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A framework for secondary mathematics technology-enhanced formative assessment (TEFA) literacy

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Digital tools can be an efficient and effective way to enhance mathematics formative assessment. Whilst there are a number of theoretical frameworks and standards to help educators understand the complexities of mathematics pedagogy, technology integration, and formative assessment, there is no clear definition of what encompasses the integration of these knowledge and skills. This study proposes a theoretical framework for secondary mathematics Technology-Enhanced Formative Assessment (TEFA) literacy and an analytic rubric for TEFA literacy that defines levels of literacy for the essential elements of the framework.

Keywords: Secondary school mathematics, Technology-Enhanced Formative Assessment (TEFA) literacy, theoretical framework.

Introduction

Research indicates that effective assessment practices lead to an increase in student academic achievement, motivation, and interest (Xu & Brown, 2016). Formative assessment, or assessment *for* learning, refers to classroom practices that elicit evidence about student achievement that is then interpreted and used by teachers and students “to make decisions about the next steps in instruction” (Black & Wiliam, 2009, p. 9). The goal of formative assessment is to promote further learning by using assessment-based evidence to help both teachers and students understand what students have, or have not, mastered.

Educational technology and formative assessment

In 21st century classrooms, educational technology has been praised for its ability to capture and streamline vital elements that make formative assessment more efficient (Spector et al., 2016). TEFAs are defined as digital tools that are used by teachers and/or students to support the formative assessment process (Looney, 2010) and can perform such actions as eliciting evidence of students’ knowledge, collecting students’ data, and providing feedback. Given the unique features of mathematics as a discipline and the diversity of available technologies, secondary teachers must develop a particular set of knowledge and skills for implementing TEFAs. Considering the plethora of open-source, digital tools specifically designed for mathematics (e.g., Desmos, GeoGebra, WolframAlpha, etc.), as well as general tools designed for assessment (e.g., Kahoot!, Google Forms, Quizlet, etc.), it is important that mathematics teachers are able to think critically “about how the use of technology influences representations of mathematics and how the use of technology influences pedagogy” (Hollebrands, 2017, p. 82), specifically, if they are *enhancing* the formative assessment process for both the students and the teacher.

Educators’ knowledge of assessment

Educators’ knowledge and skills in assessment, often referred to as *assessment literacy*, is a multidimensional concept that constitutes their knowledge used to identify high-quality assessment and skill in designing goal-oriented assessments that produce valid data on student achievement

(Stiggins, 1991). Developing assessment literacy has long been considered a critical part of teacher education (Xu & Brown, 2016), mastery of which is often measured against teacher assessment standards (Gotch & French, 2014). One of the most notable sets of American assessment standards are the *Standards for Teacher Competence in Educational Assessment of Students* (American Federation of Teachers [AFT], the National Council on Measurement in Education [NCME], and the National Education Association [NEA], 1990).

Since the publication of the 1990 standards, advances in assessment theory and practice led to development of various American standards that outline the knowledge and skills mathematics teachers must have for formative assessment (e.g., Brookhart, 2011), content specific assessment (e.g., Association of Mathematics Teacher Educators [AMTE], 2017), and technology-based assessment. (e.g., International Society for Technology in Education [ISTE], 2020). However, there are no standards that directly address *TEFA Literacy* in secondary mathematics, which we define as a multidimensional concept that constitutes teachers' knowledge and skills in identifying/designing TEFAs that successfully utilise digital tools to enhance the formative assessment process. Moreover, there are no frameworks that explain what TEFA Literacy entails. The purpose of this study is to address this gap and propose a Theoretical Framework for Secondary Mathematics TEFA Literacy.

Development of the theoretical framework

The development of the Theoretical Framework for Secondary Mathematics TEFA Literacy was guided by Jabareen's (2009) methodology, consisting of eight phases: (1) mapping literature sources, (2) categorising the literature sources, (3) naming concepts, (4) deconstructing the concepts, (5) integrating the concepts, (6) synthesising the concepts into an initial framework, (7) validating with outsiders, and (8) "rethinking" the framework.

