The Substitution Augmentation Modification Redefinition (SAMR) Model: A Critical Review and Suggestions for its Use

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Abstract

The Substitution, Augmentation, Modification, and Redefinition (SAMR) model is a four-level approach for selecting, using, and evaluating technology in K-12 settings (Puentedura, 2006). Despite its increasing popularity among practitioners, the SAMR model is not currently represented in the extant literature. To focus the ongoing conversation regarding K-12 educators' understanding and implementation of technology, we provide a critical review of the SAMR model using theory and prior research. We focus on the absence of context, its hierarchical structure, and the emphasis placed on product over process and conclude with suggestions to guide educators' and researchers' technology integration efforts.

The complex nature of new digital technologies further complicates the already difficult task of teaching with technology (Mishra, Koehler, & Kereluik, 2009). Digital technologies, such as computers, mobile devices, and their software and applications are *protean*, *unstable*, and *opaque (*Koehler & Mishra, 2008). In other words, digital technologies are ever-changing, not always predictable, and can take on many forms. For example, users can easily change their uses of tablet computers and smartphones to support various needs and interests, such as e-reading, gaming, multimedia consumption and production, as well as communication. Although some have sought to predict future digital technology, it is not always clear how yet-to-be-developed hardware and software will be designed or used. As such, this idea supports Koehler and Mishra's assertion that both developers and end-users of digital technologies do not always know nor can they always predict trends and applications of such technologies. Moreover, due to the opaqueness of design and presentation of digital technologies, those who use digital technologies may not always understand the inner-workings of the software and devices they use. These aspects of digital technologies, as explored by Mishra and Koehler, are further complicated when considering the ways in which digital technologies are (or should be) integrated into K-12 classrooms. In these instances, these aspects are combined with the complexity introduced by teachers' contexts, pedagogical choices, as well as their beliefs and motivations, making technology integration in educational settings more difficult (Hennessy, Ruthven, & Brindley, 2005; Bebell, Russell, & O'Dwyer, 2004).

In an effort to guide educators and researchers in their technology integration efforts, researchers have developed standards, frameworks, models, and theories that may be used to inform research and practice around integrating technology into teaching and learning. For example, the International Society for Technology in Education (ISTE) (2015) developed standards which exist "to support students, educators and leaders with clear guidelines for the skills, knowledge and approaches they need to succeed in the digital age" (para. 1). According to ISTE, these standards have been adopted or adapted by more than fifty percent of states and territories in the United States and may be used to support K-12 technology integration and assessment.

As another example, when educators employ the *Community of Inquiry* framework (Garrison, Anderson, & Archer, 1999) they draw upon ideas that computer-mediated teaching and learning require the existence of three interdependent presences (social, cognitive and teaching). In the *Technological Pedagogical Content Knowledge* (TPACK) framework, the work teachers do is framed by an understanding and application of three kinds of knowledge related to technology, pedagogy, content; applications of the TPACK framework also help teachers identify and understand the intersections of these aspects of teacher knowledge as a means of effectively teaching with technology (Koehler, Mishra, Kereluik, Shin, & Graham, 2014; Mishra & Koehler, 2006).

Furthermore, Zhao and Frank's *ecological perspective* (2003) posits that schools, teachers, and students are interdependent. "A school exists as a complete unit necessary for functioning over a long period of time in a hierarchical structure. It is nested in a school district, which in turn is part of a state educational system that is part of a national education system" (p. 812). Utilizing an ecological perspective enables researchers and practitioners to explain the dynamic interactions between technology, teaching, and school environments.

Still other prior work characterizes specific aspects of teachers' and students' practice, such as Salomon and Perkins' (2005) depiction of the effects with, of, and through the use of technology. This work may be used to help teachers and academics identify how users' interactions with technologies lead to different cognitive outcomes. Ertmer's (2005) scholarship with regard to teacher belief and technology empowers educators and researchers to focus on beliefs about teaching and technology as a way to more deeply understand how these two may work in tandem to predict and/or explain individual teacher's technology uses. These standards, frameworks, models, and theories are based on systematic (and peer-reviewed) research and offer ways to inform and guide K-12 teachers' understanding and uses of technology in teaching.

