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Using the e-Portfolio to Document and Evaluate Growth in Reflective Practice: The Development and Application of a Conceptual Framework

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This case study focused on the electronic portfolio (e-portfolio) as a portrait of teacher growth in an in-service chemistry education graduate program. The e-portfolio provided a multimedia space for systematic documentation of teacher professional growth within the domain of reflective practice. In this study, the outcome and illustration of authentic growth was theorized and evaluated using a system of quality criteria (ontological, educative, catalytic, and tactical). Findings showed that successful e-portfolio entries illustrating reflective practice were created when teacher participants explicitly showed how they experienced growth (increased professional competency) over time through well-coordinated sets of baseline- and post-baseline evidence. The conceptual framework introduced in this article responds to calls for robust models to analyze growth through reflective practice in the development of e-portfolio pedagogy.

Web-based or electronic portfolios (e-portfolios, ePortfolios, efolios, digital portfolios, etc.) are a relatively new, but quickly expanding, component of teacher education programs (Strudler & Wetzel, 2005). Since electronic portfolios (e-portfolios) have typically been used in teacher education as a means to: (1) demonstrate compelling evidence of growth and competency (Abrami & Barret, 2005; Smith & Tillema, 2003), (2) focus teacher thinking, and (3) serve as a medium for translating theory into practice (Hauge, 2006), the expectation is that e-portfolios help to connect professional growth to the process of learning to teach. The definitions of e-portfolios are numerous and range from a compilation of best practices or a "credential portfolio" (e.g., Snyder, Lippincott, & Bower, 1998), to a fluid product meant to demonstrate progress as well as achievement, sometimes referred to as a "learning portfolio" (Collins, 1992; Barrett, 2005). For example, Challis (2005) defines an e-portfolio using five criteria: (1) selective and structured collections of information; (2) gathered for specific purposes and showing/evidence; (3) stored digitally and managed by appropriate software; (4) developed by using appropriate multimedia and customarily within a web environment; and (5) retrieved from a website, or delivered by CD-ROM or DVD. These characteristics enable e-portfolio authors to incorporate more dynamic graphical displays, videos, and weblinks and prepare teachers to communicate in a world where technology is ubiquitous (Sanders, 2000). What is important in characterizing an e-portfolio is that it represents a purposeful collection of authentic and diverse evidence drawn from a larger archive representing learning over time (Barrett, 2005; National Learning Infrastructure Initiative, 2003).

Despite the benefits of e-portfolio use, a number of challenging issues arise from the use of e-portfolios. One current issue is the problem of defining purposeful reflection and authentic growth as well as appropriately guiding portfolio development while still encouraging authorial ownership. The issue of growth poses a particular set of problems. Bannink (2009) tackles the question of how to capture growth in a study that uses a combined written and video portfolio to show fruitful reflection. She attests that in order to show evidence of growth across time and multiple teaching events, the document must show change, and therefore must include two or more events, such as baseline and post-baseline evidence. Parkes and Kadjer (2010) suggest that rubrics might elicit and capture students' growth in reflective practice. They provide a reflective practice rubric to evaluate English and music education students' critical reflection on growth. However, while much of the existing literature describes e-portfolios as a means for documenting growth and development over time, it rarely discusses the ways in which students are encouraged to articulate growth nor does it provide a conceptual framework for evaluating growth within a particular domain (Barrett, 2005; Challis, 2005; Scholes et al., 2004).

In addition, portfolio literature highlights the tensions between structured templates, perceived as rigid by teachers, and more flexible constructions that allow for creativity and self-expression (Barrett, 2005; Borko, Liston, & Whitcomb, 2007; Zeichner & Wray, 2001). e-Portfolio templates in teacher education programs range from those that are highly structured (e.g., foliotek) to those that are loosely defined by a rubric where students independently organize and construct the format of their own entries using a website design program (e.g., Google Sites). Conforming to structured templates can give rise to e-portfolio entries that reflect lack of purpose, limited integration of knowledge, and weak connections between evidence and actual practice involving growth as learners and in learning to teach. Alternatively, providing structured templates helps teachers apply conceptual frameworks and illustrate emergent themes related to competency areas, such as use of pedagogical knowledge in designing instruction and assessment.

The purpose of this study is to introduce a conceptual framework for constructing authentic reflections for science teacher preparation programs that use e-portfolios as high stakes exit projects. We sought to develop a framework that could both support and assess authentic growth in the domain of reflective practice as illustrated by the e-portfolio in a science teacher education program. We use this framework to investigate the ways in which the structure of e-portfolio entries and the guidelines for creating the entries influence the ways that teachers illustrate reflective practice and their professional growth. The following research questions guided our study:

1. How does the structure of the e-portfolio influence how secondary science teachers illustrate evidence to reflect on their teaching and learning how to teach chemistry within an in-service teacher preparation program?
2. How is the comparison between networks of baseline and post-baseline evidence used to illustrate authentic growth within the domain of reflective practice?

Overview

We first present conceptual perspectives that discuss e-portfolios as a discursive space and briefly explore the traditions of reflective practice. We then introduce a conceptual framework in the context of the study. In this study the unit of analysis is the e-portfolio entry. The conceptual framework was used to analyze and evaluate e-portfolio entries in two phases. In the first phase reflective practice entries were analyzed using three major structural categories and a system of four quality criteria. In the second phase two representative cases, strong and weak e-portfolio entries were selected to illustrate how the four quality criteria were used to analyze evidence of growth. In both cases, our analysis included how selection of baseline and post-baseline evidence were coordinated. Direct quotations from e-portfolio entries were used to corroborate our findings.

Conceptual Perspectives

e-Portfolio as a Discursive Space

Viewed conceptually, e-portfolios are multimedia spaces that afford users the capacity to analyze and illustrate growth within the discourse and standards of a community. Within this discursive space the network of evidence used to illustrate growth and change is interlinked via the capacity to simultaneously illustrate and conceptualize practice over time. In this manner, the scope of growth is illustrated by the sources of evidence presented and interpreted by both the e-portfolio author and readers. Britzman (2003) notes that as with teaching, learning to teach requires a discursive space that joins the given and the possible with the conditions of coherence and contradictions within the process of practice. In accordance with this idea, a central feature of creating e-portfolios is realized through how professional growth (or increase in authentic competency) is theorized within past, present, and future practice and connected relationships (Yancy, 2009). The opportunities to experience growth are temporally and socially constituted structures embedded in the construction of e-portfolios. These structures bring together a convergent pathway where productive illustration and interpretation of professional growth can emerge in the context of an e-portfolio model.

At the same time, e-portfolios provide science teachers with opportunities to extend and develop evidence about new ways of thinking about teaching and learning how to teach science across and within domains of growth. These domains of potential growth are usually constituted by rubric items, such as *Understanding of Science Education Theory and Literature* and *Use of New Pedagogical Knowledge in Designing Instruction* (see Appendix A). These rubric items often serve as templates to guide and structure the creation of individual e-portfolio entries. Teacher education programs may also implement highly structured templates for e-portfolios attached to a conceptual framework, which students must follow to configure and submit their e-portfolio entries (Gibson & Barrett, 2003). Typically e-portfolio templates call for teachers to upload content material as evidence to address a particular rubric category and at the end of the entry students write a reflection about their experiences and the material presented (Parkes & Kajder, 2010; Plaisir, Hachey & Theilheimer, 2011). In this procedural disconnect e-portfolio authors must reestablish a logical connection by synthesizing and interpreting evidence through reflective practice. While we agree that the presentation and configuration of evidence along with contextual reflection(s) are important to the compilation of e-portfolio entries, we argue that each e-portfolio entry be viewed holistically as a reflection. This approach challenges conventional configurations of e-portfolio entries and acknowledges the importance of the simultaneous production (and illustration) of evidence for reflective practice. This approach also advocates that an e-portfolio entry should be viewed holistically and used as a unit of analysis for assessing growth through reflective practice.

Reflective Practice

Reflective practice is considered an important goal in teacher preparation programs (e.g., Rodgers, 2002). Reflective practice in teacher education is generally characterized as the ways in which teachers critically interrogate their teaching and learning how to teach and, as an outcome of this interrogation, consider how they might refine and improve their practice (Lyons, 1998). There are a variety of perspectives on how to identify, document, and analyze this activity. Fendler (2003) uses a genealogical lens to trace the different traditions that have coalesced to influence meanings and referents of reflective practice in teacher education. While appropriate approaches to reflective practice include assumptions that reflectivity should provide warrants and evidence for beliefs (Dewey, 1933) and a means to gain professional knowledge (Schön, 1983), theoretical referents for reflective practice continue to exist as a way for teachers to gain professional knowledge and the capacity to assert a deeper conceptual layer of analysis gained from their experiences. van Manen (1990), drawing on Freirean (1970) critical pedagogy, conceptualized reflective practice as a way of thinking about coming to decisions involving alternative courses of action linked to social justice. Consequently, differences in perspective and professional practice establish the context and experiential basis for interpretation necessary for purposeful reflective practice. However, some of the ideas used to characterize reflective practice arise from the interplay of interpreting knowledge derived from experience and the uptake and expression of that knowledge that promotes professional renewal within a community of practice. For example, a science teacher who experiences success over time with how to skillfully differentiate instruction for students in the same class but at different reading levels may, as a result of reflecting on this experience, find a renewed professional commitment to the success of inclusion science courses. Admittedly, the crisis of re/representing the immediate and long-term interpretations to demonstrate the growth (increased competency and renewal) that this teacher may have experienced within the domain of reflective practice is a formidable task.