Phase 1 consisted of "an extensive review of the multidisciplinary texts" (Jabareen, 2009, p. 53), to include a spectrum of literature related to Secondary Mathematics TEFA Literacy. The initial pool of texts included theories, frameworks, standards, research studies, news articles, as well as websites and blogs. Merriam and Tisdell (2016) recommend that a review of literature begins with checking texts "that reference specific aspects of a topic" (p. 93). Therefore, the first literature sources were identified by conducting a broad online search (e.g., Google Scholar, university/college library collections, ResearchGate, ProQuest, etc.) using various combinations of the related keywords and phrases. These keywords included, but were not limited to: mathematics, secondary mathematics, mathematics pedagogy, mathematics assessment, educational technology, technology integration, TPACK, teaching with technology, assessment, assessment literacy, formative assessment, teacher education, teacher training, and/or preservice teachers. Additional literature sources were identified using the strategy of "citation chasing", in which the researcher tracks down the references from the existing sources. Note, for the purpose of this framework, the concept of technology is limited to that of digital tools (i.e., students and teachers interact with computers, laptops, tablets, or smartphones).

In Phase 2, the literature sources were first sorted into seven categories: (1) mathematics pedagogy, (2) technology, (3) formative assessment, (4) mathematics pedagogy and formative assessment, (5) formative assessment and technology, (6) technology and mathematics pedagogy, and (7) mathematics pedagogy, technology, and formative assessment. For example, ISTE's (2020) standards

were sorted into the “technology” category as they focus solely on technology, while Hollebrands’ (2017) framework was sorted into “technology and mathematics pedagogy”, as it discussed the use of technology specifically in mathematics classrooms. Next, the literature sources were ranked on a scale of 1-3. A rank of “1” was given to sources with the highest importance and power based on the following factors: The literature source provided information directly related to its assigned category, and the literature source is research-based, fact-based (i.e., empirical study), the information can be verified by other reliable sources, and/or the author(s) is affiliated with a reputable organisation (i.e., the source is reliable). A rank of “2” was assigned to reliable sources that supplemented and/or expanded upon the information from the sources with a rank of “1”. A rank of “3” was assigned to sources that had questionable reliability, e.g. information was based on opinions rather than facts, author’s affiliation or references were missing. These sources were removed from analysis and only literature sources with rankings of “1” or “2” were used in the next phase.

Phase 3 was dedicated to reading and rereading the selected literature sources to create “a list of numerous competing and sometimes contradictory concepts” (Jabareen, 2009, p. 54). Concepts, such as theories, definitions, standards, studies of practice, or examples of practice were identified and named by their category. This resulted in identifying a number of concepts in each of the seven categories. Consider Hollebrands’ (2017) framework and AMTE’ (2017) standards, which both highlight the idea that mathematics teachers must be able to use technology in the classroom so that it *enhances* mathematics learning and deepens students’ conceptual understanding. These concepts were categorised into the “technology and mathematics pedagogy” category.

In Phase 4, each concept was analysed to “identify its main attributes, characteristics, assumptions, and role” (Jabareen, 2009, p. 54). This included identifying: the type of concept (e.g., theory definition, standard), the intended purpose or application of the concept (e.g., to provide a model or strategy, to report findings, or to set a new standard), and the potential role the concept could play in the theoretical framework (i.e., incorporated directly, a supporting role, or an underlying concept).

In Phase 5, concepts were sorted and filtered using three iterations. As concepts had already been grouped into the seven categories (noted in Phase 3), in the first iteration, the concepts were sorted and grouped by “type”. For example, the “technology concepts” that were identified as a type of standard were all grouped together. Within each of these groups, common themes were identified from repeated words, phrases, purposes, or strategies, or patterns among potential roles the concepts could play in the theoretical framework. For example, in the group of standards under “technology concepts”, a common theme between two different sets of standards was: Teachers need to have a knowledge of digital tools and the skill to use them in the classroom. Thus, the two concepts were integrated into this new one. This iteration resulted in a new, shorter list of concepts. The second iteration consisted of comparing concepts across types, identifying common themes, and integrating concepts. For example, the concepts in the standards group and the concepts in theories group of the “technology category” were compared, if there were common themes, these concepts were integrated into one, new concept. Finally, in the third iteration, the remaining concepts were compared across categories. For example, in the “technology and mathematics pedagogy category” a common theme was: Teachers should be able to choose technologies that accurately reflect the mathematics and enhance the pedagogical activity. These two themes were integrated into one, new concept that

focused on: Teachers’ knowledge to select technology that is aligned to the mathematics content and the instructional goals. The final list of integrated concepts was used in the next phase.

