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A Framework for Authenticity in the Mathematics and Statistics Classroom

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Authenticity is a term commonly used in reference to pedagogical and curricular qualities of mathematics teaching and learning, but its use lacks a coherent framework. The work of researchers in engineering education provides such a framework. Authentic qualities of mathematics teaching and learning are fit within a model described by Strobel, Wang, Weber, and Dyehouse (2013) for use in engineering education. Examples of the use of authenticity in mathematics and statistics instruction are provided.

More than half of community college students in the United States are required to take developmental mathematics courses, courses designed to supplement insufficient preparation for college level work (Ashford, 2011). This lack of mathematical literacy is also reflected in the everyday lives of American citizens. A 2012 report in USA Today noted, "a majority of young people in the United States have poor financial literacy" and young people in their 20s have "an average debt of about $45,000" (Malcolm, 2012, p. 1). Mathematical illiteracy may be one of the underlying causes for such financial difficulties. Phillips (2007) cited the National Center for Education Statistics as noting specific evidence of

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the mathematical illiteracy of United States' Citizens, stating 71% could not calculate miles per gallon and 58% could not calculate a 10% tip (p. 4). Negative attitudes towards mathematics are also common. An Associated Press poll of 1000 adults revealed 37% of those adults selected mathematics as the subject they hated the most, with the next highest percentage being 21% for English (Associated Press, 2005).

Addressing mathematics attitude and literacy requires impacting the minds of students. Skemp's (1976) discussion of understanding has provided a theoretical framework for considering the structure of student thinking that is still relevant. He noted the importance of multiply connected schema students mentally create that provide deeper and more useful understandings of the subject matter at hand, a phenomenon he called *relational understanding* (Skemp, 1976). His ideas continue to be important in mathematics education research and practice (Hassad, 2011; Van de Walle, 2007). This is evident in the most recent major work by the National Council of Teachers of Mathematics, *Principles to Actions: Ensuring Mathematical Success for All,* (2014)(PTA), which contrasts an unproductive belief in memorization for routine work with a productive belief that "making connections to prior knowledge or familiar contexts and experiences" is a vital part of student learning (p. 11).

As described by Van de Walle (2007), "understanding is a measure of the quality and quantity of connections that a new idea has with existing ideas" with relational understanding on the higher end of a continuum of understanding and *instrumental understanding* (Skemp, 1976) at the lower end. If a student only has instrumental understanding, then facts exist for the student discretely, disconnected from other facts (p. 25). Skemp's emphasis on relational understanding is echoed in the revised version of Bloom's Taxonomy, in which creating knowledge by combining information is considered the highest level of understanding (Forehand, 2005).

If understanding is based upon connectedness, then finding ways for students to actively and creatively connect mathematical ideas to multiple areas of study within and without mathematics are vital. Students who do so form a cognitive map of a subject. They can then travel their map in multiple ways, providing broader and more useful understanding than the mere memorization of discrete rules and isolated facts (Skemp, 1976). Drawing upon such a conceptual web is an important habit of mind of students who are engaging in reasoning and problem solving (National Council of Teachers of Mathematics, 2014).

In addition to enriching a student's cognitive map of an idea, Van de Walle (2007) argued that relational understanding also enhances memory, allowing the retrieval of bits of information through the retrieval of related ideas. Students may retrieve one coherent idea containing a wealth of information. Van de Walle argued that relational understanding assists in learning, improves problem solving, encourages the generation of new ideas, and improves attitudes about mathematics. He noted, "When ideas are well understood and make sense, the learner tends to develop a positive self-concept about his or her ability to understand mathematics" (p. 27). Relational understanding can then positively influence attitudes toward mathematics. The circumstances of students' personal lives provide existing ideas that can be connected in their web of understanding. In addition to the students' personal lives, ideas can be found within the students' visions for the future, such as their desired professions or other goals.