While some teacher educators offer models to describe the process of reflective practice (see Korthagen & Kessels's [1999] five cyclical phases of reflection, and Rodgers's [2002] four cyclical phases of reflection), we agree with Fendler (2003) that the schematic stewardship of reflection is not so neat. In fact, most models conceptualizing phases of reflective practice do so by outlining desired learning outcomes with what is thought to be the forms of (meta-)cognitive processes and associated practices produced in each phase. Most models, however, acknowledge that one can move iteratively back and forth among each phase. For example, Rodgers's (2002) reflective cycle consists of four phases described by outcomes associated with patterns of learning (presence-in-experience; description of experience; experimentation; analysis of experience). These interconnected phases are not hierarchical but provide a way to think holistically about reflective practice. Perhaps what is most holistically important about the strongest forms of reflective practice is the widening and deepening of the purposeful and empirical quality of the activity.

For example, once teachers decide to (and are guided to) build on salient professional experiences through reflective practice, they are more likely to make their trajectory of ideas about teaching and learning visible and available for collaboration and revision. Accordingly, Davis (2006) and other researchers (Zeichner & Liston, 1996) have characterized reflection as productive and unproductive, or as strong or weak. The factor that is instrumental in distinguishing between these types of reflections is that strong reflection is supported by evidence for claims that allows teachers to generate alternatives to their decisions or question their assumptions (Davis, 2006; Farrell, 2007; Richards & Lockhart, 1994). Ash and Clayton (2009) emphasize that strong (critical) reflection is a purposeful "evidenced-based examination of the sources of and gaps in knowledge and practice, with the intent to improve both" (p. 28).

In this research, e-portfolios provide a discursive space for reflecting on teaching and learning. We conceptualize purposeful reflective practice in e-portfolios as comprised of three critical factors: (1) selection and presentation of baseline and post-baseline evidence; (2) application of a conceptual framework; and (3) articulation of growth. These requisite components grow out of Dewey's (1933) work and align closely with Rodgers' (2002) four phases of reflection. For us, reflection is comprised of identifying and describing an experience through selection of evidence, analyzing it using a conceptual framework, and uncovering assumptions and conveying future action by articulating growth. These central characteristics of reflection are included in the e-portfolio, interactively and iteratively. In this way, e-portfolio entries are viewed as gross reflections, such that the entry's evidence, conceptual framework, and articulation of growth represent the outcome of reflective practice. Since general criticisms of reflective practice suggest what is illustrated as reflections is often unstructured, lacks serious academic work, and is comprised of a series of statements summarizing informal thoughts about participation in professional activity (Ash & Clayton, 2009; Farrell, 2007), it is important to examine the ways in which selection of baseline and post-baseline evidence impacts the illustration of growth through reflective practice.

As mentioned above, a key aspect of our conceptual framework concerns how growth within the domain of reflective practice is depicted in the e-portfolio. A focus on qualifying growth adds to the e-portfolio literature because, while it is cited as a desired outcome of reflective practice (Davis, 2006; Rodgers, 2002) and construction of e-portfolios (Abrami & Barrett, 2005), standards for characterizing and evaluating growth are underdeveloped. We address this issue in the next section by introducing and by drawing on examples from the context of this study.

Contextual and Theoretical Frameworks

Context of Study

This e-portfolio study took place within the context of a masters degree granting Math Science Partnership (MSP) program funded by the National Science Foundation (NSF) at a major urban northeastern university. The MSP is a collaborative initiative between the university's chemistry department and its school of education and provides in-service secondary science teachers with content knowledge, science education theory, and model instructional strategies in order to encourage participants to improve teaching and learning chemistry in their schools. The program was organized for participants to complete within 26 months across three full-time summer sessions and two academic year sessions consisting of ten courses: eight dedicated to chemistry content knowledge and two focused on the theory and practice of teaching and learning chemistry. A cohort model was used to guide participants through the program where members of the same cohort enrolled in two courses per session. Successful completion of the program required participants to complete all coursework with a cumulative grade point average of 3.0 or greater, pass a final comprehensive chemistry content exam, write a thesis within a chemistry discipline, and pass the e-portfolio exit project requirement.

Structure of the e-Portfolio Exit Project

The e-portfolio was a high stakes assessment that was added as a degree requirement to the program in 2005. Teacher participants were required to use the e-portfolio to demonstrate their growth as a result of having participated in the program. It was required that participants use appropriate baseline and corresponding post-baseline evidence to explain and depict growth within all e-portfolio rubric item entries (e.g., what the evidence was, why it was chosen and how it illustrates growth). To this end, the assignments given in this teacher preparation program facilitated teacher reflection on significant educational priorities and practices, especially action research projects, journal writing, autobiography/ethnography accounts, chemistry content projects, video and/or conversational analysis, cogenerative dialogues (see Tobin & Roth, 2006), leadership projects, microteaching, or the publishing of work to share with professional communities.

The e-portfolio project was designed with general guidelines outlined in a rubric (Appendix A) that was accompanied by the *Guidelines for Writers and Readers (GWR)* (Appendix B) document. The rubric outlining the program's expectations for the e-portfolio specified that the e-portfolio must contain evidence that illustrates the author's growth within each rubric item (domain of competency). The rubric consisted of eleven items concerning the content of the e-portfolio and four additional rubric items that addressed the technical merit and aesthetics. The first eleven items required students to show growth related to both chemistry content and associated pedagogical knowledge. Each rubric item was evaluated by two raters (potentially three if the first two raters disagreed) and was scored on a "pass," "needs revision," or "fail" basis. Program participants were required to pass all rubric items in order to receive an overall passing score for their e-portfolio project. The GWR was developed after it was determined that the rubric did not effectively direct program participants to create documents that satisfied the program evaluators. This document elaborated on each rubric item and explicitly stated what was required (e.g., the number of artifacts corresponding to baseline and post-baseline evidence) in order to pass a particular area of the rubric. While this measure limits the freedom of participants, it was deemed necessary for normative assessment purposes. On the other hand, program participants were still free to choose any other pieces of evidence that they regarded as meaningful, as long as it pertained to the rubric items in an appreciable way. The GWR was implemented with the intent of creating a delicate balance such that the e-portfolio was both appropriately scaffolded and allowed enough freedom to encourage teacher ownership. In order to explore what participants articulated as evidence for growth within the domain of reflective practice, we chose to focus on the e-portfolio rubric item *Reflective Practice*.

