AC 2012-3097: CONCEPTUALIZING AUTHENTICITY IN ENGINEERING EDUCATION: A SYSTEMATIC LITERATURE REVIEW

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Conceptualizing Authenticity in Engineering Education: A Systematic Literature Review

Abstract

The term *authenticity* is pervasive in the education literature in general and specifically in the engineering education literature; yet, the construct is often used un-reflected and ill defined. The purpose of this paper is (1) to critically examine current conceptualizations of authenticity as principles to design curricula and learning modules within engineering education and (2) the development of a systematically derived model of authenticity. The context of the project is towards pre-college engineering education yet findings are applicable across the lifespan of engineering education. A systematic literature review guided by procedures set forth by the Centre for Reviews and Dissemination was conducted in the engineering education literature to synthesize the findings. Based on an initial sample of papers (n = 36) a rubric was developed to identify authenticity and authentic experiences in engineering education. Using the developed rubric, a total pool of 1,058 references was evaluated using the rubric with 88% to 100% inter-rater reliability for each category of authenticity. A frequency analysis of references revealed that the majority of work is seen in undergraduate education, and only 14 instances of authenticity in engineering education appeared at the K-12 level. The model of authenticity includes two additions to existing models such as impact authenticity and value authenticity. The findings and the model are described. Implications include the use of different types of authenticity to provide more appropriate and promising principles for better design of engineering curricula and standards for curriculum developers and professional development providers, including more use of authenticity in the K-12 classroom.

Introduction

With the infusion of engineering into K-12, the field uses existing paradigms and develops new models and frameworks. Within the NAE[1] report on K-12 Engineering Education, engineering is strongly connected with "posing authentic problems" (p.99) and introducing students to "authentic engineering practice" (p.129). The term authenticity, however, is often used without reflection or clear definition as "the term of authenticity and its synonyms lull us into the belief that we do not need to explain ourselves" (p.13). [2] The ubiquitous use of the term makes it difficult to not only operationalize the term for the development of learning environments but for empirical research into the effectiveness or role of different dimensions and different constructs. Due to the lack of specificity about what authenticity entails, Radinsky, Bouillion, Lento, and Gomez[3] question even its usefulness as a principle to design curricula. Robust empirically derived models of authenticity are necessary to enhance the value of pursuing the design of authentic learning environments.

Research on STEM education and underrepresented minorities and women may serve as an example for the significance and impact of authentic learning experiences and the need for more reflection: Data show that STEM fields are not as attractive to underrepresented minorities and girls. While reasons differ, girls are turning away from science/math as early as third and fourth grade and for the ones persisting, the current climate provided by STEM curricula produces a high level of anxiety and low self-efficacy.[4,5] Similarly, engineering is considered more object-oriented than people-oriented.[6] As a result, many students who are interested in careers related to helping people may not pursue an engineering-related field, but instead go into a field that is thought to be more people-oriented (e.g. medical fields).[7] Rahm,[8] Buxton[9] and Basu and Barton[10] highlight in their research on science education, that underrepresented minorities and women are more engaged and learn more in authentic learning activities as compared to simple experiments and simple inquiry projects (for the distinction see Chinn & Malhotra).[11] Yet as Preston[12] points out, it is not clear what forms of authentic engagement are contributing to these effects, highlighting the need to provide robust models and operational definitions for authentic practices. In addition, while research on authenticity and authentic practices is fully developed in science education, similar work in engineering is rudimentary.

Literature Review

Conceptualization and Embodiments of Authenticity

The traditional classroom has often been described as inauthentic, with learning taking place inside a classroom environment consisting mostly of lecture.[13] In contrast, the constructivist learning environment is one in which students are actively constructing their knowledge based on integrating their current experiences with their prior experiences to understand novel ideas or situations.[14] Authentic learning experiences often take place in this type of classroom. Maor[15] described a constructivist-oriented learning program, of which "simulated authentic learning environments" (p. 46) was a design principle.