Authenticity in Education

The idea of *authenticity* as currently used in education defines the creation of such personal and practical connections (Lombardi, 2007; Tran & Dougherty, 2014). In education, *authentic tasks* seek to pull in accurate data and authentically reproduce activities students might do in their personal or professional lives (Harris & Marx, 2009). Authenticity has been described as involving real world problems and being situated in the real world outside of the classroom (Burton, 2011). Because of this close connection to lived experiences, authentic tasks and assessment must be flexible and adaptable to the changing nature of reality (Burton, 2011). Students being assessed authentically are expected to display thinking that would serve them well in a complex real world setting. Although Burton (2011) listed several qualities of authentic tasks and authentic assessment found in the literature, the closeness of the task being assessed to real world problem solving situations was the most commonly cited feature of authenticity noted. Suggested parameters for determining real-world authenticity noted by Burton (2011) included ensuring students will (a) do what a person in the real world situation would do, (b) work with tools the person in the real world situation would use, and (c) work under the conditions a person in the real world would encounter. In this way, Burton (2011) surmised, the degree of authenticity relies more on the structure and nature of the task than on the setting of the task.

A model for authenticity drawn from engineering education will serve as framework for a discussion of selected educational literature related to authenticity and mathematics education. The resulting framework will be helpful to mathematics teachers at all levels, providing them with a structured means for bringing authenticity into the classroom. Authenticity has the potential to increase relational understanding by strengthening the students' cognitive web of associations with mathematics because it increases the connections between mathematics and other areas of interest and study. Implications for practice will be discussed.

Authenticity in Engineering Education

Engineering education researchers Strobel, Wang, Weber, and Dyehouse (2013) conducted a systematic review of the literature related to authenticity. They found authenticity influences the potential complexity of the task, the multiplicity of possible solutions, and the potential disciplinary ideas to be taught with the task. Their analysis resulted in a framework describing five types of authenticity that can aid in categorizing and framing mathematical work intended to connect abstract ideas to real life contexts. The five types of authenticity will be described and linked to discussions of authenticity impacting mathematics teaching and learning.

Five Types

The types of authenticity found in the model described by Strobel et al. (2013) can be sorted into two dimensions: external and personal (see Table 1). A discussion of each type of authenticity follows Table 1.

Table 1
Types of Authenticity Described by Strobel et al. (2013)

External Dimensions of Authenticity	
Type	Description
Context authenticity	"[C]ontext resembles real-world context (e.g. patient data in medical school)" (p. 144)
Task authenticity	"[A]ctivities of students resemble real-world activities (e.g. scientific inquiry or chemical analysis)" (p. 144)
Impact authenticity	"[P]roducts of students are utilized in out-of school situations (e.g. collected data are utilized in NASA products)" (p. 144)
Personal Dimensions of Authenticity	
Type	Description
Personal authenticity	"[P]rojects are close to students' own life (i.e. life-stories of their neighborhood, biodiversity in the forest nearby" (p. 144)
Value authenticity	"[P]ersonal questions get answered or projects satisfy personal or community needs" (p. 144)

External dimensions. *Context authenticity* is present when students examine empirical data or data closely mimicking empirical data rather than unrealistic, fabricated data. Such authenticity situates the work in reality and allows students to gain genuine understanding of a phenomenon in a scientific way. It helps "bring real world experience to the classroom" (Strobel et al., 2013, p. 147). Complex interdisciplinary situations exhibit context authenticity. Activities also possess context authenticity when the activities situate the learning within parameters found in those situations. For example, students may be asked to design a product within constraints such a design would actually require, such as a container for a product that minimizes the amount of material needed.

Task authenticity occurs when students are engaged in the type of work actually done within a profession. It prepares students for the type of problem solving employers will expect them to engage in and connects the study of mathematics to such practical goals. Authentic tasks “challenge students in decision-making in practical contexts” (Strobel, et al., p. 147). They are related to the contextual quality of complexity of situation in that they are “ill-structured problems [with] no pre-specifications” as to how they should be solved (p. 147). Such work requires creativity and interpretation. Another way of ensuring task authenticity is the application of technology for the learning task those who work in a particular field would actually use, such as the use of AutoCAD for a task situated in the field of engineering (Strobel et al., 2013).