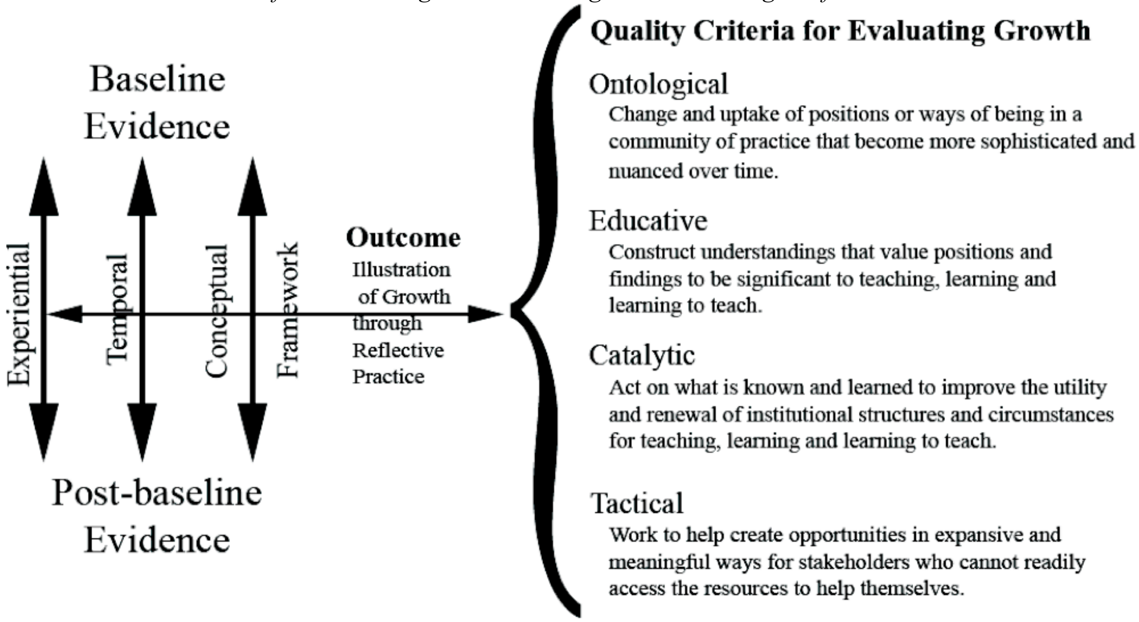
Conception of Growth

One of the primary purposes of constructing science teacher e-portfolios is to show authentic professional growth associated with practices and outcomes over time (Abrami & Barret, 2005). This was also a central purpose of implementing e-portfolio in the MSP program. Employing authentic growth as an analytic category entails exploring and recognizing purposeful attempts to interpret transformative experiences associated with teaching science. It is important to recognize that the activity of growth in learning (or improving) how to teach science is framed by particular social, cultural, and historical contexts (Tobin & Roth, 2006; Stetsenko, 2008). In this manner, authentic growth is multi-dimensional and is always embedded in the processes of being, becoming, and belonging to the professional field of science education. What has been seen in this multi-dimensional context of growth are emergent themes and interrelated voices that make apparent the continuous endeavor of teaching to learn and learning to teach. Many program participants express discovering "blind spots" in their patterns of classroom interactions after conducting their classroom action research. For example, one participant expressed not realizing how often he did not give enough time for students to answer questions during review periods. As such, self-reported descriptions and assertions of authentic growth are confronted by the continuum between long-term and short-term patterns attached to the human experience of learning how to teach science. Farrell (2008) suggests that, “reflective practice takes place along a continuum” and “as a result it may be unreasonable to expect all teachers to engage in reflection at every moment and stage of their teaching” (p. 4). From our current perspective, the educative value gained from reflective practice is not a static constituent of what has been experienced and observed. Rather, reflective practice facilitates different lenses to explore and explain the capacity to grow (and assert growth) in and across professional stages and levels of competencies. For science teachers an important aspect of this capacity is to communicate understanding of teaching and learning to teach science in meaningful and purposeful ways (Collins, 1992).

Figure 1 provides a conceptual framework for authentic growth through reflective practice. Networks of baseline and post-baseline evidence are formed in the framework when they have been experienced over time and are deliberatively analyzed using a consistent conceptual framework. The vertical bidirectional arrows between baseline and post-baseline evidence symbolize the necessity to constantly contemplate how each type of selected evidence is comparatively illustrated, generating new and more nuanced reflective insights that illustrate growth. The horizontal bidirectional arrow represents the iterative and generative nature of reflective practice (Rodgers, 2002). The framework incorporates four interrelated quality criteria (ontological, educative, catalytic and tactical) to evaluate the illustration of reflective practice. The four quality criteria are introduced to provide generative pathways to theorize and make sense of experiences within the context and complexities of successful teaching and learning of science and learning how to teach science. These quality criteria are adopted from Guba and Lincoln (1989) originally used as part of a system of criteria to judge experiences and outcomes associated with qualitative research. Since then, Tobin and Roth (2006) and Bayne (2009) have adopted this set of quality criteria to understand and judge the extent to which research participants and other stakeholders attend to ongoing, meaningful changes in their perspective due to participation in science education ethnographic research.

Articulated by Bayne (2009), ontological quality criterion encompasses the extent to which an individual's personal constructions are improved, matured, expanded and elaborated as a result of participating in sites and experiences that are intended to improve how to teach science. Just as science teachers shift roles and positions from pre-service teachers to in-service teachers, so too do their ways of *being in and with* others change as they continue to gain new understandings related to teaching and learning science. Ontological criterion not only encompasses the new construction of the teachers’ way of being, but also the construction of others as they participate in teaching and learning science. For example, the manner in which science teachers construct their identities in the classroom and the identities of their students are often an emergent theme as teachers reflect on their pedagogical strategies. Educative criterion involves the understandings that value positions and findings have in being significant to teaching and learning and learning to teach. This also includes the extent to which individual participants' understanding of and appreciation for the construction of others in their community of practice are enhanced. In the context of e-portfolios in this program, the ontological and educative criteria refer to the learning of all stakeholders during the process of reflective practice. The catalytic criterion is the extent to which action is stimulated and facilitated among stakeholders as a result of participating in experiences that improve how to teach science. For example, the catalytic criterion is exhibited when science teachers use action research to confront complexities of teaching science while simultaneously encouraging those involved in their study to engage in action to change the circumstances in the classroom or school. This criterion requires that science teachers act on what is known and learned to improve the utility and institutional structures and circumstances for teaching and learning and learning to teach. The tactical quality criterion is evidenced when, as a result of participation of stakeholders in the process, help is provided in meaningful and expansive ways to those who cannot readily access the resources to help themselves. This means that teachers consider the structures of their classrooms and classroom research and ensure that all students benefit from their

Figure 1
Framework for Illustrating and Evaluating Growth Through Reflective Practice



reflective practice. Taken together, this system of quality criteria shapes and defines a generative understanding of authentic growth in the production of practices and outcomes (including reflective practice) of learning how to teach science.

Using Interpretive Frames to Depict Baseline and Post-Baseline Evidence

We turn now to discuss the conceptual framework for producing baseline and post-baseline evidence within the structure of e-portfolios. In this study, we are specifically concerned with the types of evidence selected and the impact of evidence on the nature and quality of illustrating reflective practice in the e-portfolio. Consistent with what we have argued above is the need to illustrate and coordinate interpretive perspectives across forms of evidence to examine different approaches to authentic growth within the domain of reflective practice. In this process we are guided by the quality criteria to interpret diverse possibilities for depicting growth. We consider data as evidence when used in an iterative and generative process to illustrate coherent and contradictory patterns of growth in reflective practice. Accordingly, the discursive spaces afforded by the creation of e-portfolios are springboards for emergent themes connecting and coordinating networks of baseline- and post-baseline evidence. In this manner, interpretive frameworks used to characterize authentic growth can simultaneously constitute and structure how reflective practice is depicted within and across network(s) of evidence. What is important about the application of a coordinated interpretive framework is that it addresses (1) the changes in professional practice and (2) the creation of evidence that implicates authentic growth in knowledge and competency within the domain of reflective practice. In other words, depiction of growth in teaching and learning to teach science must be synthesized across baseline- and post-baseline evidence (Roth, van Eijck, Reis, & Hsu, 2008). In this process, networks of baseline and post-baseline evidence emerge conceptually linked in e-portfolio entries, not only by documenting practice and experience, but also by a set of consistent interpretive frameworks used to theorize artifacts (including practice and experience) and produce evidence from them.

Research Methodology

Participants

This study focuses on the completed e-portfolio project produced by all participants of cohort eight, comprised of nine in-service secondary science teachers. These e-portfolios were selected for this study because this was the first cohort to experience the e-portfolio as a program component from their initial entry into the program. Throughout the program participants were able to build on their e-portfolio and were coached to ensure the use of both baseline and post-baseline evidence for each e-portfolio entry. The teacher participants represent a diverse range of teachers. Of the nine teachers there were three male and six female teachers, aged 25 to 49, teaching in urban, suburban and rural, public and private schools. Years of teaching experience ranged from one to nine years. Additionally, four of the teacher-participants entered the teaching profession in a traditional manner while five others came to teaching through an alternate route program.

Rubric Item: Reflective Practice

This rubric item requires that program participants demonstrate “a disposition toward inquiry on teaching, and an ability to apply educational theory to do research on teaching and learning in his or her own classroom.” In order to fulfill the requirement for this area, students were required to conduct classroom research. This rubric area was further clarified through the GWR. The GWR suggests that reflective practice be conceived of as classroom research related to teaching and learning chemistry. The intent of this rubric area was for participants to conduct and come to understand the importance of continuing to conduct classroom research. In order to show competence in this area, teacher-participants were required to present a minimum of one set of corresponding baseline and post-baseline pieces of evidence that illustrated growth in reflective practice. The GWR suggested that teacher-participants demonstrate growth through comparison of post-baseline evidence from their classroom research project and baseline evidence from their paper portfolio submitted prior to entering the program or other past lessons. The GWR also indicated that teacher-participants were required to summarize these projects in their reflection and provide additional discussion about dispositions toward continuing to inquire into their own teaching.

Study Design

We use the case study as our empirical inquiry approach to investigate the use of e-portfolios within the context of a teacher education program using a variety of evidence – documents, artifacts, and observations (Yin, 2009). Using the e-portfolio entry as the unit of analysis, we looked for continuities, consistencies and patterns of meaning, as well as contradictions. The goal was to capture the process of reflective practice and change over time based on teacher participants' experiences in the science education program and the requirements embedded within the e-portfolio exit project.

Data Collection

We accessed each participant's completed e-portfolio online and archived each teacher’s reflective practice entry, including external links, embedded audio-visual information and linked-to documents. Teacher-participants completed their e-portfolios in October of 2008 and we accessed and archived the entries used for the analysis in April of 2009.

Data Analysis

Data analysis was completed in two phases. In phase 1, we quantitatively scored the e-portfolio entries based on the essential components of reflection using a rubric, which was different from the more subjective rubric used by the program evaluators but specific to our theoretical framework (Table 1). We then employed purposeful sampling to select information-rich cases for in-depth study (Patton, 1990). To select the cases, we used the e-portfolio scores and selected extreme-cases in order to highlight the strongest and weakest examples of reflective practice (Patton, 1990). The entries of two teachers were selected as cases for qualitative analysis of reflective practice. In phase 2, we compare these cases to examine the variable outcomes of growth in reflective practice as portrayed by the e-portfolio.