Barab, Squire, and Dueber[16] described authenticity as taking place "in the learner-perceived relations between the practices they are carrying out and the use value of these practices" (p. 38). However, in the paradigm of constructivism, critique grew that classrooms are not "authentic" enough: activities are only relevant within the walls of the classroom; the products are not relevant or well-connected to problems outside of schools, so school work is not contributing to an outside world; the audience is only the teacher (or some students); what is considered authentic to the teacher is not necessarily authentic to the student;[16] separation from learning and authentic use leads to fail of transfer; and the prior knowledge and experience of students is perceived and treated as irrelevant or something to overcome (misconceptions, naïve conceptions, low critical thinking skills).

The concept of authenticity was introduced simultaneously with a strong call for student centered learning. Providing students with "real-world" experiences resulted in many project and problem-oriented curricular components (e.g. students' contributions to newspapers or local pond projects). Deeply rooted in Deweyian pragmatism, as Petraglia[2] states: Authenticity becomes the "desideratum of the American educational system" (p.10). Major theories and design models were developed to increase authenticity including the use of simulations, cognitive apprenticeship, and problem-based learning frameworks. For instance, the use of simulations or reifications to "create as accurate a facsimile of real objects or events as possible" (p. 336). [17] Another example is problem-based learning, which focuses on engaging students in expert-like activities (designing, scientific inquiry) and providing "real-world" cases and problems.[18]

Workplace-based authenticity contains several of these external dimensions – implemented in many student-centered learning environments: (a) Context authenticity - context resembles real-world context (e.g. patient data in medical school), (b) Task authenticity (including process/procedural) - activities of students resemble real-world activities (e.g. scientific inquiry or chemical analysis), and (c) Impact authenticity - products of students are utilized in out-of school situations (e.g. collected data are utilized in NASA projects).[16]

These three dimensions of authenticity are conceptualized as bringing the learner closer to the realities of the workplace, providing features derived from external social and environmental constructs, such as the corporate world or cultural norms;[19] in other words these dimensions represent the view of the *Canonical Science Perspective (CSP)*.[9] CSP positions authentic science learning as a pedagogical tool that engages learners in science practices that reflect the epistemic and shared practices of scientists in their community.

This paper makes the case that other, less developed, dimensions of authenticity are promising supplements to the existing landscape and so reduce the shortcomings of existing STEM activities: (a) Personal authenticity - projects are close to students' own life (i.e. life-stories of their neighborhood, biodiversity in the forest nearby) and (b) Value authenticity - personal questions get answered or projects satisfy personal or community needs. These new dimensions are derived from an Applicative or Sociocultural Perspective (ASP), which recognizes that authentic learning acknowledges the importance of the cultural practices of science, "everyday-life" problems or experiences[20] and identity of the scientists.[21]

Purpose and Research Questions

The purpose of this study is (1) to critically review current conceptualizations of authenticity as principles to design engineering curricula in the K-12 setting and (2) to develop a systematically derived model of authenticity. Research questions are: (a) What are the different conceptualizations of authenticity with their general features and attributes? (b) What is a framework of authenticity that encompasses these features and attributes? and (c) What are initial recommendations for K-12 engineering education curriculum developers based on these findings?

Methodology

The methodological framework for this study is a systematic literature review guided by the National Health Service (NHS) Centre for Reviews and Dissemination (CRD).[22] Following the CRD guidelines of conducting a systematic literature review, we followed four major steps: (a) identifying key research terms, (b) selecting studies, (c) extracting/monitoring data, and (d) data synthesis. Additionally, (e) validation/modification and (f) frequency analysis were used to evaluate the results from data synthesis.

Analysis and Results

Six search terms were identified and 36 key papers were studied to develop a rubric to identify categories or types of authenticity in the literature. Papers specifically within engineering education and general education with authenticity as the main focus were selected and researched to extract definitions of authenticity. As a result, 59 descriptions and definitions of “authenticity” and “authentic experience” were extracted and incorporated into the rubric. Finally, a total pool of 1,058 references (journal articles, conference proceedings, and books) were collected, and each study was read and evaluated using the evaluation rubric, focusing on the description of authenticity or authentic experience and the principles included (along with a rating of the reviewer’s confidence in the findings).