Impact authenticity occurs when student's work impacts the real world in some way. For example students may present findings regarding school lunch consumption to their school cafeteria manager. When students present their work to someone else who can be impacted by that work, then they will learn mathematics impacts lives. The impact may take the form of “participation as effective citizens” and promote “minorities’ experiences in the role of engineers and scientists” (Strobel et al., 2013, p. 147). Another example of impact authenticity would be the implementation of student designs in a real life setting, such as the use of a student’s invention in the workplace.

Personal dimensions. *Personal authenticity* occurs when the topics of study are those directly impacting the students' personal lives or the lives of those directly involved with the students. If students are directly involved with a topic, they bring an understanding of said topic to the mathematical work. This can help them to make cognitive connections and build relational understanding. This type of authenticity involves students’ personal culture and professional goals. It allows the learning activity to do more than “simply [prove] their competence” (Strobel et al., 2013, p. 147). Students engaging in learning that has personal authenticity are able to connect academic topics of study with things important to them in their personal lives. An example of a project involving personal authenticity is the "collect[ion of] data on the use of water in [a student's] household throughout the year [to] investigate possible ways to reduce consumption" (Strobel et al., 2013, p. 149). Personal authenticity ensures the idea of real world as used for teaching and learning is close to students' lives. Figure 1 illustrates the relationship between the real world as used in the classroom and the students' real world. The closer the real world problems used in the classroom are to the student's real world (that is, the more personally authentic they are), the more fluid this flow of understanding will be.

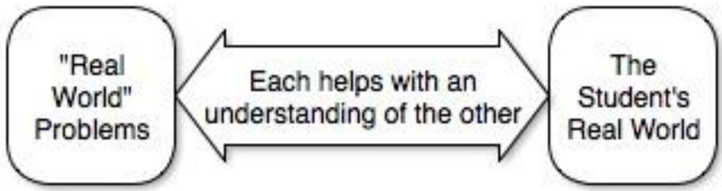

Figure 1: The flow of understanding between real world as used in the classroom and the student's real world.

Value authenticity is related to impact authenticity. Whereas impact authenticity refers to the learning being shared with and directly impacting someone else, value authenticity refers to the learning directly impacting the student's own life, community, or occupational goals. Learning that has value authenticity allows students to "develop self-learning skills benefitting them throughout life" (Strobel et al., 2013, p. 147). A task having value authenticity would be the analysis of transportation needs in a student's own neighborhood leading to a change in the way transportation systems are organized or run.

Authenticity in Mathematics Education

In order to help teachers make practical use of authenticity in the mathematics classroom and provide a coherent framework for discussions of authenticity in the mathematics education literature, descriptions of authenticity as commonly used in discussions of mathematics teaching and learning will be presented and situated within the model described by

Strobel et al. (2013). Following the presentation of this coherent framework, implications for practice will be discussed. These will provide examples of how teachers can use the authenticity framework in practical ways to increase authenticity in the secondary and post-secondary mathematics classroom.

Authenticity as used in mathematics education has referred to the quality of methods of assessment, the use of analogies, qualities of learning, and the types of topics and tasks with which students engage. These aspects of authenticity connect to the types of authenticity found in the model developed by Strobel et al. (2013) as a result of their systematic literature review. A framework connecting the model to ideas of authenticity as discussed in mathematics education is found in Table 2. A discussion of the framework follows the table.

Context authenticity: Analogies, data, and realities. Well-chosen topics of study give the learning activity context authenticity. They answer the question: *What are we studying with the mathematics and why?* The situations discussed or data used in the mathematical activity may be drawn from professions students wish to pursue. They may also be drawn from activities with which the student is directly involved or events having occurred in the student's personal life.

Analogies are a form of authenticity helping students connect abstract concepts to something meaningful for them. They connect mathematical ideas to everyday experiences (Sarina & Namukasa, 2010). Everyday experiences are more meaningful to students than contrived textbook situations and help to increase task authenticity (Harris & Marx, 2009). When everyday experiences and authentic data are used in learning tasks, then those tasks are considered grounded in reality (Lombardi, 2007). Reality, however, is different for different students. The reality and relevancy of authentic tasks is also one of their challenges (Harris & Marx, 2009). In addition to the messiness of reality, meaningfulness is personal and topics of study chosen by the teacher may not be meaningful to everybody. Some of the pedagogical movements seeking to improve meaningfulness for all students are critical mathematics pedagogy and teaching mathematics for social justice.