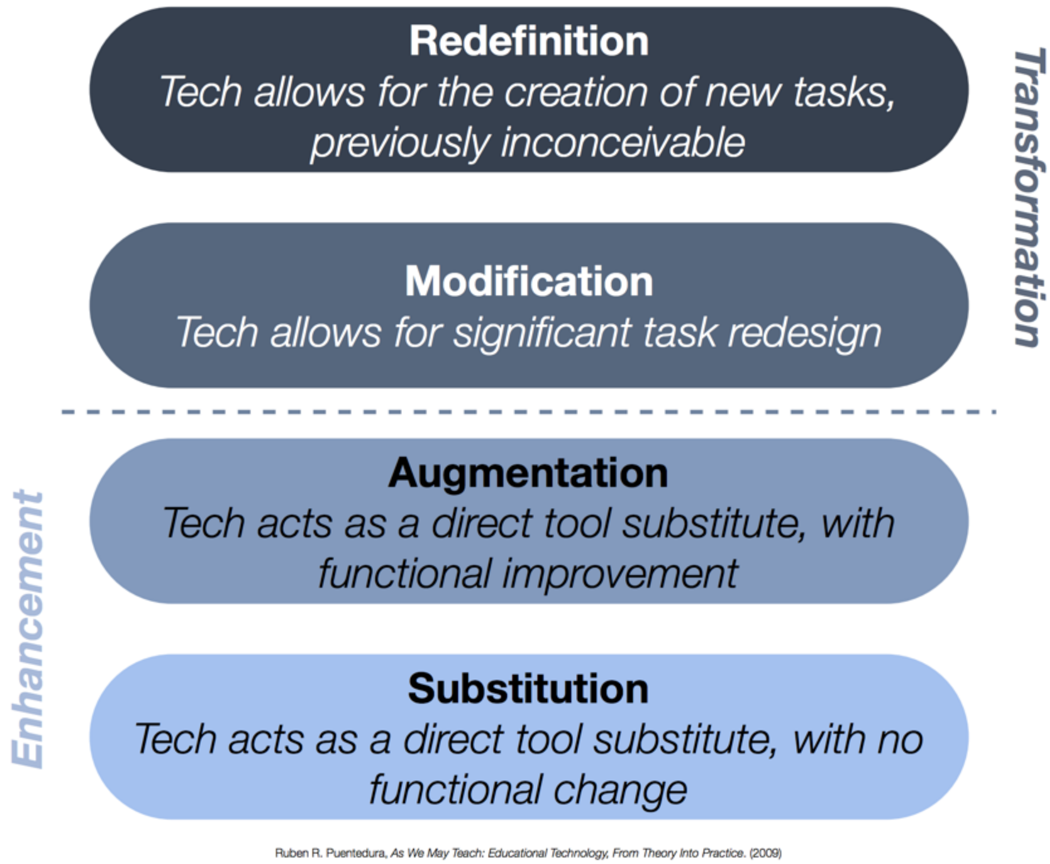
Puentedura's (2006) *Substitution, Augmentation, Modification, and Redefinition* (SAMR) model is a recent addition to K-12 teacher learning and professional development with respect to educational technology. According to the ISTE (2015) website, at the 2013 ISTE conference, only one session out of approximately 800 included the term "SAMR." The 2014 Conference program featured 30 workshops and presentations out of approximately 900 total sessions, and among 1,000 sessions at the 2015 ISTE conference, 44 included "SAMR."

Despite its increasing popularity among practitioners, the SAMR model is not currently represented in the extant literature. The purpose of this article is to provide a critical review of the SAMR model in order to focus the ongoing conversation regarding its use among K-12 educators. In the next section we introduce and explain the SAMR model. Following this, we provide a critical review of the SAMR model, framed by three challenges. The first centers on the absence of context, the next on the emphasis placed on product over process, and the third on the hierarchical structure of the SAMR model.

The SAMR model

The SAMR model, represented as a ladder, is a four-level approach to selecting, using, and evaluating technology in K-12 education. According to Puentedura (2006), the SAMR model is intended to be a tool through which one may describe and categorize K-12 teachers' uses of classroom technology (Figure 1).

Figure 1. Puentedura's (2006) Substitution, Augmentation, Modification, and Redefinition (SAMR) model (retrieved from http://www.hippasus.com/rrpweblog/)