Phase 6 is one that is “iterative and includes repetitive synthesis and resynthesis until the researcher recognizes a general theoretical framework that makes sense” (Jabareen, 2009, p. 54). Analysis of the final concepts from Phase 5 showed that there were a number of “essential elements” that described the different knowledge and skills secondary mathematics teachers must have in order to successfully implement TEFA. These essential elements were established through an iterative process that included grouping, analysing, and re-grouping concepts to form a cohesive group that focused on one fundamental idea. For example, concepts that highlighted the different types of feedback teachers should provide, how and when feedback should be provided, and how students should participate in giving and receiving feedback were grouped together. These formed the essential element that focused on teachers’ knowledge and skill in the fundamental idea of the Feedback Process.

Once the essential elements had been established and named, they were classified into “components”. In a similar process of grouping, analysing, and re-grouping, the components were developed to link essential elements with a shared overarching concept. For instance, the essential elements: Feedback Process (FP), Elicit Student Understanding (ESU), Moving Learning Forward (MLF) are all linked to formative assessment and were grouped into a Formative Assessment Component. This process formed the initial framework, named the *Theoretical Framework for Secondary Mathematics TEFA Literacy*, and consisted of three components composed of eight essential elements. Other theoretical frameworks (Angeli & Valanides, 2009; Hollebrands, 2017; Mishra & Koehler, 2006; Xu & Brown, 2016) were analysed to guide development of a visual representation of the initial framework. Further, qualitative descriptors were developed to define the levels of TEFA Literacy for each essential element. The descriptors were organised into an analytic rubric using ascending levels of proficiency that highlight observable knowledge and skill that demonstrate TEFA Literacy (Table 1).

Table 1: Example of the qualitative descriptors for the essential element ESU

Advanced	Proficient	Partially Proficient	Novice
The teacher demonstrates they are analysing, selecting, or designing questions/prompts on TEFAs that strongly emphasise explanation, justification, and problem solving; almost no questions utilize rote memorization or procedures without connections	The teacher demonstrates they are analysing, selecting, or designing questions /prompts on TEFAs that emphasise explanation and justification, and very few questions utilize rote memorization or procedures without connections	There is some evidence the teacher is analysing, selecting, or designing questions/prompts on TEFAs that emphasise explanation and justification, although many questions still utilize rote memorization or procedures without connections	The teacher selects or designs questions/prompts on TEFAs that primarily focus on rote memorization and procedures without connections

Lastly, in Phases 7 and 8, the rubric was validated through an iterative process of content examination by two experts in the field and inter-rater reliability by two external raters who used the rubric to

evaluate responses to the *TEFA Literacy Test for Secondary Mathematics*. The test was designed by the researcher as part of a dissertation study on TEFA Literacy in preservice mathematics teachers. The framework and rubric were finalised when inter-rater agreement reached 90%.

The theoretical framework for secondary mathematics TEFA literacy

The Theoretical Framework for Secondary Mathematics TEFA Literacy encompasses three main components that include seven essential elements describing the exchange of knowledge and skills (Heritage, 2007) necessary for secondary mathematics teachers to effectively engage students in TEFAs (Figure 1).