Table 2
A Framework for Authenticity in the Mathematics Classroom

Area of Authenticity	Authenticity Themes in Mathematics Education	Professional Authenticity	Personal Authenticity
Context: *What are we studying with the mathematics, and why?*	Analogies (Sarina & Namukasa, 2010) Use of authentic data (Lombardi, 2007) Mathematics for social justice (Bartell, 2013; Gutstein, 2013) Problem based approaches (Chagas et al., 2012) Critical mathematics pedagogy (Aslan et al., 2011)	Situations, issues, or data are drawn from those present in students' chosen field of study or desired professions	Situations, issues, and data are drawn from the students personal lives, from situations or contexts with which they are personally involved
Task: *How are we using the mathematics to study it?*	Authentic Tasks (Tran & Dougherty, 2014) Authentic Learning (Lombardi, 2007)	Tasks are similar to those that might be done in students' desired professions.	Students engage in work they are likely to carry over into their personal lives
Impact: *What about the mathematical conclusions is valuable?*	Authentic Assessment (Arter & Spandel, 1992; Lombardi, 2007)	Results are shared with others from outside of the classroom or impact those in the profession in some way.	Work impacts students' lives, answers students' questions, or affects their family or community. Students, their families, and/or their communities see the value of the work.

Critical mathematics pedagogy involves "a critical examination of how things are currently done and how they might be done differently to liberate and empower citizens"

(Aslan Tutak et al., 2011, p. 67). Aslan Tutak et al. (2011) noted mathematics has the power to create or expose distortions affecting people's perceptions of the world. One example is the use of the Mercator Map of the World, which exaggerates the size of Europe and makes Africa appear smaller in relation to Europe and other landmasses (Aslan Tutak et al., 2011). Examining such applications of mathematics can help students become critical thinkers who are able to use mathematics to help them critique other situations as well.

Critical mathematics pedagogy is related to the movement to teach mathematics for social justice, which seeks to tap into students’ social realities. Through critical mathematical analysis, students can create logically supported arguments that promote a fairer society (Bartell, 2013). The investigations are drawn from their own lives and the issues they care about to engage students mathematically. Investigations based in their own realities can allow students to impact those realities in ways promoting fair treatment for all citizens (Gutstein, 2013).

One approach to introducing social justice concerns in a mathematical setting is to have students examine the accuracy and fairness of surveys and graphs intended to influence socially relevant issues (Gregson, 2013). This might begin with an examination of a topic to which all students can relate, such as the relationship between arm span and height. This can then lead to a discussion of graphs linking two constructs together in order to influence public opinion, such as a connection between minor offenses perpetrated by youth and hardened criminal behavior—an idea sometimes referred to as "the criminalization of youth" (Gregson, 2013, p. 181). Students can be helped to see correlational relationships do not necessarily imply causational relationships. Similar to problem based learning, critical mathematics pedagogy and mathematics for social justice situate mathematical study within complex situations.

Problem based learning is "characterized by the use of real problems as a learning context for students to develop problem solving skills and to acquire scientific knowledge about the subjects under study" (Chagas et al., 2012, p. 2). Students engaged in problem based learning solve complex real world problems (Marklin Reynolds & Hancock, 2010, p. 175). The instructor acts as a guide for student investigations and a facilitator of student decision-making. Such work develops reasoning skills that can be transferred to real life situations the student may later encounter. Examining such complex problems drawn from reality changes the nature of learning tasks. That is, context authenticity leads to task authenticity.