Phase 1: Evaluating Purposeful Reflection

In order to characterize the nature of the reflection and provide a context for more in-depth examination of specific e-portfolio entries, we scored each of the e-portfolio entries on the three dimensions we identified earlier as essential components of purposeful reflection: selection and presentation of baseline and post-baseline evidence (E), application of a conceptual framework (CF) and articulation of growth (G). The rubric we developed (Table 1) was used to score the entries of all eight teacher-participants. For the category of evidence (E), we looked for artifacts that truly represented pre-program data, were clearly articulated and connected to the rubric area and were robust, such that they provided a window into teachers’ reflective practice before and after participation in the program. When we evaluated e-portfolios based on the category of application of conceptual framework (CF) we analyzed the e-portfolio entries for a consistent conceptual framework for baseline and post-baseline evidence that was sufficiently tied to literature. For both the criteria of evidence and the conceptual framework we considered Challis’ (2005) “A checklist for a mature ePortfolio” (Salient Differences section, Table 1) to develop the

Table 1
Researcher Rubric for Scoring Reflective Practice e-Portfolio Entry

	Under-developed (1)	Good (2)	Excellent (3)
Evidence	Not carefully selected or not relevant to the rubric area. Missing either baseline or post-baseline evidence.	At least one piece of evidence is relevant and carefully selected. Does not highlight or excerpt the salient pieces.	Both baseline and post-baseline evidence is relevant, carefully selected, makes a useful contribution and is processed to highlight appropriate excerpts
Conceptual Framework	Not adequately explained or appropriately selected. Not applied to the evidence presented.	Not consistently applied – may be applied to only one piece of evidence or use different frameworks.	Embedded, thoroughly and accurately explained and consistently applied across baseline and post-baseline evidence
Growth	Not explicitly discussed, but implied. Reveals present but not future action. May reflect only a small portion of quality criteria.	Discussed, but oversimplified discussion. Does not illustrate all components of the quality criteria.	Illustrates self-awareness and growth – focused on future action. Quality evaluation based on the presence of quality criteria.

three levels of achievement. Based on the list of characteristics of purposeful selection of evidence and reflection we created descriptions for under-developed, good, and excellent e-portfolio entries in these categories. Finally, for the category of growth (G) we looked for the explicit discussion of growth and clear articulation of how the program promoted this change over time. Specifically, we identified whether teachers' entries addressed the quality criteria (Table 1) and how they used evidence to speak to the ways in which their dispositions as science educators changed. We articulated the achievement levels for the category of growth based on our framework and the presence or absence of the quality criteria as referents of authentic growth.

To score the e-portfolios, the researchers scored the entries independently according to the rubric, isolated specific excerpts from the entries and provided narrative to support their decisions. The scores were then discussed until they were able to come to consensus around the relative scores (3 to 9) of the teacher's e-portfolio entries based on the scores given in each category. For the category of growth, we first evaluated each teacher's entry to determine the presence (P) or absence (NP) of each of the quality criterion. The results of this analysis can be found in Table 2. Based on this analysis and the ways in which the entry articulated self-awareness and growth, we arrived at scores from a low of one, representing the minimal illustration of quality criteria, and a high of three, necessitating the presence of all of the quality criteria in the teacher's entry. The e-portfolio entries ranged from total scores from a low of three to a high of nine, representing the diverse products that emerged within the same program structures and e-portfolio requirements (Table 2). This suggests that despite the similar requirements set forth by the structure of the rubric and GWR, the nature of the reflection varied across participant entries. In addition to the e-portfolio scores, we looked at the quality of artifacts and students' overall performance in their coursework in the program as another indicator of student progress (Table 2), to consider the use of e-portfolios as an alternative assessment mechanism.

While many people advocate for authentic assessments, the issues of predictive validity and reliability across assessments still exist (Darling-Hammond & Snyder, 2000). e-Portfolios are a step away from teaching itself and a step away from coursework in the teacher education program. Since no single measure of teaching is adequate (Darling-Hammond & Snyder, 2000), looking across assessments for coherence or contradictions provides an additional layer of analysis of growth in learning how to teach science. In Table 2, grades derived from more traditional assessments are highlighted to make a comparison between how the different assessment approaches evaluate various aspects of a teacher's practice, including pedagogical decisions, mastery of content knowledge, and catalytic leadership projects. In the case of cohort eight, we noticed that teachers with the highest e-portfolio scores tended to have higher overall grade point averages and teachers with the lowest e-portfolio scores tended to have lower overall grade point averages. This suggests that e-portfolios require similar skills to traditional coursework. For example, teachers who have more sophisticated critical thinking and analytical skills and are more experienced with reflective writing may select more robust artifacts as evidence and portray more

Table 2
Summary of e-Portfolio Reflective Practice Scores and Traditional Assessment Data for Cohort 8

Teacher Participant	E	CF	Quality Criteria for Assessing Growth				G	Total Score	Post-Baseline Evidence	Grade on Selected Evidence	Overall GPA
			Ont	Edu	Cat	Tac					
Dorian	1	1	NP	P	NP	NP	1	3	Action research project	3.3	3.20
Amy	1	1	NP	P	NP	NP	1	3	POGIL	4.0	3.33
Steven	2	2	NP	P	NP	NP	1	5	Action research project	4.0	3.47
Benjamin	1	2	P	P	NP	NP	2	5	Action research project	4.0	3.97
Polly	2	1	P	P	P	NP	2	5	Action research project	4.0	3.77
Leonard	2	2	P	P	P	NP	2	6	Action research project	3.0	3.13
Dina	2	2	P	P	P	P	3	7	CSSE blog response	4.0	3.33
Grayden	3	2	P	P	P	P	3	8	Action research project	4.0	3.97
Michele	3	3	P	P	P	P	3	9	Action research project	3.0	3.90

Note. E – Evidence, G – Growth, CF – Conceptual Framework, NP: Not Present, Ont – Ontological, P: Present, Edu – Educative, Total Score: 3 (under-developed) to 9 (excellent), Cat – Catalytic, Tac – Tactical

progress due to traditional academic prowess. However, some differences were noted. In the middle range of e-portfolio scores we find teacher-participants with both higher and lower grade point averages. Also, when considering the grade on selected evidence we also noticed that the grade on selected evidence does not always correspond to the e-portfolio score. For instance, the teacher whose e-portfolio entry received the highest score received the lowest grade on the coursework. These contradictions suggest that e-portfolios add an additional layer of assessment providing new information about the teachers and how they have transformed in their teaching and learning to teach science.

Phase 2: Using the Quality Criteria to Analyze Growth, Strong, and Weak Reflections

From the analysis in phase 1, we found a diverse sample of reflection and reflexivity as the teacher-participants highlighted the action research, conversational analysis, cogenerative dialogues, professional workshops and writings, and application of new pedagogies in their classrooms that demonstrated growth. We used this initial scoring scheme to select specific entries to further explore the extremes of reflective practice afforded by the e-portfolio. Specifically, we highlight and compare the articulation of growth against the standards of the four quality criteria, by examining educative, ontological, catalytic and tactical nature of the teachers' practice made visible through their entries. We selected Dorian's and Michele's e-portfolio entries to present and examine the disparate ways that growth within the domain of reflective practice was illustrated. These two entries represent what we considered as strong (Michele) and weak (Dorian) reflective practice e-portfolio entries (see Table 3). In particular, we examined how continuities, consistencies and contradictions of growth were illustrated and conceptualized across corresponding forms of baseline and post-baseline evidence.

Michele's Reflection Practice Entry (Strong Reflection)

Michele's e-portfolio reflective practice entry focused on her experiences with using education literature to conduct what she came to consider as salient action research in her classroom to improve teaching and learning chemistry. A key resource to understanding Michele's growth within the domain of reflective practice is found in the way she inculcates a conceptual framework that allowed her to present, connect and analyze networks of baseline and post-baseline evidence. She incorporates and links one piece of baseline and two pieces of post-baseline evidence with a conceptual framework that encompasses two central themes: (1) improved formulation of research questions that induce changes in teaching practice and (2) increased use of

Table 3
Summary of Michele's (strong) and Dorian's (weak) Reflective Practice e-Portfolio Entries

	Evidence (E)			Growth (G)	
Teacher - Participant	Baseline (B)	Post-Baseline (PB)	Time Between Evidence	Theoretical Frame Applied to B and PB	Teacher's Voice OR Excerpt from e-portfolio entry
Michele (Strong Reflection)	Excerpts from self reflection on video taped baseline lesson	Research question on research proposal draft Summary of the outcomes of research	1-2 years	Action research Constructivism Qualitative and quantitative research methods	"My growth in my ability to formulate questions worthy of research is shown by the refinement of my research question as I continued to work on my research proposal in Edu536. As I encountered the literature (for the first time!) I began to understand and to integrate a constructivist framework that gave me the vocabulary and insight to observe my teaching and discern what I needed to change. "My growth in my ability to perform classroom research has much to do with my increased awareness of assessing the effectiveness of pedagogical practice. As I became more aware of my need to evaluate change I had implemented, became more comfortable with the use of both quantitative and qualitative methods of assessment
Dorian (weak reflection)	Discussion board with research project proposal on implementing POGIL	Action research paper, survey questions, interview questions	~1 year	Traditional versus inquiry methods of teaching	"What I learned from my research was NOT to make POGILs the only pedagogy in my classroom throughout the year. It should go hand-in-hand with the traditional way of teaching.

quantitative and qualitative methods in assessing the impact of pedagogical changes. In the first theme, Michele asserts her interest in analyzing how she used education literature to formulate salient research questions within a constructivist framework for her action research project. Michele indicates that, "As I searched the literature (for the first time!) I began to understand and to integrate a constructivist framework that gave me the vocabulary and insight to observe my teaching and discern what I needed to change." While Michele seems to be aware that an important outcome of classroom action research is to gain knowledge that can potentially improve practice, her overarching goal in this particular e-portfolio entry is to conceptualize and depict her growth within the domain of reflective practice. In a complementary fashion, the second theme brings a lens to interpret Michele's experience to become increasingly aware of the need to integrate quantitative and qualitative methodologies in assessing the effectiveness of her pedagogical strategies. As such, both themes afford a space for reflective practice where understanding of new and productive ways of thinking about professional participation are linked to classroom action research that inform learning how to teach chemistry.