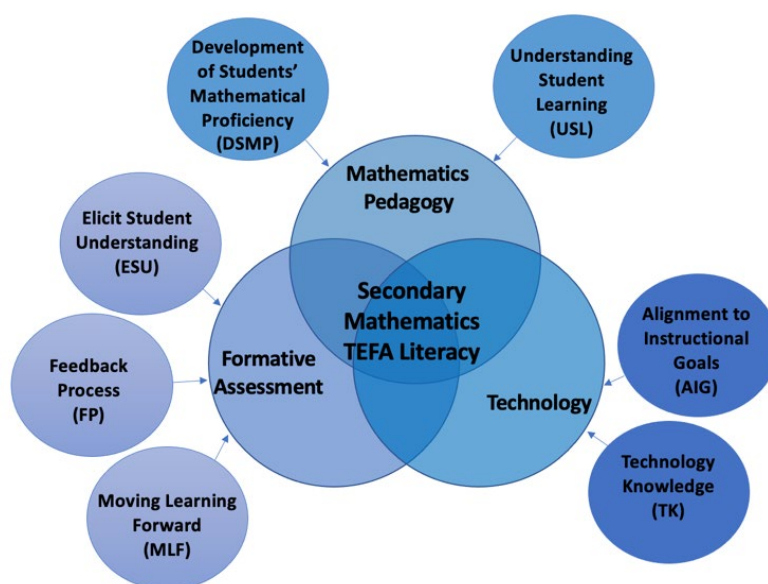


Figure 1: The theoretical framework for secondary mathematics TEFA literacy

Explanation of the framework components and their essential elements

The Mathematics Pedagogy Component (MPC) is focused on teachers' knowledge and skills necessary for implementing TEFAs that support Development of Students' Mathematical Proficiency (DSMP) and Understanding Student Learning (USL). At the advanced level, DSMP can be demonstrated by the mathematics teacher's analysis, selection, and design of TEFA questions that promote students' conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive dispositions (Kilpatrick et al., 2001). For USL, a teacher can demonstrate an advanced level of proficiency by analysing, selecting, and designing TEFA tasks that provide appropriate challenges to students while accounting for prior knowledge. This includes teachers' knowledge of common mistakes and misconceptions and, based on that, skills to design TEFA tasks that identify these mistakes and misconceptions in order to determine students' strengths and weaknesses. Proficiency in DSMP and USL are intrinsically linked to proficiency in the Technology (TC) and Formative Assessment (FAC) Components. An understanding of technology enables teachers to select, use, and modify tools that account for students' prior knowledge and prompt for evidence of their mathematical proficiencies. Similarly, an understanding of formative assessment is the basis for selecting and designing TEFA questions that elicit evidence of students' strengths, weaknesses, and how to address them with relevant feedback.

The TC focuses on teachers' analysis and selection of appropriate and capable digital tools to design TEFAs that are Aligned to the Instructional Goal (AIG) of formative assessment and the mathematical learning objectives. A mathematics teacher may demonstrate an advanced level of AIG by effectively analysing and selecting technologies that are appropriate for the mathematical content (i.e., mathematical fidelity) while also enabling students to engage in a formative assessment (i.e., pedagogical fidelity). For example, an Algebra teacher using a Desmos quiz as a formative assessment on linear functions should demonstrate that they are selecting or designing questions that accurately represent linear functions, allow students to show their understanding of linear functions (e.g., analysing, writing, and drawing), as well as enhancing the formative assessment process (e.g., provide instant feedback, collect student data, etc.). Fundamental to mathematics teachers' proficiency in AIG is their Technology Knowledge (TK). An advanced level of TK includes a familiarity with a variety of digital tools and how to operate them from both the teacher and student perspective. Judging the fidelity of the tool depends on the teachers' proficiency in MPC and FAC.

The FAC focuses on the knowledge and skills that teachers must have to ensure TEFAs are designed to effectively Elicit Students' Understanding (ESU), engage them in the Feedback Process (FP), and Move Learning Forward (MLF). A teacher can demonstrate an advanced level of ESU by consistently using TEFA questions that emphasise explanation, justification, and problem solving. Accordingly, questions should avoid an extensive use of computational procedures that rely heavily on memorization. Essential to the FAC, is engaging students in the FP. A teacher can demonstrate an advanced level of proficiency in FP by selecting or designing TEFAs that provide targeted feedback and, when necessary, making plans for supplemental feedback. Crucial to the FP is ensuring that students are actively engaging with the feedback they receive. Consequently, teachers will need to apply their skills in USL, AIG, and TK to determine if they should utilise the features within the digital tool to engage students with feedback, or if a different tool or strategy would be more appropriate. As the ultimate goal of formative assessment is to move students' learning forward, a teacher may demonstrate proficiency in MLF (in connection with proficiency in TK), by effectively analysing students' data collected through the TEFA to make appropriate adjustments to instruction.