Task authenticity: Authentic tasks and authentic learning. Problem based learning, critical mathematics pedagogy, and mathematics for social justice focus on what is being studied with the mathematics: complex realities. Authenticity in the mathematics classroom also focuses on the nature of the learning tasks provided to students. Authentic tasks focus on what students are being asked to do in response to the realities they are studying. The types of mathematical tasks used to study the authentic context and the learning environment created for students as they do so answer the question: *How are we using the mathematics to study it?*

Harris and Marx (2009) described authentic tasks as “reflect[ing] the way tasks might be found and approached in real life" (para. 1). Authentic tasks may be challenging to implement due to several factors (Harris & Marx, 2009). Because of their nature, they may need extended time for their solution and there may not be an easy solution to the problem being examined. Teachers must carefully sequence and scaffold authentic tasks to ensure that the mathematical content embedded within them is learned (Harris & Marx, 2009).

Tran and Dougherty (2014) provided criteria for authentic tasks as situated within mathematical modeling. In addition to noticing the importance of context authenticity, their criteria speak to what students must do as they make sense of authentic data. The purpose of the task must be clear in the context as if it were actually encountered outside of the classroom so students know what is to be done in context. The data involved must be specifically described and accessible so it can be used by students. The language used to describe the task must include terms that do not hinder students unnecessarily. Finally, the tools accessible to the student must be similar to those that would be available in the real situation (including knowledge and skills).

Tran & Dougherty (2014) gave three recommendations for selecting authentic tasks. They include 1) using mathematics going beyond basic operations and algorithms so students must decide what mathematics to use and what information is relevant, 2) the context of the task might really occur, and 3) multiple solutions are possible, "with justification" (p. 678). Their recommendations situate task authenticity as a way of dealing with context authenticity. Context authenticity invites task authenticity, as in the case of problem based learning, which requires students to discover the solution methods for complex problems, as opposed to following a prepared template (Marklin Reynolds & Hancock, 2010).

Literature on authentic learning focuses on what it is like for the student to learn mathematics by engaging in authentic tasks addressing realistic contexts. It seeks to describe the experience of the student as authenticity is brought into the classroom. Lombardi (2007) characterized authentic learning as "learning by doing" (p. 2) and stated it involves "real-world, complex problems and their solutions, using role-playing exercises, problem-based activities, case studies, and participation in virtual communities of practice" (p. 2). She noted authentic learning can be compared to the idea of learning through an apprenticeship. Students may be uncomfortable with authentic learning's messiness and ambiguity because it involves complex problems and learning by doing. Nevertheless, the uncomfortable realism of authentic learning helps students develop experience pertinent to a profession so their transition to professionalism will be smoother. By working with authentic data, students experience "the messiness of real-life research where there may not be a single right answer" (Lombardi, 2007, p. 6).

Impact authenticity: Authentic assessment. Discussions of task authenticity emphasize the experience of students in a classroom centering on authenticity; engaging in work having context authenticity. Authentic assessment focuses on methods for evaluating students’ learning experiences in such a setting. The quality of assessments used is important.

In discussing the use of portfolios for mathematics assessment, Arter and Spandel (1992) noted teachers must clearly understand authenticity before they know how to ensure the work in the portfolio and the associated assessment of that work is authentic.

> What is meant by authentic? . . . Authentic to what? . . . An authentic reflection of classroom work or an authentic representation of ability to [use a skill] in real life? One must come to grips with this issue before even beginning to discuss authentic tasks. (p. 37)

Lombardi (2007) echoed their concerns having noted when authentic learning is taking place the assessment must be adjusted to match the authentic situation. This will likely involve multiple forms of assessment. One possible form of assessment that improves authenticity is including stakeholders from beyond the classroom in the evaluation process. This can allow students to receive feedback "naturally over the course of the project… from several sources (as [they] would in real life)" (Lombardi, 2007, p. 9). It can also help students "know what it feels like for actual stakeholders beyond the classroom to hold them accountable for their work products" (p. 9).

Such authentic assessment including genuine stakeholders is a key part of impact authenticity, and helps determine the value of students' work. Teachers who approach assessment by asking, "*What can be truly valuable about the work students will do? What stakeholders might have an interest in this work?*" will have a clearer idea of how to incorporate impact authenticity. In professionally related activities, the value of the work may be found by sharing the work with others outside of the classroom in a way impacting the profession.

The idea of value authenticity described by Strobel et al. (2013) is folded into the idea of impact in this framework. When students engage in personally connected work and the results impact students' personal lives or the lives of students' families or communities, students, their families, or their communities can see impactful value in the mathematical.