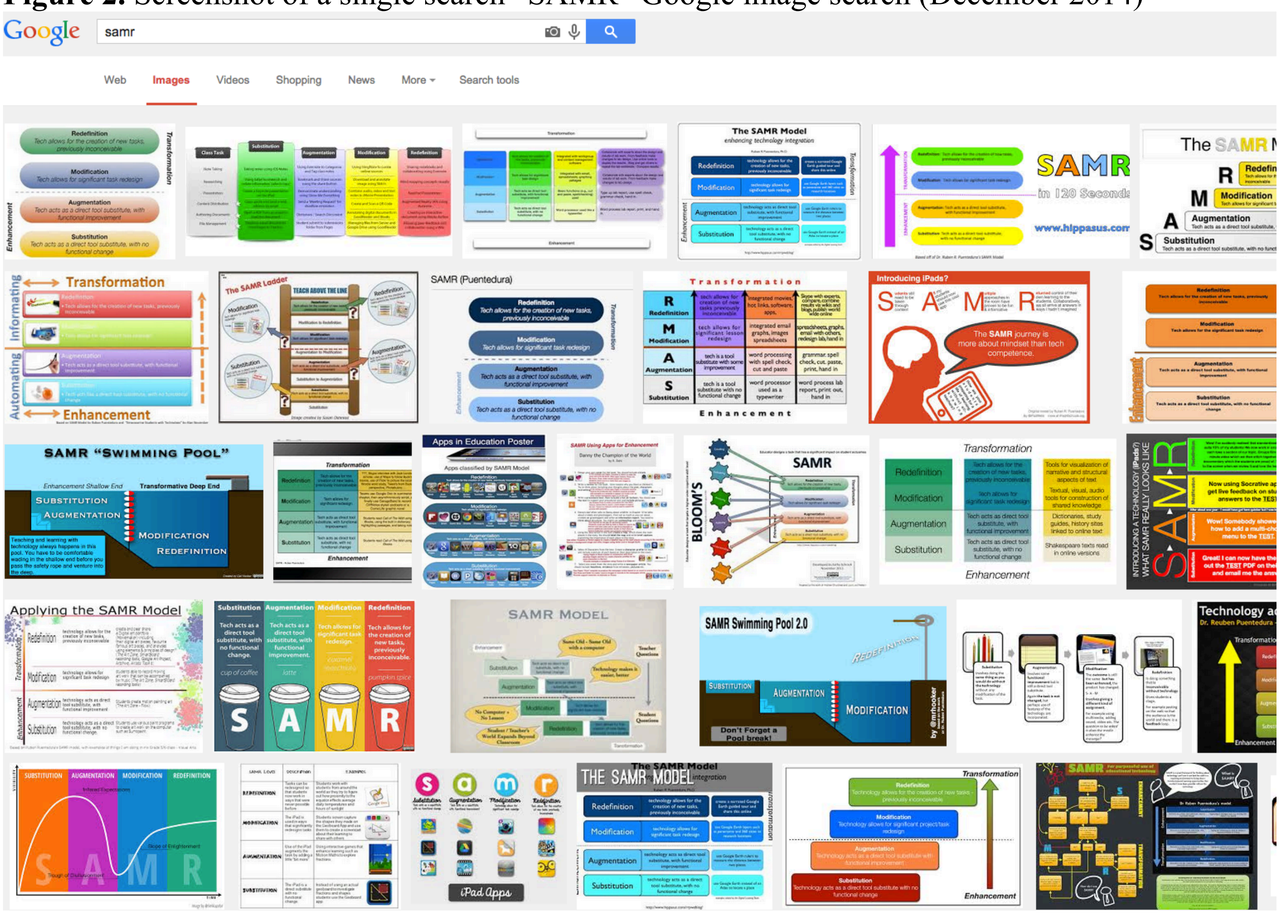
The model encourages teachers to "move up" from lower to higher levels of teaching with technology, which, according to Puentedura, leads to higher (i.e., enhanced), levels of teaching and learning. To aid readers' understanding and to illustrate applications of SAMR, we include brief descriptions and hypothetical examples we created from content provided on Puentedura's website.

At the *Substitution* level*,* digital technology is substituted for analog technology, but the substitution generates "no functional change" (Puentedura, 2014a). For example, in a middle school math class an instructor chooses to substitute a set of hard copy test review questions for digital versions. At the *Augmentation* level, technology is exchanged and the function of the task or tool positively changes in some way. In a first-grade classroom, for instance, instead of a teacher-led, whole class read-aloud lesson students instead use hand-held devices to simultaneously read and listen to individual digital stories. In this case, hand-held devices augment the reading task. At the *Modification* level, technology integration requires a significant redesign of a task. For example, in a secondary science class, an instructor shifts how students learn about light, from showing a diagram of light traveling to providing an interactive computer simulation of light with variables students can change. Finally, the *Redefinition* level is achieved when technology is used to create novel tasks. For example, instead of assigning a social studies-based persuasive essay, a fifth grade teacher requires students to create and present their arguments through individually created and edited videos.

Analysis of the SAMR Model: Three Challenges

Despite its increasing popularity, there is not yet a theoretical explanation of the SAMR model in the peer-reviewed literature. Moreover, the only reference to its lack of theoretical explanation we found was in Linderoth's (2013) blog post, in which the author shared an open letter to Puentedura, inviting further dialogue and discussion. Puentedura shares his SAMR-related work--which largely consists of copies of presentation slides--via his website. Within these web-based materials, there exists limited explanations or details regarding how to understand, interpret and apply the SAMR the model – in part or whole. Moreover, there are few connections to theory and prior research, and there is limited qualitative or quantitative evidence to support the differentiation of the SAMR levels. As a result of this lack of theoretical explanations or explorations of the SAMR model, both teachers and others involved with educational technology integration, such as professional development providers and technology specialists, may be led to interpret and represent the SAMR model in different ways. For example, results from a recent Google "Images" search provided differing representations of the SAMR model, such as likening it to various depths of a swimming pool, different types of coffee drinks, and the life cycle of technology adoption, among others (Figure 2).

Figure 2. Screenshot of a single search "SAMR" Google image search (December 2014)



Vastly different representations can lead to misunderstandings and confusion, such as with some of the SAMR depictions highlighted in Figure 2, as they actually reflect inconsistent interpretations and understandings of the model. For example, in Brubaker's (2013) representation of SAMR, the four levels represent different types of coffee-based drinks (e.g., black coffee [Substitution]; latte [Augmentation]; caramel macchiato [Modification]; and, pumpkin spice [Redefinition]). Based on Brubaker's (2013) interpretation and representation of the SAMR model an educator could interpret using technology in education as making small adjustments, just as adding pumpkin spice adjusts the flavor of a cup of coffee. Such interpretation does not align with how Puentedura defines "Redefinition".