As mentioned earlier a key assumption of reflective practice is that teachers' attempts to gain professional knowledge and the capacity to assert that a deeper conceptual layer of analysis acquired from their teaching experiences are educative. That is, there is educative value attached to learning how to teach when the process is transformative and informs perspective, meaning and orientation obtained from cumulative teaching experiences. This concept was found to be well defined in Michele's e-portfolio entry. Michele's baseline evidence consisted of data from three excerpts from a reflective evaluation of a lesson she conducted prior to entering the MSP program. It was required that all program applicants conduct and submit a reflective evaluation of one of their chemistry lessons. Using her conceptual framework, Michele selected and analyzed excerpts from her reflective evaluation and asserts that at the time she conducted the lesson she:

> . . . was still hesitant and uncomfortable with changing my instruction…and did not understand its assessment of student understanding and the efficacy of my own teaching value, nor have much experience with the variety of qualitative and

> quantitative research methods I could use to get a more comprehensive perspective of what was happening in my classroom.

Michele expressed that the overarching goal of her classroom action research was to find a more effective way to teach her students how to integrate and apply familiar math concepts to understand and solve chemistry related word problems. As such, her first piece of post-baseline evidence originated from her action research project assigned in the first education course in the program. Post-baseline evidence from Michele's action research project illustrated how her thinking changed as she attached educative value to publications found during her literature research and review. Michelle's analysis of education literature informed how she updated her action research questions across several months (Jan 2008- April 2008). Michele identified five key scholarly publications that informed the way in which she re-formulated her research questions. She chronicles and connects (1) how each iteration of her research question(s) catalyzed her thinking and (2) how each iteration was informed by one or more of the five key publications she identified. For example, in the second iteration she posed five research questions. The first question addresses the replication of algorithmic and conceptual understanding outcomes Nakhleh (1993) identified in his work with college chemistry students. Michele indicated,

> I was encouraged to do exploratory research of the algorithmic-conceptual disconnect Nakhleh had observed in college classes in my own *high school* classroom. I asked the question because I was somewhat interested, but the questions I was asking seemed mildly pedantic-not a driving force in my own classroom.

The other four questions in the second iteration focused on investigating a variety of related topics- from student attitude and motivation to the use of calculators in reinforcing mathematical concepts. Michele identified that investigating these groups of research questions would display academic learning but would "not be a driving force in improving my own classroom." In the fourth iteration where she finalized her research question she was able to use the following question to help narrow her focus: "Does the creation and use of manipulatives depicting the particulate nature of matter decrease the disparity between performance on algorithmic and conceptual problems?" This question was informed by an earlier Nakhleh (1992) article and one by Johnstone (1993). Michele described that these two articles were of interest because:

> Through my reading of Nakhleh (1992) and Johnstone (1993), I realized I wanted to do something very specific in my classroom to improve conceptual understanding. In particular, I wanted to attack the problem of student's inability to understand the **p**articulate **k**inetic **n**ature of **m**atter (PKNM). Eventually, in my classroom, I not only integrated the use of manipulatives, but also a broad range of tools targeting students' understanding of PKNM, from animations and applets representing the submicroscopic aspect of nature to questions asking students to draw representations. Finally, I had arrived at a question that was of particular value to me in my classroom, of importance to a larger community, and focused enough to be meaningfully researched.

Through Michele's reading of education literature she established teacher ownership of the centrality of the research process – asking good and salient questions to inform her pedagogical practice. As discussed in the next paragraph, Michele also used education literature and quantitative analysis to help catalyze and link her understanding of student performance to her teaching practice.

An important orientation in the quality criteria outlined above to evaluate growth within the domain of reflective practice is for in-service teachers to express shifts in ontological terms that merit productive and transformative changes to science teaching and learning. In other words, it is important not only to express shifts in participative thinking but also shifts in accordance with professional participation. Accordingly, participative thinking needs to be applied to current practice and to catalyze new possibilities in ways that engage students, and when possible other stakeholders in different teaching strategies (i.e., catalytic criterion). For example, Michele's second piece of post-baseline evidence illustrates how she used statistical methods to investigate her research question. She used a chemistry final exam administered to two separate cohorts of her students to analyze the effectiveness of integrating more submicroscopic representations of matter into her teaching. Submicroscopic representations were implemented using multimedia applets and manipulatives to represent the particulate nature of matter. She used these types of representation extensively with the 2009 cohort and compared their results to the 2008 cohort where previously little integration was infused. Comparisons were conducted using questions that gauged algorithmic (calculation-heavy) understanding and conceptual understanding of gasses, chemical equations, limiting reagents and empirical formulas. From the results, Michele noted that:

> It is evident from the data that, contrary to what I expected, my students showed significantly less

> conceptual understanding of gases, even as they improved their algorithmic ability to solve problems related to gas laws. There was no significant difference in any of the other question area. Since NO ONE got just the conceptual question correct, my conjecture, in looking over the actual answers chosen, is that I may have taught my lesson in a way that encouraged students in learning or retaining a misconception – they often thought that when gases are cooled, the gas not only slows down, but condenses, even at temperatures above the gas boiling point . . . I think I may have actually improved my teaching of gases in general, but made the unfortunate mistake of not accounting for a common misconception that could arise once students started visualizing and qualitatively associating particulate motion, physical state, and the effect of temperature.

For Michele, reflective practice brought opportunities to catalyze change, albeit with mixed results. It also provided her with a sense of professional renewal that incorporated productive opportunities to contemplate and enact tactical vision of teaching and learning with others. Michele used participative thinking to contemplate future action when she hypothesized that, "the use of this web-based support software (which is easily integrated into pre-existing materials to make them interactive) will improve class participation, accountability, and student enjoyment of my courses." Reflective practice is a process that requires coming to know the past, present, and what can be envisioned in the future with rearranged views about teaching and learning science. Her conceptual framework helped to organize future action as she, "hope(s) to gain a more thorough assessment in the future by making use of qualitative surveys and evaluations in concert with quantitative analysis."

Dorian's Reflective Practice Entry (Weak Reflection)

Dorian, like Michele, focused his e-portfolio entry on his research project, as the rubric area recommended that teacher-participants demonstrate the ability to apply educational theory to do research on teaching and learning in the classroom. Dorian organized his e-portfolio entry into three discrete sections, (1) *What, Why, How*, (2) *Baseline Reflection*, and (3) *Growth Reflection*. In *What, Why, How*, Dorian explains how he was introduced to Process-Oriented Guided Inquiry Learning (POGIL) (Moog et al., 2008) the first summer of the program in organic chemistry. This pedagogical strategy is used in the content and pedagogy courses throughout the program and teacher-participants are encouraged to try this in their own classrooms. In *Baseline Reflection* and *Growth Reflection*, Dorian presents and summarizes his baseline and post-baseline evidence, respectively. He then brings it all together through a concluding section where he summarizes what he learned from reading educational literature and from conducting classroom research.

Dorian's baseline reflection indicates that he decided to do research in his own classroom when he was having difficulty successfully implementing POGIL activities. He states, "At the beginning of the second year into the program I started constructing my own POGILs and was not completely successful in implementing the method in my classroom. This initiated the attempt to start research in my own classroom." Despite his commitment to action research, the e-portfolio entry does not provide a conceptual framework to connect and analyze the networks of baseline and post-baseline evidence he presents. Instead, chosen research methods are presented with little to no support from established educational research.

In the section entitled *Growth Reflection*, Dorian includes a survey and interview questions used to conduct interviews with individual students. The interviews and surveys were intended to gauge student affect, including "how students feel about each of the pedagogies" and "feelings towards NOT making POGIL the only pedagogy in my classroom." While the questions are provided as evidence, there is no theoretical framework with which to analyze the data obtained, resulting in lack of synthesis across baseline and post-baseline evidence. His lack of a consistent interpretive framework makes it difficult to assess growth and evaluate his participation in teaching science. Dorian's e-portfolio entry lacks coherence in his expression of growth within the domain of reflective practice. Even in his hyperlinked research paper, the interview questions and survey are provided, but there are no results, analysis or findings (i.e., no transcript of conducted interviews, no statistical analysis of survey data, no achievement indicators), making it impossible to attach educative value to his research.