Eliciting student, family, or community feedback regarding such an impact could be part of authentic assessment.

Summary. Efforts to bring authenticity into the mathematics classroom have included considerations of context authenticity as those efforts have focused on what to examine with mathematics, such as the use of authentic data and examinations of complex realities. Acknowledgments of what needs to be done to make examinations of complex realities and how to orchestrate that work, bring in task authenticity, and include attention to students' authentic learning experiences. Finally, provisions of ways to assess the process and the results can involve forms of impact authenticity, a method of authentic assessment.

Examples

Teachers must be familiar with the mathematical nature of contexts in order to create learning experiences for students involving authentic contexts, tasks, and impacts. They must also examine their course objectives and identify the types of contexts that can be mathematized using the mathematical content. They can then consider what students will be studying with the mathematics, how they will be using the mathematics to study it, and what will be valuable about the mathematical products students will produce.

Examples from two different mathematical courses are provided as examples of how teachers can increase authenticity in their classrooms. The first is an example of one assignment used for a pre-calculus algebra course showing how authenticity can be brought into a unit of study, in particular the study of functions. The second example shows how an authentic task can be used over the course of a semester to tie statistics throughout the course to something authentic to students.

Authenticity in the Study of Functions

Students can be asked to find or gather real life data exhibiting the properties of a functional relationship situated within an externally or personally authentic context. As they do so, they must consider what questions they have about the context and what data can be examined to provide answers to those questions. In this way students are directly involved with answering the question "What are we studying?" The students will bring context authenticity to the work through the data they gather and the real life question interesting to them.

Once the data is gathered, students must choose the mathematical model that will properly address the question asked. The difficulty of choosing the best function to model the data, the type of representation used to represent the data, and the question of whether or not those choices answer the original question are part of the complex nature of addressing an authentic question. Technology can be used to find a function equation to fit the data, but students must change the parameters of the model until it fits, connect algebraic and graphical representations, and then decide whether or not this information is useful.

After students have created the model, can they tell the worth of the model? Does it shed helpful light upon the questions they asked, or not? If so, is this something others might be interested in knowing? As students address the question of whether or not the model they have developed is genuinely useful, they are learning about the importance of impact authenticity. If the mathematical model created is not useful, then it does not possess impact authenticity. If it does, then they can be encouraged to find a forum in which to present their model. Such opportunities can occur within other departments at the institution of learning (traffic patterns shared with campus police or traffic officials), as shared opinions at public forums (data related to neighborhood issues such as crime prevention methods), or in family councils (data related to energy consumption or family budgets.) An example of personal connections, drawn from student work collected as part of a research study conducted by the first author during Fall 2013 is provided in Table 3. The student whose work is described, Michael, suffered from allergies noting in his explanation of why he chose that topic: “Yesterday, it felt as though the pollen level went from a very low state, to an

EXTREMELY high state in one point of the day.” He used an allergy application on his phone to examine what the pollen levels were over the course of a day. Figure 2 shows the resulting graph.

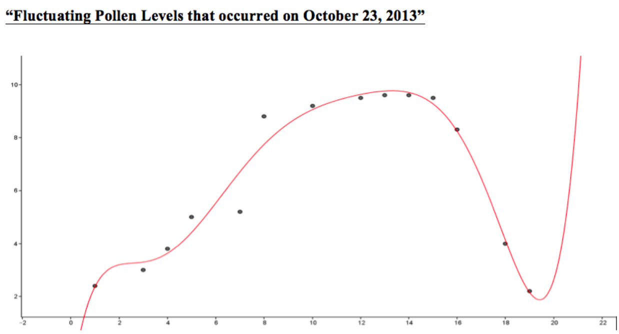

Figure 2: Michael’s graph showing pollen level as a function of the hour of the day modeled by a polynomial function