Another example is Hooker's (2014) *SAMR Swimming Pool 2.0*, which is a "remixed" representation of the SAMR model. Hooker uses the SAMR model to represent students' uses and learning with technology and in this model, so that "Redefinition" is represented by a high dive at the pool, in which students become their own lifeguards and invent the pool rules. This representation of "Redefinition" suggests that students use technology to guide and facilitate their own learning and is quite different than making small adjustments to one's teaching with technology, as represented by Brubaker's (2013) visual. These examples demonstrate the inconsistent ways in which individuals understand and visually represent the SAMR model.

The lack of systematic evidence further complicates how to accurately interpret and apply the SAMR model. For example, in a recent presentation, Puentedura (2014b) shared Mueller and Oppenheimer's (2014) comparative study of students' taking digital or longhand notes. Puentedura notes this "switch" as a good example of "substitution." In his presentation materials, Puentedura focused on the change in the task (i.e., typing on a computer versus writing longhand on paper), ignoring the authors' important finding that this instance of substitution actually resulted in a negative impact on student learning. In this instance, although Puentedura offers this study as a positive example of substitution, the researchers' findings actually argue *against* substitution. Despite the larger implied message of the SAMR model, namely that teaching with technology may be ranked and connected to one of four levels, using technology (even at the substitution level) is not always better nor is it always necessary, as evidenced in the following three challenges.

Challenge One: Absence of Context

Context is important in educational research and practice (Berliner, 2002). However, the SAMR model includes no accommodation for context. As a result, important contextual components, such as technology infrastructure and resources (Ertmer, 1999), community buy-in and support (Zhao & Frank, 2003), individual and collective student needs (Lei, Conway, & Zhao, 2008; Mishra & Koehler, 2006), and teacher knowledge and support for using technology (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012, Morsink et al., 2011) are not recognized. We acknowledge there is no one uniform solution regarding integration and use of educational technology. However, technology integration frameworks that are designed and put forth without attention to context, such as the SAMR model, often over-generalize their prescriptions and ignore the complex settings in which this technology integration occurs. For example, a science teacher in a high-poverty middle school setting aims to create a computer-supported investigation for her students so that each student could independently investigate a particular phenomenon during a class period. However, she only has two classroom desktop computers available for student use. In this instance, although the activity she creates may rank "higher" on the SAMR ladder, in practice having ten students sit in front of one computer is both practically and educationally not feasible. The contexts in which educators teach matters and is an important consideration for any model connected to teaching and learning.

We know from prior research that differences in context contribute to (sometimes vastly) different educational outcomes (Design-Based Research Collective, 2003; Kelchtermans, 2014). It is a central tenet of both research and practice and is important for understanding and explaining motivation (Urdan, 1999), development (Eccles & Roeser, 2011), and teaching and learning (Tabak, 2013). Berliner (2002) describes educational research as the hardest science because of the difficulty of obtaining experimental control (more common in many natural science fields) and the complexity of schools and classrooms. Modifying instruction through technology is complex and should occur in tandem with teachers' decisions and plans, which often shift dynamically based upon noticing and responding to students' learning within and across contexts (Sherin & Van Es, 2005).

Context is also a helpful construct for studying the multi-faceted, complex nature of educational settings (Porras-Hernández & Salinas-Amescua, 2013). Including context in models, frameworks, and theories directs researchers' and practitioners' attention to the broader systems in which teaching and learning with technology take place. The complex systems in which teachers work impacts their learning and the decisions they make (Opfer & Pedder, 2011). As a result, we know that teachers' learning, pedagogy, and instructional practices as well as students' learning experiences, are contextual and embedded within complex systems (Opfer & Pedder, 2011). Because SAMR does not acknowledge aspects of context, attempts to connect the SAMR model to research and teaching practice may be a challenge.

Challenge Two: Rigid Structure

A taxonomy is a hierarchical framework in which categories are arranged in a graduated order. The SAMR model is structured as a taxonomy that represents technology integration as belonging to one of four categories. As a result, it dismisses the complexity of teaching with technology by defining and organizing teachers' uses of technology in predefined ways. As we argue previously, there are educational models and frameworks that provide general guidance rather than prescribe specific practices and assign value to different levels. For example, in TPACK framework (Mishra & Koehler, 2006), teachers are informed about the necessary components for effective use of technology in teaching, but no specific activities or practices are suggested, based on the understanding that every teaching context is unique. Additionally, there are other frameworks that are descriptive rather than prescriptive, such as descriptions of the resources and teacher beliefs that serve as barriers to teachers use of technology (Ertmer, 1999). In the SAMR model the emphasis remains on the levels of technology use teachers should align themselves with in order to move themselves along the hierarchical continuum of SAMR. This minimizes the more important focus on using technology in ways that emphasize shifting pedagogy or classroom practices to enhance teaching and learning (Hennessey, Ruthven, & Brindley, 2005; Hughes, 2005; Windschitl & Sahl, 2002).

