, 16, 3-118. doi:10.1207/s1532690xci1601_2

Appendix: Patterns of assessment interventions in technology-enhanced K-14 education

Group description	Nature of assessment intervention	Emphasis	The role of technology	Studies
Outcome orientated (n = 8, 14%)	Culminating activity	Academic performance	Providing/facilitating assessment and feedback	1
	Culminating activity	Academic performance	Creating opportunities/spaces for group work	1
	Culminating activity	Academic performance	N/A	1
	Continuous assessment	Academic performance	Providing/facilitating assessment and feedback	3
Collaboration (n = 8, 14%)	Continuous assessment	Academic performance	Providing opportunities to encourage reflections/self-regulation	1
	Intrinsic component of learning	Academic performance	N/A	1
	Culminating activity	Collaboration	Creating opportunities/spaces for group work	1
	Culminating activity	Collaboration	N/A	1
	Continuous assessment	Collaboration	Providing/facilitating assessment and feedback	1
	Continuous assessment	Collaboration	Providing opportunities/spaces for group work	2
	Intrinsic component of learning	Collaboration	Providing/facilitating assessment and feedback	1
	Intrinsic component of learning	Collaboration	Creating opportunities/spaces for group work	1
	Intrinsic component of learning	Collaboration	Providing opportunities to encourage reflections/self-regulation	1
	Culminating activity	Collaboration	N/A	1
Disciplinary substance (n = 23, 40%)	Continuous assessment	Disciplinary substance	Creating opportunities/spaces for group work	6
	Dynamic assessment	Disciplinary substance	Providing/facilitating assessment and feedback	1
	Dynamic assessment	Disciplinary substance	Making learning/assessment activities/tasks authentic	2
	Dynamic assessment	Disciplinary substance	N/A	1
	Intrinsic component of learning	Disciplinary substance	Providing/facilitating assessment and feedback	4
	Intrinsic component of learning	Disciplinary substance	Making learning/assessment activities/tasks authentic	4
	Intrinsic component of learning	Disciplinary substance	Creating opportunities/spaces for group work	1
	Intrinsic component of learning	Disciplinary substance	Mix	1
	Intrinsic component of learning	Disciplinary substance	N/A	2
	Intrinsic component of learning	Disciplinary substance	Providing opportunities to encourage reflections/self-regulation	2
Immersion (n = 15, 26%)	Culminating activity	Learning how to learn	Providing opportunities to encourage reflections/self-regulation	2
	Continuous assessment	Learning how to learn	Creating opportunities/spaces for group work	1
	Intrinsic component of learning	Learning how to learn	Making learning/assessment activities/tasks authentic	1
	Intrinsic component of learning	Learning how to learn	Creating opportunities/spaces for group work	3
Does not fit into the orientations (n = 3, 6%)	Intrinsic component of learning	Learning how to learn	Providing opportunities to encourage reflections/self-regulation	4
	Intrinsic component of learning	Learning how to learn	Mix	4
	Intrinsic component of learning	N/A	Making learning/assessment activities/tasks authentic	1
	Intrinsic component of learning	N/A	N/A	1
	Culminating activity	N/A	N/A	1
	Continuous assessment	N/A	N/A	1
Total				57