Overall, Dorian focuses not on a changing disposition toward inquiry in his own classroom, but rather how his thinking about using POGILs in the classroom was shaped by his classroom research project. Although he attempts to provide a coherent picture of how his classroom research shaped his practice, his conclusions and the conceptual framework from his literature review are disconnected, and the presentation of evidence and what he learned from his research are inconsistent. The e-portfolio reflection seems to suffer from confirmation bias. In other words, rather than collecting evidence on all sides of the approach in question and evaluating it as cogently as he can (Nickerson, 1998), Dorian instead builds a case by selectively gathering (i.e. providing a survey to find out how students feel about *NOT* using POGIL as the only strategy) or giving undue weight to his position. Hence, despite the research Dorian cites, he implements research methods that support his initial disposition toward using POGILs in the classroom and neglects to gather (or present) evidence that would tell against it. For example, Dorian provides references that question the traditional method of teaching (Hanson & Wolfskill, 2000; Pintrich, 2003) and states,

> According to the research-based generalization, I should be aware that after traditional teaching there will be: (1) Lack in the connection among concepts, formal representation, and real world (2) Lack in overcoming certain conceptual difficulties and that may not help to increase the understanding of the basics of these concepts, because some students will not grasp the concept by telling them. (3) Lack in the growth in the reasoning ability.

However, despite the research cited from education literature and without presenting research findings from his classroom, he still concludes that

> . . . what I learned from my research was NOT to make POGILS the only pedagogy used in my classroom throughout the year. It should go hand-in-hand with the traditional way of teaching. . . . It is not right to abandon the traditional teaching approaches. Traditional methods of teaching can be adapted, modified, and improved.

His e-portfolio entry provides the past and present of his teaching, but does not contemplate future improvements in teaching and professional practice. There is an incomplete picture of his interpretation of professional growth and what is present suggests that this experience did not catalyze change in his classroom or create an ontological shift in the way he approached the teaching and learning of chemistry. Instead, his reflective practice led him to support his baseline thinking, without supplying convincing evidence to support that conclusion. Importantly, his reflective practice did not seem to contribute to tactical changes in the way he approached the teaching and learning of chemistry or how he will use the knowledge gained through inquiry to change future actions.

Outcomes

At the beginning of this article we asked: *How does the structure of the e-portfolio influence how secondary science teachers depict evidence to reflect on their teaching and learning how to teach chemistry within an in-service teacher preparation program?* The e-portfolio entries of teacher participants were guided by the same rubric and Guidelines for Writers and Readers (GWR). An affordance of this structure is that all entries provided evidence to demonstrate temporal and experiential change over the course of the program and were not limited to a specific template or formatted software. In accordance with the characteristics of strong reflection (Davis, 2006), requiring *both* baseline and post-baseline evidence pushed all teachers toward more purposeful reflection. In addition, the ability to choose the format of the entry gave teachers some level of ownership of and self-expression within their e-portfolios (Borko, Liston, & Whitcomb, 2007). However, the structure was constraining in that teacher participants tended to select the baseline and post-baseline evidence that were recommended by the GWR (see Table 2). Of the nine e-portfolio entries examined, all but two teacher participants selected their action research project as evidence of growth, which corresponded to the evidence recommended by the GWR. When e-portfolios were evaluated based on the rubric, the teachers who demonstrated authentic growth based on the quality criteria also had a strong conceptual framework and clear rationale for the evidence selected, Therefore, while growth framed and organized the entry the nature and quality of the reflections differed significantly. In cases of strong and purposeful reflection of authentic growth, teachers tended to begin by outlining the conceptual framework they would weave throughout the rest of their entry and apply in their action research and analysis of growth. In contrast to these entries stood those entries that described disconnected experiences as baseline and post-baseline evidence without using a conceptual framework to link both corresponding forms into an interpretive and connective whole. Accordingly, in methodological and practical terms we regarded the structure of the entire e-portfolio entry as a complex whole illustrating both reflective practice and reflection simultaneously. A lack of integration with a conceptual framework across the networks of evidence and absence of an articulation of authentic growth leads to weak reflection and reflective practice based on the application of our interpretive framework.

At the beginning of this article we also asked: *How is the comparison between networks of baseline and post-baseline evidence used to illustrate authentic growth within the domain of reflective practice?* We conceptualized and utilized four interrelated quality criteria to analyze e-portfolio entries that attempted to illustrate growth within the domain of reflective practice. Authentic growth was evaluated against the standards of the quality criteria. Applying this framework supported an in-depth analysis of both Michele's and Dorian's reflective practice, and more specifically their growth, as illustrated in their e-portfolio entries. A major outcome of this work is seen in the use of corresponding baseline and post-baseline evidence to illustrate and corroborate growth in reflective practice. In this context corroboration means how opportunities are joined to create a believable whole against the standards of the quality criteria, particularly on what fits from what is already known. For example, Michele (strong reflection) introduces a conceptual framework that allowed her to present, connect, and analyze networks of baseline and post-baseline evidence in a way that guided her analysis and illustration of authentic growth within reflective practice. Michele's reflection of her own teaching of chemistry led to an educative experience that truly catalyzed change in both her teaching practices and her disposition towards future inquiry and action research with other stakeholders. This represented a form of catalytic exchange and development of reflective practice that emerged simultaneously from individual and collective activity of stakeholders in a community of professional practice. That is, experiencing, enacting and illustrating reflective practice, and associated schemas, can produce new forms of knowledge about how learning to teach science is experienced and understood. In this sense science teachers can experience ontological criterion by learning and sharing their world and disposition to learn how to teach science in new ways.

As already emphasized, in illustrating what otherwise can seem disconnected, it is important to connect networks across a coherent conceptual framework to illustrate reflective practice. What gets left out and what is not connected is often as important as what gets included and interpreted (Parkes & Kajder, 2010). In this study we considered an important objective of authoring an e-portfolio: to convincingly engage formal evaluators and readers as interpretive witnesses to reflective practice. Unfortunately, Dorian's entry (weak reflection) does not provide a conceptual framework and for this reason, his evidence remains disconnected and the reader is unable to determine the conceptual framework that Dorian utilizes to render a pattern of analysis of his growth within reflective practice. Dorian's entry corroborated the claim that an action research project had been conceived of and conducted. However, his disposition towards using POGILs in the classroom remained unchanged. In addition, his illustration of reflective practice did not indicate organizing for future action. In Dorian's case, he had strong working knowledge of the POGIL technique through working with it in the program, but needed to make better distinctions between his specific action research project focused on integrating POGILs and a more general approach to inquiry into his own teaching.

Limitations of this Study

This study analyzed nine e-portfolio entries, each created by science teachers in the participating cohort. Entries were created using electronic text, figures and graphs to illustrate the outcome of reflective practice. The e-portfolio entry was used as the unit of analysis. There are limitations to this analytical context. One limitation is that the sample size was small. This cautions generalization to broader contexts. It is important to note that the intent of this study was to introduce a conceptual framework for illustrating and evaluating the outcome of growth in the domain of reflective practice and to show how the framework could be applied in the context of a science teacher education program using e-portfolio. More studies on the effectiveness of this framework need to be conducted, possibly correlating survey or interview data from teachers. This would afford a deeper understanding of the ways in which science teachers conceived of using e-portfolios to illustrate their professional growth in the context of this framework.

Additionally, although we noted differences in the nature of reflective practice afforded by the e-portfolio, we were working under the assumption that in-service teachers entered the graduate program as proficient writers. Participants in the program were also required to submit drafts of their e-portfolio to receive feedback and requests for edits. We do acknowledge, however, that there could be significant variation in language ability in writing about reflective practice among participants. Research indicates that graduate students are still novices when it comes to using writing as a tool for self-growth and learning (Parkes & Kajder, 2010). Therefore, it is also worthy to note that strong reflections, certainly partially, are the product of students who may be more skilled as writers (Jenson, 2011). Since e-portfolios are a step away from the process of reflection this written electronic medium might privilege a candidate's ability to select and write about artifacts of teaching disproportionately to the candidate's growth in reflective practice. It could be that growth, in this framework, is a mixture of growth and language ability. An instrument to measure language ability was not administered to participants, thus limiting our ability to control for language ability in our analysis. As the pedagogy of e-portfolio improves within teacher education, as well as other professions, there is a need to address the important role of language ability within the process of accessing and evaluating reflective practice illustrated in the e-portfolio.

Conclusions and Implications

Two key purposes of reflective practice in teacher education are to interrogate forms of participation and participative thinking and subsequently learn from them by exploring new possibilities for improvement. In this study, we described a conceptual framework to assess and evaluate e-portfolio entries created by in-service science teachers to illustrate growth within the domain of reflective practice. Our conception of reflection as holistically represented in an e-portfolio entry, using the quality criteria as a means for qualifying authentic growth, can improve the design and evaluation of other e-portfolios in teacher education. At the core of the matter is depicting a unified representation through the process of deciding what is important to include and exclude along with what works to corroborate a standard of authentic growth within the domain of reflective practice. Consistent with the literature (e.g., Borko et al., 2007), clear tensions emerged between the rigidity constraining participant reflection for evaluation and the flexibility necessary for true self-assessment of growth. In some cases, teachers completed categories in order to "pass," as indicated by a tendency to choose evidence suggested by the guidelines, because portfolios were high-stake assessments. Programs must therefore consider how much structure to provide, when to provide descriptive feedback, and when and if evaluative feedback is required to meet the desired goals of the e-portfolio.