Based upon the first author’s experience implementing such a task, teachers must be prepared to help students in several ways. First, students may have difficulty selecting a topic and finding appropriate data. Although this is challenging, it also provides the teacher with an opportunity to engage in productive conversation with students, learn more about students, and aid students in learning to mathematize the world around them. Secondly, students must be taught to use the technology involved. For this implementation, a mathematics computer lab coordinator was trained in the task and was available to help students with the task. Sufficient technology instruction time must be allowed. Once trained, students can use the technology for multiple purposes throughout the semester if the teacher wishes. In this manner, the use of technology can help provide relational understanding of the qualities of mathematical ideas as students consider how the personally authentic data they have chosen can be modeled with mathematics. In addition to applications in pre-calculus, personal authenticity can be increased in statistics courses even though the study of statistics naturally lends itself to real life applications, as will be shown in the next two examples.

Table 3
Authenticity in the Study of Functions: Example from Student Work

Area of Authenticity	Authenticity Themes in the Mathematics Education Literature	Personal Authenticity: Practice	Personal Authenticity: Example
Context: *What are we studying?*	The use of empirical data, examination of social realities	Students choose data related to something personal.	A student with allergies chose to examine the change in pollen levels over the course of a day.
Task: *How are we studying it?*	Students must create and study complex functions and model complex data. They can use technology to create such models and then study the models for mathematical properties.	Students find the best function to model the data they found.	The student used technology to create a scatterplot of the data and regression tools in the software to find the function most closely modeled by the data.
Impact: *What is valuable about this work?*	Authentic Assessment that involves multiple methods and multiple observers.	Students use or learn from their findings.	The student was able to note the pollen levels matched what he felt was happening and to mathematize the situation using a polynomial function.

Authenticity in a College Statistics Course

With its emphasis on the examination of real life data, the study of statistics naturally lends itself to the incorporation of authenticity. Research provides evidence (Garfield & Ben-Zvi, 2008) students can build knowledge based on their experiences by using real life data sets, providing context authenticity. Garfield and Ben-Zvi (2008) cited the American Statistical Association's (2005) definition of real-life data sets as including archival data, data collected in research projects, and classroom generated data.

An example from college statistics instruction illustrates how authenticity can be incorporated through a semester long project. In one of the authors' introduction to psychological statistics class, students were informed on the first day of class they were required to do a semester long project. This statistics course was a second year required course for those pursuing a degree in psychology. The enrollment varied from 40–50 students per section. Students in the course were pursuing different majors, such as psychology, sociology, nursing, occupational therapy, and social work. Topics covered in the course included an introduction to research methods, descriptive statistics, normal distribution and z-scores, correlation, sampling distributions, confidence intervals, and hypothesis tests using t-scores. The course was taught through three weekly one-hour lectures.

Detailed guidelines of the project were given to students at the beginning of the semester. The students' progress was discussed regularly in the classroom. First they choose a topic based on their personal interests and the kind of research methods they would use to study their topic (e.g, doing a survey, an experiment, observation, or a study based on available data). During the fourth week of the semester, the students submitted a description of their topic. The instructor examined student topics to see whether they were too simple or too complicated, or would not meet the strict guideline of human subjects research. This step helped the instructor and the students to quickly weed out those projects not meeting the guideline of the Human Subjects Research Committee or any project that had the potential for controversy. In this way, the work built task authenticity because the students were working to meet professional requirements. Students discussed their topics with the instructor individually by office hour appointment or by email, so they would understand what was expected for the project.

During the fifth week of the semester, students submitted a detailed description of their experimental design. The instructor checked with students to see if their proposal met the guidelines for including variables that could be examined for possible relationships. Many students needed feedback at this step to focus their ideas. Consequently, the instructor spent a lot of time meeting with them.

During the eighth week of the semester, the instructor required students to submit their survey instruments as well as their data. Students who did surveys and experiments turned in their tabulated data. Students who did studies based on available data turned their copies of data. At this stage, some of the basic statistical content, such as measurement, reliability, validity, displaying data, graphs, and histograms was covered by textbook examples. During the ninth week of the semester, students began to analyze their data, and submitted their results. At this time point, the majority of the statistical knowledge from the textbook had been covered, including cross-classified data, scatterplots, correlation, and linear regression. Final documents for their project were submitted at the end of the semester. The semester's work is summarized in Table 4.