Discussion and implications

Secondary Mathematics TEFA Literacy is represented by the interaction between all of the essential elements, where proficiency in one essential element influences one's ability to demonstrate proficiency in another. For example, if a teacher is strong in TK, but weak in DSMP and ESU, they may be able to use the digital tool to collect student data, but these data will not provide evidence of students' conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, or productive dispositions (Kilpatrick et al., 2001). On the other hand, proficiency in one essential element can promote proficiency in others. For example, a teacher advanced in DSMP may have better judgement of the pedagogical and mathematical fidelity (i.e., AIG) of digital tools. Further examples of the connections between the essential elements are found in Figure 2. From both a practical and a research perspective, the Theoretical Framework for Secondary Mathematics TEFA Literacy and rubric serve as a conceptual lens of the knowledge and skills that secondary mathematics teachers need to successfully plan and implement TEFAs. Theoretical frameworks, like this one, can help teachers and teacher educators develop an understanding of a phenomenon, leading to the

dexterity to apply the concepts to their profession. This framework can guide teacher educators in course design to develop the knowledge and skills for successful implementation of TEFAs.

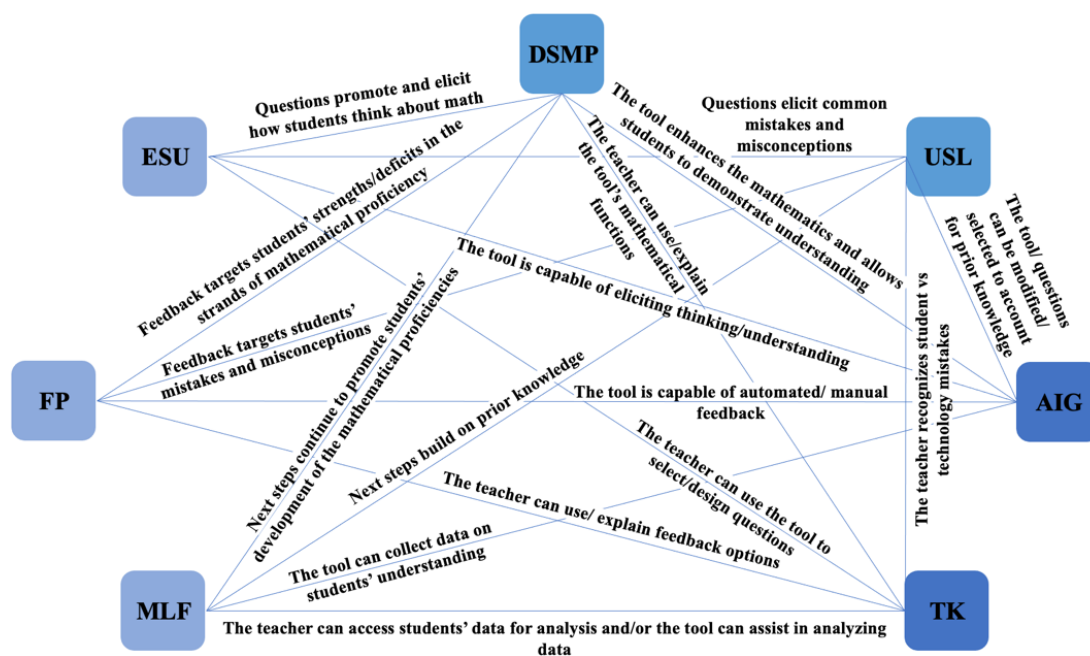


Figure 2: Examples of connections between the essential elements

This framework, including the rubric, also provide educational researchers with a number of tools that could be used to evaluate TEFA literacy of pre- and in-service mathematics teachers. Much like the descriptions of assessment literacy (Stiggins, 1991) and TPACK (Lyublinskaya & Kaplon-Schilis, 2022) the qualitative descriptors of the essential elements proposed in this study furnish educational researchers with tools that may be used in future studies of Secondary Mathematics TEFA Literacy.