Although the framework used in this study was developed in the context of a graduate science education program, we feel that the conclusions and implications are relevant for a wider audience. Keeping in mind that there is more to reflective practice that can be depicted in e-portfolio, we advocate that teacher education programs using e-portfolios encourage the explicit use of baseline and post-baseline evidence. This is particularly important if the intention is to demonstrate evidence-based growth with in the domain of critical reflective practice (Ash & Clayton, 2009). Also, programs must be explicit about what it means to demonstrate growth and provide appropriate guidelines to evaluate the outcome of growth.

Our framework for evaluating growth (within the domain of reflective practice) using a system of four quality criteria (see Figure 1) adds to the literature by establishing standards for articulation and evaluation of professional growth within science teacher education. Each criterion, however, can be shaped in relation to the other to address specific foundational dispositions particular to growth in a community of practice. For example, engineers can develop more nuanced ways of approaching design plans (ontological criteria) as they come to value new design theories (educative criterion) and advocate for their widespread adoption in manufacturing codes (catalytic criterion) and education and industry standards (tactical criterion). In doing so these quality criteria can potentially guide the evaluation of reflective practice for engineering professionals and students. The key idea in the use of the quality criteria is the acknowledgment that reflective practice is deepened when individuals construct more nuanced ways of understanding how concepts and material, as well as human and institutional resources are used to meet goals within a community of practice.

If e-portfolios are being assessed, it is important to consider what type of evaluative instrument to use. Ascribing evaluation to reflective inquiry is complex, challenging, and potentially contentious (Ghaye, 2010). Programs must consider whether to create a program-specific rubric and determine how specific to make it. Additionally, with The National Council for Accreditation of Teacher Education (NCATE) program accreditation requirements at nearly all educational institutions, programs must consider whether it is appropriate or necessary to link the rubric to NCATE standards (Strudler & Wetzel, 2005). Finally, the timeline and method for assessment of e-portfolios is critical. If e-portfolios are to truly be created within a community of practice, specific structures must be in place to enable feedback and improvement along the way. In so far as e-portfolios serve as an alternative assessment method (Darling-Hammond & Snyder, 2000), programs should consider whether reading the written statements provided by teachers is enough, or whether an accompanying "oral defense" of sorts would be appropriate for providing a clearer picture of teacher growth.

e-Portfolios have the potential to be catalytic within programs for pre- and in-service teachers. We hope that by making explicit how incorporating corresponding baseline and post-baseline evidence helps to develop a framework for growth, we might inspire important considerations for new reforms linked to e-portfolio development aligned with current professional teaching standards. Accordingly, additional research on how science teachers connect growth in practice, theoretical understandings, and inquiry within the domain of reflective practice is needed. Demonstrating growth over time in a static electronic document is difficult. Science teacher education programs, and teacher education programs in general, must coach teachers to select exemplars and scaffold the process of reflection and articulation of growth. This may also mean helping students become better reflective writers and creators of reflective media salient to their career trajectories (Parkes & Kajder, 2010). In our research, teachers tended to select the suggested piece of evidence suggested by the rubric. The program GWR (see Appendix B) that was added to further guide the science teachers as they completed their e-portfolios seemed to constrain the teachers in this study. The science teachers tended to select evidence that aligned with suggestions in the GWR. We suggest that instead of providing e-portfolio guidelines that highly suggest evidence to present, programs integrate the idea of what Rodgers (2002) calls being "present-in-experience" and help teachers "learn to see." In doing so programs can help teachers to both improve their reflectivity and responsiveness to pedagogy by choosing and iteratively linking salient professional practice (including baseline and post-baseline exemplars) for evidence of growth through reflective practice (Lyons, 1998). As the possibilities and utility of the e-portfolio continue to emerge and mature as a multimedia medium that affords illustration of reflective practice and authentic growth, science teacher education programs must continue to explore the value and validity of the e-portfolio as a meaningful discursive space for professional renewal and continued development.

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Appendix A
Program Rubric for Evaluating Teacher-Participants' e-Portfolios

An e-portfolio must contain:

1. Pieces of **evidence** that illustrate the author's growth in each of the areas covered by the rubric items below.
   - Evidence can include coursework, student work, correspondence, etc.
   - You should include evidence from one or more Penn STI courses and/or your teaching practice for each rubric area, as appropriate.
2. A **reflective statement** or critical analysis for *each* piece or grouping of evidence. Reflections must explain:
   - **What** the piece of evidence is (to an outside reader)
   - **Why** you chose it (what it illustrates about you)
   - **How** it illustrates your **growth** in one or more specified areas of the rubric

For each rubric item:
"Exceeds Expectations" indicates that your e-portfolio shows evidence of very significant growth and/or your reflections show a very sophisticated understanding of your growth process.
"Passing" indicates that you have proven sufficient growth in the rubric area through reflecting on evidence.
"Needs Revision" indicates that your e-portfolio gives little or no evidence of and/or reflection on your growth or understanding in a particular area. Specific suggestions for changes or additions needed to receive a passing score will be provided by your reviewer.

<u>Achievement in Science and Education:</u>

Comprehension of Science/Chemistry Content Enduring Understandings – The participant has grown to have a stronger comprehension of science content as described in the program and course Enduring Understandings.		**Exceeds Expectations**
		Passing
		Needs Revision
Use of Accurate Scientific Language – The participant has grown in his/her ability to accurately use scientific language.		**Exceeds Expectations**
		Passing
		Needs Revision
Synthesis of Scientific Concepts Across Science/Chemistry Courses – The participant has demonstrated a synthesis of key program ideas across the program content.		**Exceeds Expectations**
		Passing
		Needs Revision

Application of Scientific Concepts – The participant has grown in the ability to apply concepts and scientific principles to practical problems and/or real-world situations.		**Exceeds Expectations**
		Passing
		Needs Revision
Use of New Science/Chemistry Content Knowledge in Designing Instruction – The participant has demonstrated the application of new scientific knowledge in the design of teaching materials, lesson plans, and/or assessments used in his or her own classroom.		**Exceeds Expectations**
		Passing
		Needs Revision
Understanding of Science Education Theory & Literature – The participant has grown to have a stronger understanding of important education literature and theory.		**Exceeds Expectations**
		Passing
		Needs Revision
Reflective Practice – The participant demonstrates a disposition toward inquiry on teaching, and an ability to apply educational theory to do research on teaching and learning in his or her own classroom.		**Exceeds Expectations**
		Passing
		Needs Revision
Use of New Pedagogical Knowledge in Designing Instruction – The participant has demonstrated the application of improved knowledge of educational theory in the design of teaching materials or lessons used in his or her own classroom.		**Exceeds Expectations**
		Passing
		Needs Revision
Use of New Pedagogical Knowledge in Designing Assessment – The participant has demonstrated the application of improved knowledge of educational theory in the design of assessments used in his or her own classroom.		**Exceeds Expectations**
		Passing
		Needs Revision

Leadership – The participant has grown as a leader in science education.		**Exceeds Expectations**
		Passing
		Needs Revision
Integration of Available and Appropriate Technology into Classroom Practice – The participant has become more skilled and sophisticated in his or her use of appropriate technology in classroom practice.		**Exceeds Expectations**
		Passing
		Needs Revision

<u>Technical Merit of the E-Portfolio:</u>

Organization – The site is well organized and pages are clearly labeled with author, subject and date.		**Exceeds Expectations**
		Passing
		Needs Revision
Clarity of navigation – Site navigation makes it easy to find items of interest. Evidence pieces are limited to relevant sections of large documents, or relevant sections are clearly identified visually.		**Exceeds Expectations**
		Passing
		Needs Revision
Functionality – There are very few malfunctioning buttons, links, or images. HTML pages are used when possible, and other documents are in a universal format (PDF, JPEG, etc.).		**Exceeds Expectations**
		Passing
		Needs Revision

Visual presentation – Color and font are chosen so that text is easy to read, and any visual effects used enhance the presentation, rather than distracting the reader.		**Exceeds Expectations**
		Passing
		Needs Revision

Appendix B
Guidelines for Writers and Readers

General:

- **Evidence is to be specific to the rubric area and not a full thesis/capstone or other large document, but rather specific pieces from such documents.**
- **Evidence is to be imbedded into the reflection document or linked from the reflection document so that it opens in a browser window such as PDFs in IE or Safari**
- **All reflections are to be webpages not PDFs or other file formats.**

Comprehension of Content Enduring Understandings –
The participant has grown to have a stronger comprehension of science content as described in the program and course Enduring Understandings.

The intent of this rubric area is for the participant to demonstrate their new and/or increased understanding of fundamental science concepts studied in program courses, not small facts.

Passing:

1) A minimum of 3 content EUs (MISE – across both physical and non-physical science disciplines; MCE across content from several courses; BOTH – over the full span of the program)
2) Evidence: baseline and later for each EU
3) Reflection discusses the specific concepts and acknowledges courses in which it was studied, as well as discussion of participant's own growth.
4) Content must be accurate!
5) Growth is demonstrated through the baseline vs. later evidence and is explained in the reflection.