Students' experiences using real life data helped deepen their understanding of basic statistical terms and statistical methods, but also provided enjoyment for them in the learning of statistics (Cobb, 1992; Diamond & Sztendur, 2002; Garfield & Ben-Zvi, 2008; Scheaffer, 2001). At the end of semester, the instructor asked students to critique the course, including the project component. Forty-five students completed a survey related to the course during the 2014 Fall semester. Forty students had positive feedback about the course project. The majority of them felt the course project provided additional information for them, allowing them to practice what they learned from the textbook. Their positive feedback also confirmed the project provided them with an opportunity to tie their knowledge to a real life situation. The positive feedback provided regarding the course was related to the engagement the authenticity of the work fostered. For example, when asked to provide suggestions to help improve the course, one of the students said, "I think the professor help me engage and experience statistics."

Table 4
Weekly Progress and Different Types of Authenticity

Week	Assignments	Type of Authenticity
Week 1 to week 4	Each student chose a topic based on his or her personal interests, at the end of the fourth week, submitted his or her description of the project.	Context Authenticity
Week 5	Students submitted detailed information about their experimental design.	Task Authenticity
Week 6 to week 8	Students collected their data.	Task authenticity
Week 9 to week 12	Students analyzed their data and submitted their final report, answering a question they had about a topic of personal interest. They may also be selected to present their work at research conferences.	Impact authenticity

The current study was based on a small number of undergraduate students: 20 psychology majors and 25 students distributed among social work, nursing, and occupational therapy majors for a total of 45 students. Therefore, the results may not generalize for students from other majors. Student characteristics, for example, such as year of study, different majors, and interest in statistics, as well as course characteristics such as the level of the statistics course being completed may influence the perceived benefits of real life data. There were also challenges for both students and instructor during the semester. The biggest challenge for students was how to choose a topic based on their interests at the beginning of semester. The topic needed to not be too simple or too complicated to be implemented. In order to address this challenge, every group had to discuss their topic with the instructor separately and make sure it was suitable. Some students complained because of the short time allowed for the research, they could not select a good topic. In addition to the issue of topic selection, students indicated also being challenged by the lack of time and lack of collaboration among group partners. On the other hand, the instructor and the students probably spent extra time working on individual topics compared with a course in which the instructor gives them one topic as an assignment for all students. It is important, however, for students to explore the topics by themselves. The ability to do this is part of the knowledge needed for them to develop statistics literacy and competency.

Conclusion

Drawing upon work done in engineering education research, the various ways mathematics teachers seek to bring authenticity into their classrooms can be summarized in a framework addressing context, task, and impact. Three questions associated with context, task, and impact can drive instructional choices for increasing authenticity. Context can be addressed by asking, *what are we studying with the mathematics, and why?* Task can be addressed by asking, *how are we using the mathematics to study it?* Impact can be addressed by asking, *what is valuable about the mathematical conclusions?* Using these questions can help teachers to shift the focus of study to realistic personally connective contexts, engage students with complex tasks in which they seek to understand those contexts, and show students the value of mathematics for answering their own questions. Functional relationships and statistical analyses are two of many mathematical settings in which real life problems and data can be analyzed.

The experience of the authors suggests teachers should carefully consider the content they are teaching and the time available during the semester. The example from a college statistics course shows how a semester long project can include multiple curriculum content goals. The example of the analysis of data exhibiting the properties of a functional relationship was presented as one assignment, but it can be reframed as a semester long project as well. An examination of how the data looks when graphed on the xy-plane can lead to ensuring the chosen data exhibits the properties of a functional relationship.

The same data can then be used to consider equations and graphs associated with quadratic, polynomial, exponential, and logarithmic functions as well as combinations and transformations of functions as students seek to determine the type of functional relationship that will provide a useful model. The connection of one project to multiple topics provides the kind of relational understanding allowing students to access many pieces of information in a coherent way. In this way, authenticity can provide much needed coherence for students so mathematics is no longer just a set of discrete ideas to be memorized. It can become for them a connected body of knowledge that is personal, engaging, and useful.

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