As a taxonomy, the SAMR model represents the idea that teachers more effectively use technology when they enact modification or redefinition, rather than substitution or augmentation. For example, a table in one of Puentedura's (2014a) recent presentations depicts the idea that using technology in ways aligned with the hierarchical levels in the SAMR model lead to better learning outcomes (Table 1). The four studies in the table were extracted from Pearson, Ferdig, Blomeyer and Moran's (2005) meta-analysis of 20 research articles connected to specific uses of digital technologies and learning environments to enhance middle school students' literacy skills.

Table 1. SAMR levels and effect sizes (additional information added for clarity)

Study	**SAMR Level**	**Description**	**Effect Size** (Hedge's

			g)
Ligas (2002)	S	Computer Aided Instruction (CAI) system used to support direct instruction approach for at-risk students.	0.029
Xin & Reith (2001)	A	Multimedia resources provided to conceptualize learning of word meanings and concepts for elementary students with learning disabilities.	0.264
Higgins & Raskind (2005)	M	Software/hardware used for text-to-speech, definitions, pronunciation guide for children with reading disabilities.	0.600
Salomon, Globerson & Guterman (1989)	R	Software presents students with reading principles and metacognitive questions as part of the reading process for seventh grade students.	1.563

In their analysis, Pearson et al. (2005) refrain from a “one size fits all” approach to using technology in middle-school literacy programs to enhance student learning. For example, the authors argue that learner characteristics (e.g., students with exceptionalities) are an important variable when examining outcomes from technology integration. They conclude that although there exists reason to be optimistic about there is also a need for further research regarding the use of digital technologies and learning environments to broaden the scope of specific middle school student interventions and outcomes.

However, these studies are not necessarily representative of all of those in Pearson et al.’s (2005) meta-analysis: The different effects sizes for the four studies Puentedura selected could be due to varying population characteristics, measures, and the contexts in which these interventions occurred. Instead, Puentedura uses four selected studies’ findings from Pearson et al.’s meta-analysis to argue for a conclusion that may not be supported, namely that the various levels of the SAMR model lead to “better” or “higher” outcomes. As a result, the effect sizes from the four selected studies seem to have been chosen to advance the idea that better learning outcomes are achieved for the modification and redefinition levels of the SAMR model, rather than through a systematic process of evaluating the impact of different uses of technology. None of these four studies were originally designed to give agency to technology. Rather, researchers across all four studies focused on the *interactions between learners and technology*. For example, Puentedura aligns Higgins and Raskind’s (2005) effect sizes with the Modification level. In contrast to the notion that using technology at the modification or redefinition levels leads to enhanced learning outcomes, Higgins and Raskind (2005) acknowledge that the effects of technology use depend strongly on the nature of the teachers and students using it as well as the specific task for which it is being used.

Aligned with the Redefinition level of the SAMR model, Puentedura relies on the effect sizes reported in Salomon, Globerson, and Guterman’s (1989) study. These authors examined whether an intellectual partnership (i.e., a student learning through the use of computer software) could support students’ text comprehension and improve their writing ability. Despite the positive results (as noted by the authors), the findings point to the positive impact of the metacognitive-like guidance with which students were provided, not the actual technology itself. In fact, the authors argue that the technology used in their study was still relatively underdeveloped and primitive. Thus, one might ask whether similar results could be obtained with the use of print-based, peer-based, or teacher-based guidance, instead of guidance that is computer-based. In making these comparisons using Pearson et al.'s (2005) work, Puentedura (2014b) communicates the belief that technology integration along the SAMR ladder leads to better results, a conclusion different from Pearson et al.'s (2005) original intentions and/or findings.

Hierarchical representations, often reflected in taxonomies, inevitably depict the top levels as more desirable than those at the bottom. In some instances, taxonomies may be a useful construct for supporting understanding of phenomena (Anderson et al., 2001). For example, teachers often rely on teaching-learning progressions (TLPs) (Alonzo & Gotwals, 2012) to identify the development of knowledge and skill over time. Similarly, many teachers use Bloom's Taxonomy (1956), as well as its revised version (Krathwohl, 2002), to organize and label teaching and learning using specific categories related to educational objectives. Taxonomies, however, often reflect a perspective in which teaching and learning are linear processes and belong to one exclusive category (Hamblen, 1984). Because of the continuous and reciprocal nature of teaching and learning (Hmelo-Silver & Azevedo, 2006), it is difficult to label and classify instructional objectives. Therefore such taxonomies, as is the case with the SAMR model, are deterministic and linear, and are often in direct contrast with the dynamic processes they seek to represent.

Challenge Three: Product over Process

The instructional design process starts and ends with learning objectives and learning outcomes (Morrison, Ross & Kemp, & Kalman, 2010; Wang & Hannafin, 2005). However, within the SAMR model, the technology integration process is simplified because the goal centers on changing a product (i.e., instructional activity) rather than learning processes. To illustrate, consider a high school English Language Arts (ELA) instructor who assigns an interactive research report presentation that students must create using an online tool of their choice. Focusing on the end product, however, he may inadvertently de-emphasize important processes inherent to the research process such as supporting students' understanding of online presentation tools, the process of identifying, vetting and using reputable research, and the ways in which students create and share their work with additional audiences. As a result, although this integration of technology seemingly occurs at a higher level according to the SAMR model, the process of student learning may not be enhanced, and may, in fact, suffer from the emphasis on a technology-based product.