References

- American Federation of Teachers (AFT), National Council on Measurement in Education (NCME), & National Education Association (NEA). (1990). *Standards for teacher competence in education assessment of students*. <https://files.eric.ed.gov/fulltext/ED323186.pdf>
- Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, 52, 154–168. <https://doi.org/10.1016/j.compedu.2008.07.006>
- Association of Mathematics Teacher Educators (2017). *AMTE standards for preparing teachers of mathematics*. <https://amte.net>
- Black, P., & Wiliam, D. (2009). Developing a theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, 21, 5–31. <https://doi.org/10.1007/s11092-008-9068-5>
- Brookhart, S.M. (2011). Educational assessment knowledge and skills for teachers. *Educational Measurement: Issues and Practice*, 30(1), 3–12. <https://doi.org/10.1111/j.1745-3992.2010.00195.x>

- Gotch, C.M., & French, B.F. (2014). A systematic review of assessment literacy measures. *Educational Measurement: Issues and Practice*, 33(2),14–18. <https://doi.org/10.1111/emip.12030>
- Heritage, M. (2007). Formative assessment: What do teachers need to know and do? *Phi Delta Kappan*, 89(2), 140–145. <https://doi.org/10.1177/003172170708900210>
- Hollebrands, K.F. (2017). A framework to guide the development of a teaching mathematics with technology massive open online course for educators (MOOC-ED). In E. Galindo & J. Newton (Eds.), *Proceedings of the 39th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 80–89). Hoosier Association of Mathematics Teacher Educators.
- International Society for Technology in Education (2020). *ISTE standards: Educators*. International Society for Technology in Education. <https://www.iste.org/standards/iste-standards-for-teachers>
- Jabareen, Y. (2009). Building a conceptual framework: Philosophy, definitions, and procedure. *International Journal of Qualitative Methods*, 8(4), 49–62. <https://doi.org/10.1177/16094069090080040>
- Kilpatrick, J., Swafford, J., & Findell, B. (Eds.) (2001). *Adding it up: Helping children learn mathematics*. National Academy Press. <https://doi.org/10.17226/9822>
- Looney, J. (2010). *Making it happen: Formative assessment and educational technologies*. Thinking deeper research paper no.1 - Part 3. Promethean Education Strategy Group. <https://dimensionssystem.com/email-blasts/Promethean/Pedagogy/Making-it-Happen-Formative-Assesment.pdf>
- Lyublinskaya, I., & Kaplon-Schilis, A. (2022) Analysis of differences in the levels of TPACK: Unpacking performance indicators in the TPACK Levels Rubric. *Education Sciences*, 12(2), 79. <https://doi.org/10.3390/educsci12020079>
- Merriam, S.B. & Tisdell, E.J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.
- Mishra, P., & Koehler, M.J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054. <https://doi.org/10.1111/j.1467-9620.2006.00684.x>
- Spector, J.M., Ifenthaler, D., Sampson, D., Yang, L., Mukama, E., Warusavitarana, A., Dona, K. L., Eichhorn, K., Fluck, A., Huang, R., Bridges, S., Lu, J., Ren, Y., Gui, X., Deneen, C.D., Diego, J.S., & Gibson, D.C. (2016). Technology enhanced formative assessment for 21st century learning. *Journal of Educational Technology & Society*, 19(3), 58–71. <http://www.jstor.org/stable/jeductechsoci.19.3.58>
- Stiggins, R.T. (1991). Assessment literacy. *The Phi Delta Kappan*, 72(7), 534–539. <http://www.jstor.org/stable/20404455>
- Xu, Y., & Brown, G.T.L. (2016). Teacher assessment literacy in practice: A reconceptualization. *Teaching and Teacher Education*, 58, 149–162. <https://doi.org/10.1016/j.tate.2016.05.010>