Use of Accurate Scientific Language –
The participant has grown in his/her ability to accurately use scientific language.

The intent of this rubric area is for the participant to demonstrate their ability to use accurate scientific language to explain fundamental scientific concepts, rather than to demonstrate their increased vocabulary.

Passing:

1) A minimum of 2 sets of baseline and later evidence of improved use of scientific language in explaining concepts.
2) Reflection discusses specific language to be seen by reader in evidence as well as discussion of participant's own growth.
3) Content and language must be accurate!
4) Growth is demonstrated through the baseline vs. later evidence and is explained in the reflection.

Synthesis of Scientific Concepts Across Courses –
The participant has demonstrated a synthesis of key program ideas across the program content.

The intent of this rubric area is for the participant to select broad concepts such as energy, the use of models, the importance of bonding, scale, systems, time, scientific method, etc., not small scientific facts, and to be able to synthesize content learning around this idea. Note – no growth must be demonstrated.

Passing:

1) At least 1 broad concept (MISE – across both physical and non-physical science disciplines; MCE – across several courses; BOTH --over the full span of the program)
2) The reflection may be where the synthesis is presented if no assignment/evidence is appropriate. In this case, the evidence would be assignments/documents from courses where content was learned.
3) If evidence is provided as the synthesis, then the reflection discusses the concepts as they relate to appropriate courses over which participant's evidence is now demonstrating synthesis of the conceptual understanding.

Application of Scientific Concepts –
The participant has grown in the ability to apply concepts and scientific principles to practical problems and/or real-world situations.

The intent of this rubric area is that the participant applies science content learning to real life and/or practical problems, not that the content is applied to their teaching.

Passing:

1) Minimum of 3 real life/practical applications of science concepts (MISE – from both physical and non-physical science disciplines; MCE – from several courses; BOTH --over the full span of the program)
2) Evidence may come from lessons within participant's own classroom, which could make 'baseline' and 'later' evidence easier to find.
3) Reflection is to specifically yet briefly discuss where content was learned, where/how application was learned, and how growth is shown through the evidence.

Use of New [Science] Content Knowledge in Designing Instruction -
The participant has demonstrated the application of new scientific knowledge in the design of teaching materials, lesson plans, and/or assessments used in his or her own classroom.

The intent of this rubric area is that participant has learned science content through program courses that has been and can be applied in their classroom, and is able to demonstrate the application.

Passing:

1) Minimum of 2 instances of participant's classroom use of their own new science content knowledge, at least one of which is to have already been implemented in their classroom.
2) Evidence: Baseline and later authentic[1] evidence is to be provided (e.g., part of previous authentic lesson plan [w/o new content knowledge] vs. new authentic lesson plan [with new content knowledge] in order to demonstrate growth).
3) Reflection is to specifically discuss the newly acquired content knowledge, from which course(s), as well as how/why/when the participant was able to apply it in participant's own classroom.

Understanding of Science Education Theory & Literature –
The participant has grown to have a stronger understanding of important education literature and theory.

The intent of this rubric area is that the participant has studied and been significantly affected by some aspect of science education literature or theory as a result of some program course.

Passing:

1) The quality of the impact will be judged as more important that the number of references.
2) Evidence: To be provided for where the literature was encountered, in what context, including specific citations and/or specific pieces of annotated bibliography (e.g., course assignments that included the citations), discussion boards on the particular literature/theory.
   NOTE: evidence is not required of implementation of teacher practice change (e.g., no lesson plans, assessments are required)
3) The specifics of the literature or theory selected by the participant should be cited and accurately summarized in the reflection, including a description of the course(s) and context in which they encountered this literature.
4) The specifics and comparisons of the 'baseline' and 'later' (i.e., change) of the participant's practice/philosophy that are based on this literature/theory should be explained in detail in the reflection.
5) Growth is demonstrated through the discussion in the reflection.

Reflective Practice (i.e., Classroom Research) –
The participant demonstrates a disposition toward inquiry on teaching, and an ability to apply educational theory to do research on teaching and learning in his or her own classroom.

The intent of this rubric area is that the participant has conducted, and come to understand the importance of continuing to conduct, classroom research.

[1] "Authentic" means "participant created" (e.g., not copied from teacher guide, text, developed by a colleague, etc.).

Passing:

1) Evidence: Later evidence will be selection(s) from participant's classroom research project(s). Baseline evidence may be from participant's Baseline Teaching Portfolio or other lessons but needs to relate to their later evidence.
2) Reflection: The selected piece(s) of participant's classroom research project(s) is (are) to be summarized in the reflection (e.g., Why participant selected the topic, brief overview of literature, summary of the project and outcome[s]). Some additional discussion should demonstrate participant's disposition toward continuing to inquire into their as well as some comparison of baseline and later to discuss their own Growth.
3) Growth is demonstrated through comparison of baseline and later evidence and discussion in reflection.

Use of New Pedagogical Knowledge in Designing Instruction –
The participant has demonstrated the application of improved knowledge of educational theory in the design of teaching materials or lessons used in his or her own classroom.

The intent of this rubric area is that the participant will provide evidence of using their new pedagogical knowledge in their classroom practice but not including assessments.

Passing:

1) Evidence: A minimum of baseline and 2 later pieces of evidence should be provided. Baseline evidence may be from Baseline Teaching Portfolio or other 'baseline' materials, lessons, units. Later evidence is to be authentic new materials, lessons, units implementing the pedagogical knowledge in the participant's own classroom. Pieces of evidence are to be carefully selected and targeted to the new pedagogical knowledge, not large documents but specific pieces of large documents that apply here.
2) A minimum of the Baseline and 1 of the later pieces of evidence should have been used in the student's classroom, not just planned for use.
3) If the pedagogical knowledge is based on literature/theory already discussed in previous rubric area, linking to that is encouraged. If not, then citation(s), detailed summary of the research/theory basis for this new pedagogical knowledge needs to be included in a reflection here.
4) Reflection discusses participant's new pedagogical knowledge, how/where attained and how participant has used that knowledge in designing instruction (i.e., classroom materials, lessons, units). Specifics of the evidence provided and connections to the pedagogical knowledge are to be clearly described in the reflections.

Use of New Pedagogical Knowledge in Designing Assessment –
The participant has demonstrated the application of improved knowledge of educational theory in the design of assessments used in his or her own classroom.

The intent of this rubric area is that the participant will provide evidence of using their new pedagogical knowledge in their classroom assessments.

Passing:

1) Evidence: A minimum of baseline and 2 later pieces of evidence should be provided. Baseline evidence may be from Baseline Teaching Portfolio or other 'baseline' assessments. Pieces of evidence are to be carefully selected and targeted to the new pedagogical knowledge. They should not be large unit documents but specific pieces of such large documents that apply here.
2) A minimum of the Baseline and 1 of the later pieces of evidence should have been used in the participant's classroom, not just planned for use.
3) If the pedagogical knowledge is based on literature/theory already discussed in previous rubric area, linking to that is fine. If not, then citation(s), detailed summary of the research/theory basis for this new pedagogical knowledge needs to be included in a reflection here.
4) Reflection discusses participant's new pedagogical knowledge, how/where attained and how participant has used that knowledge in designing assessments (i.e., quizzes, tests, formative, alternative, performance, etc.). Specifics of the evidence provided are to be described for the reader.

Leadership –
The participant has grown as a leader in science education.

The intent of this rubric area is that the participant will provide evidence of their influence and/or cooperative work with others in the school community, outside of their own classroom.

(We are sensitive to the variety of possibilities that can be thought of as leadership and that the teaching situations of some participants do not provide support and/or opportunities for them to demonstrate the leadership of which they are capable.)

Passing:

1) Evidence: Baseline evidence may be from participant's application essay or other documents but Baseline evidence is to be provided.
2) Later evidence must be provided; hopefully, more than 1 piece of evidence (e.g., minutes of mentoring meetings, conference abstracts, emails between colleagues, etc.)
3) Reflection discusses specifics of participant's understanding of 'teacher as leader' and how this understanding has changed over their time in the MISE/MCE program.

Integration of Available and Appropriate Technology into Classroom Practice –
The participant has become more skilled and sophisticated in his or her use of appropriate technology in classroom practice.

The intent of this rubric area is that 'technology' is to be interpreted broadly, including computer software usage, webquests, probes, sensors, smartboards, lab equipment, etc. and that the emphasis is on the participant's growth in using the technology.

Passing:

1) Evidence: Baseline evidence may be from participant's application essay, Baseline Teaching Portfolio, or other baseline lessons but it must be provided. Evidence should not simply be a picture of students or participant using technology, but rather should also include the lesson plan or other instructional evidence that demonstrates the pedagogical relevance of the technology used.
2) Evidence: A minimum of 1 piece of Later evidence is to be provided except in the case of a teacher whose teaching situation offers no possibility for this. In this case, participant needs to specifically describe their teaching situation and its limitations.
3) Reflection discusses specifics of participant's Baseline use of 'available and appropriate technology' in their classroom, as well as their current ability to use, use of and pedagogical relevance/importance/impact of the use of the technology.