A recent definition of instructional technology acknowledges that using technology for instructional purposes involves a systematic process of design (Reiser, 2012). Therefore, the complexities inherent to the teaching and learning processes require us to consider education as a *process*, rather than education the production of simplistic, independent stand-alone *products*. This perspective toward learning as process rather than learning as product has important pedagogical implications, especially in terms of interactions between the individuals and the technologies that lead to cognitive changes (Salomon & Perkins, 2005).

From an instructional design perspective, technology plays a role in reaching learning outcomes, but as long as objectives are reached, one instructional method or tool is not promoted over others. When integrating technology, the purpose of this integration should be on enhancing and supporting student learning rather than using a particular technology. In doing so, the processes associated with teaching and learning remain central, rather than the specific technology used to support these processes. However, in the SAMR model it appears that the products, which are associated with the levels of SAMR, remain the focus rather than the important processes of meeting instructional objectives and achieving learning outcomes (Reiser & Dempsey, 2012).

Discussion

To support and extend student learning with technology, educators must seek out and use flexible and adaptive, vetted frameworks that promote a deeper understanding of teaching and learning rather than a focus on the affordances or constraints of a given tool (Mishra, Koehler, & Kereluik, 2009). Within any framework connected to technology integration and/or teaching with technology, an emphasis must be placed on teachers' understanding of technology as important precursors to teachers' actual use (Inserra & Short, 2012). This requires teachers to plan for and enact instruction that offers students meaningful technology-based learning experiences, rather than focusing on "moving up" a hierarchical, techno-centric model.

Despite its increasing popularity, there are challenges to the SAMR model and its potential applications as identified in the previous sections. Technology and other instructional tools are intended to play supporting roles in the learning process. In the SAMR model, however, Puentedura challenges teachers to differentiate their uses of technology(s) as a means of examining what teachers can (and, perhaps, should) do. As a result, the emphasis is on what and the type(s) of technology teachers should use to move themselves along the hierarchy, from substitution and augmentation to modification and redefinition. This movement contrasts with the more important focus on utilizing technology to emphasize pedagogy and practices that support, and when possible, enhance teaching and learning (Hennessey, Ruthven, & Brindley, 2005; Hughes, 2005; Windschitl & Sahl, 2002). In its current form, the SAMR model is a task and technology-focused model. Specifically, our analysis supports the inclusion of contextual factors that inform teachers' understanding and uses of technology.

Because the SAMR model has not been critically analyzed in the peer-reviewed literature, educators involved with educational technology integration sometimes understand and apply the SAMR model in fragmented ways which further complicates the ways in which the SAMR model may be understood and applied. For example, in Pepe's (2014) YouTube video, *SAMR Wheel of Fortune,* she explains how the SAMR model is similar to the "Wheel of Fortune" (in the game show of the same name). In her explanation, Pepe argues that the SAMR model is not hierarchical but, rather, a fluid model of technology integration. This illustration, of which many more exist, demonstrates fundamentally different interpretations of the SAMR model.

Conclusion and Suggestions

Although models such as SAMR have potential for guiding practitioners in their efforts to navigate a complex landscape by seemingly simplifying a multifarious process, they also represent teaching with technology in sterile and hierarchical ways that most often serve to misinform and mislead teachers rather than enhance pedagogy and practice. To refocus the conversation regarding K-12 educators' understanding and use of the SAMR model, our analysis of the SAMR model focused on the absence of context, emphasis on products over processes, and rigid structure. In light of these challenges, the SAMR model may underemphasize the multi-faceted and complex nature of teaching and learning with technology. Instead, it emphasizes the types of technology teachers should use to move themselves up the hierarchical continuum of SAMR, giving primacy to technology rather than good teaching.

Based on our analysis, we offer the following suggestions for how the SAMR model could be more productively used to guide educators' and researchers' technology integration efforts. We are not proposing a new framework or visual representation of the SAMR model, which is beyond the scope of this paper. Rather, our goal is to present ways in which the SAMR model may be further refined and clarified. First, we propose that the SAMR model be revised or augmented to become context-sensitive. This could include adding context as a formal aspect of the framework, as is the case in the TPACK framework (Koehler & Mishra, 2008). Context could also be considered as an implicit part of SAMR, in which case suggestions for how teachers can use the SAMR model based on contextual factors such as appropriate learning outcomes, students' needs, and school and community expectations can be developed. Doing so supports Zhao and Frank's (2003) argument for maintaining an ecological perspective when implementing educational technology.

We also suggest redesigning the taxonomic format of the SAMR model to account for the dynamic nature of teaching and learning with technology. Placing more value on higher tasks or levels, as defined through the use of a taxonomic structure, suggests that it is the technology, rather than a teacher's goals and learning objectives that guide pedagogy and practice (Branch & Merrill, 2012). Rather than labeling the types of technology use, practitioners and researchers would benefit from having and using flexible models in which the processes of teaching and learning with technology are central and dynamic (Mishra, Koehler, & Kereluik, 2009). A teacher's choice to substitute one tool for another (i.e., the lowest level in the SAMR model) may be the most appropriate choice given the targeted motivational and learning outcomes, the design of the learning environment, and the students in the classroom. In this instance, the teacher's decision reflects the dynamic and fluid nature of teaching and learning.

Finally, contrary to what is implied by the SAMR model, we also suggest that technology integration is neither an educational goal nor is it sufficient on its own to enhance learning outcomes (Russell, Sorge, & Brickner, 1994). The SAMR model does not attend to these processes and does not reflect the purposeful, recursive, and systematic process of instructional design (Reiser, 2012). This is an important and problematic limitation, making it difficult to suggest possible modifications because of the incompatibility between the SAMR model and the complexities we know to be inherent to teaching with technology (e.g., Reiser & Dempsey, 2012; Wang & Hannafin, 2005).

With the ubiquity of technology in today's interconnected world, it is imperative for teachers to understand how to use technology to promote student learning and achievement (Lei, Conway, & Zhao, 2008). Specifically, teachers must first understand the relationships between teaching, technology, and learning to promote student growth and achievement (Koehler, Mishra, Kereluik, Shin, & Graham, 2014). If they understand these relationships, they will be better equipped to access and use technology to support and enhance student learning.

References

Alonzo, A. C., & Gotwals, A. W. (2012). *Learning progressions in science: Current challenges and future directions.* New York, NY: Springer Science & Business Media.

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., ... & Wittrock, M. C. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives, abridged edition.* White Plains, NY: Longman.

Bebell, D., Russell, M., & O'Dwyer, L. (2004). Measuring teachers' technology uses: Why multiple-measures are more revealing. *Journal of Research on Technology in Education, 37*, 45-63. http://dx.doi.org/10.1080/15391523.2004.10782425

Berliner, D. C. (2002). Comment: Educational research: The hardest science of all. *Educational Researcher*, *31*(8), 18-20. http://dx.doi.org/10.3102/0013189x031008018

Bloom, B. (1956). *Taxonomy of educational objectives* (Vol. 1). New York: McKay.

Branch, R. M., & Merrill, M. D. (2012). Characteristics of instructional design models. In R.A. Reiser & J. V. Dempsey (Eds.). *Trends and issues in instructional design and technology* (3rd ed., pp. 8-16). Boston: Pearson.

Brubaker, J. (2013). SAMR: Model, metaphor, mistakes. Retrieved from http://techtipsedu.blogspot.com/2013/11/samr-model-metaphor-mistakes.html

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

Eccles, J. S., & Roeser, R. W. (2011). Schools as developmental contexts during adolescence. *Journal of Research on Adolescence*, *21*, 225-241. http://dx.doi.org/10.1111/j.1532-7795.2010.00725.x

Ertmer, P. A. (1999). Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, *47*(4), 47-61.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development*, *53*(4), 25-39. http://dx.doi.org/10.1007/bf02504683

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012).Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*, 423-435. http://dx.doi.org/10.1016/j.compedu.2012.02.001

Garrison, D. R., Anderson, T., & Archer, W. (1999). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education, 2*, 87-105. http://dx.doi.org/10.1016/s1096-7516(00)00016-6

Hamblen, K. A. (1984). An art criticism questioning strategy within the framework of Bloom's taxonomy. *Studies in Art Education, 26,* 41-50. http://dx.doi.org/10.2307/1320799

Hennessey, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution, and change. *Journal of Curriculum Studies, 37*(2), 155-192. doi: 10.1080/0022027032000276961

Higgins, E. L., & Raskind, M. H. (2005). The compensatory effectiveness of the Quicktionary Reading Pen II® on the reading comprehension of students with learning disabilities. *Journal of Special Education Technology*, 20(1), 31–40.

Hmelo-Silver, C. E., & Azevedo, R. (2006). Understanding complex systems: Some core challenges. *The Journal of the Learning Sciences*, *15*, 53-61. http://dx.doi.org/10.1207/s15327809jls1501_7

Hooker, C. (2014). SAMR swimming lessons. Retrieved from http://hookedoninnovation.com/2014/08/01/samr-swimming-lessons/

Hughes. J. (2005). The role of teacher knowledge and learning experiences in forming technology-integrated pedagogy. *Journal of Technology and Teacher Education, 13*, 277-302.

Inserra, A., & Short, T. (2012). An analysis of high school math, science, social studies, English,and foreign language teachers' implementation of one-to-one computing and their pedagogical practices. *Journal of Educational Technology Systems*, *41*, 145-169. http://dx.doi.org/10.2190/et.41.2.d

International Society for Technology in Education. (2015). *ISTE standards*. Retrieved from http://www.iste.org/standards/iste-standards

Kelchtermans, G. (2014). Context matters. *Teachers and Teaching*, *20*, 1-3. http://dx.doi.org/10.1080/13540602.2013.848519

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice, 41*, 212-218. http://dx.doi.org/10.1207/s15430421tip4104_2

Koehler, M. J., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Technology and Innovation (Eds.), *Handbook of Technological Pedagogical Content Knowledge (TPCK) for educators* (pp. 3–29). New York, NY: Routledge.

Koehler, M., Mishra, P., Kereluik, K., Shin, T., and Graham, C.R. (2014). The technological pedagogical content knowledge framework. In J. M. Spector, M. D. Merrill, J. Elen & M. J. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 101-111). New York, NY: Springer.

Lei, J., Conway, P. F., & Zhao, Y. (2008). *The digital pencil: One-to-one computing for children*. Mawhaw, NJ: Erlbaum.

Linderoth, J, (2013, October 17). Open letter to Dr. Ruben Puentedura [Blog post]. Retrieved from http://spelvetenskap.blogspot.com/2013/10/open-letter-to-dr-ruben-puentedura.html

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

Mishra, P., Koehler, M. J., & Kereluik, K. (2009). Looking back to the future of educational technology. *TechTrends, 53*(5), 48-53. http://dx.doi.org/10.1007/s11528-009-0325-3

Morrison, G. R., Ross, S. M., Kemp, J. E., & Kalman, H. (2010). *Designing effective instruction.* Hoboken, NJ: John Wiley & Sons.

Morsink, P. M., Hagerman, M. S., Heintz, A., Boyer, M. D., Harris, R., Kereluik, K., . . . Withey, K. (2011). Professional development to support TPACK technology integration: The initial learning trajectories of thirteen fifth and sixth grade educators. *Journal of Education*, 191(2), 1-18.

Mueller, P.A., & Oppenheimer, D.M. (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note taking. *Psychological Science*, *25,* 1159-1168. http://dx.doi.org/10.1177/0956797614524581

Opfer, V. D., & Pedder, D. (2011). Conceptualizing Teacher Professional Learning. *Review of Educational Research, 81*(3), 376-407. doi: 10.3102/0034654311413609

Pearson, P.D., Ferdig, R.E., Blomeyer, R.L. Jr., & Moran, J. (2005). *The effects of technology on reading performance in the middle-school grades: A meta-analysis with recommendations for policy.* Naperville, IL: Learning Point Associates.

Pepe, C. [Device Smashing Diva]. (2014, January 3). SAMR Wheel of Fortune [Video file]. Retrieved from https://www.youtube.com/watch?v=1s0quYx53PI

Porras-Hernández, L. H., & Salinas-Amescua, B. (2013). Strengthening TPACK: A broader notion of context and the use of teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research, 48*, 223-244. http://dx.doi.org/10.2190/ec.48.2.f

Puentedura, R. (2006). Transformation, technology, and education [Blog post]. Retrieved from http://hippasus.com/resources/tte/

Puentedura, R. (2014a). Building transformation: An introduction to the SAMR model [Blog post]. Retrieved from http://www.hippasus.com/rrpweblog/archives/2014/08/22/BuildingTransformation_AnIntroductionToSAMR.pdf

Puentedura, R. (2014b). Learning, technology, and the SAMR model: Goals, processes, and practice [Blog post]. Retrieved from http://www.hippasus.com/rrpweblog/archives/2014/06/29/LearningTechnologySAMRModel.pdf

Reiser, R.A. (2012). What field did you say you were in? Defining and naming our field. In R.A. Reiser & J. V. Dempsey (Eds.). *Trends and issues in instructional design and technology* (3rd ed., pp. 1-7). Boston, Massachusetts: Pearson.

Reiser, R. A., & Dempsey, J. V. (2012). *Trends and issues in instructional design and technology* (3rd ed.). Boston, Massachusetts: Pearson.

Russell, J. D., Sorge, D., & Brickner, D. (1994). Improving technology implementation in grades5-12 with the ASSURE model. *THE Journal (Technological Horizons In Education), 21*(9), 66-70. Retrieved from https://www.questia.com/library/p1140/t-h-e-journal technological-horizons-in-education

Salomon, G., Globerson, T., & Guterman, E. (1989). The computer as a zone of proximal development: Internalizing reading-related metacognitions from a Reading Partner.*Journal of Educational Psychology, 81*(4), 620-627.

Salomon, G., & Perkins, D. (2005). Do technologies make us smarter? Intellectual amplification with, of, and through technology. In R. J. Sternberg & D. D. Preiss (Eds.), *Intelligence and technology: The impact of tools on the nature and development of human abilities* (pp. 69–86). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Sherin, M., & van Es, E. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education*, *13*, 475-491.

Tabak, I. (2013). Lights, camera, learn: When the set is as important as the actors. In R. Luckin, S. Puntambekar, P. Goodyear, B.L. Grabowski, J. Underwood, & N. Winters (Eds.), *Handbook of Design in Educational Technology* (pp. 397-405). New York, NY: Routledge.

Urdan, T. (1999). *The role of context.* Bingley, UK: Emerald Group Publishing.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, *53*(4), 5-23. http://dx.doi.org/10.1007/bf02504682

Windschitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal, 39*, 165-205. http://dx.doi.org/10.3102/00028312039001165

Zhao, Y., & Frank, K. A. (2003). Factors affecting technology uses in schools: An ecological perspective. *American Educational Research Journal, 40*, 807-840. http://dx.doi.org/10.3102/00028312040004807