Identifying Research

We are interested in the design of authenticity in K-12 STEM curricula, and the conceptualization and embodiments of authenticity. Therefore, we searched for the literature using two sets of keywords. One set is “authenticity” and “authentic”. The other set includes “integrity”, “realistic”, “genuine”, and “legitimate”, which are synonyms of “authentic” in the domain of education. These keywords were searched both in the article titles and in the body of the text.

Selecting Studies

The selection of studies was based on electronic searches. To build up a thorough database of related studies, we searched in engineering education and more general education fields to find studies, while using a variety of relevant databases and search terms.

Databases

Four databases were utilized – ERIC, WilsonWeb, Engineering Research, Compendex, and Inspec, and 1 digital library – IEEExplore.

Engineering Education

Considering that education in engineering is our primary focus, we selected journals, proceedings, and books in this area, which included 21 journals, two conference proceedings, and six books (Table 1).

General Education

Next, in order to compare the definitions of educational authentic experience in the engineering education domain and the definitions in the general education domain, we selected several journal papers in the general education area as well. They are from Instructional Science, Educational Technology Research and Development, Australian Journal of Educational Technology, Journal of Science Education and Technology, and Journal of Curriculum Studies. In addition, the book "Authentic Involvement in Interdisciplinary Design"[29] are also examined.

Finally, within these journals and proceedings in the database and digital library, articles with "authenticity" and/or "authentic" in the title and body of the text were searched and saved. In addition, articles with "integrity", "realistic", "genuine", and "legitimate" in the title and body of the text were searched in the following journals: Journal of Professional Issues in Engineering Education and Practice, IEEE Transactions on Education, IEEE Transactions on Learning Technologies, Science and Engineering Ethics, International Journal of Electrical Engineering Education, Computer Applications in Engineering Education, Engineering Education (open access), Engineering Science and Education Journal, European Journal of Engineering Education, International Journal of Mechanical Engineering Education, which were saved in a separate archive.

The results are summarized in Table 1.

Table 1. Authenticity literature search.

	Keywords (#title/#fulltext)	
Journals	Authenticity	Authentic
Journal of Engineering Education	0/0	0/7
International Journal of Engineering Education	2/10	2/9
Journal of Professional Issues in Engineering Education and Practice	0/1	0/2
IEEE Transactions on Education	0/4	1/3
IEEE Transactions on Learning Technologies	0/0	0/0
Science and Engineering Ethics	0/1	0/0
International Journal of Electrical Engineering Education	0/0	0/0
Computer Applications in Engineering Education	0/1	0/0
Engineering education (open access)	0/1	0/1
Engineering Science and Education journal	0/0	0/0
European Journal of Engineering Education	0/5	1/1
International Journal of Mechanical Engineering Education	0/0	0/0
Australasian Journal of Engineering Education	0/0	0/0
International Journal of Continuing Engineering Education	0/7	0/0
Research in Engineering Design	0/0	0/0
Engineering Studies	0/0	0/0
Online Journal for Global Engineering Education	0/0	0/1
Education for Chemical Engineers	0/0	0/0
Chemical Engineering Education	0/0	0/0
WSEAS Transactions on Advances in Engineering Education	0/4	0/3
The International Journal of Applied Engineering Education	0/0	0/0
Proceedings	Authenticity	Authentic
American Society of Engineering Education (ASEE)	21/726	0/116
Frontiers in Education (FIE)	4/208	0/39
Books		
"Research on PBL Practice in Engineering Education" [23]	0/0	0/0
"Management of Change"[24]	0/0	0/0
"Models and Modeling in Engineering Education: Designing Experiences for All Students" [25]	0/0	0/0
"Service Science, Management and Engineering: Education for the 21st Century (Service Science: Research and Innovations in the Service Economy)" [26]	0/0	0/0
"Rethinking Engineering Education: The CDIO Approach" [27]	0/0	0/0
"Educating Engineers: Designing for the Future of the Field" [28]	0/0	0/0
Sum	27/968	4/182
Downloaded	**1, 058**	

Extracting/Monitoring Data

The purpose of extracting data is to identify and collect various definitions of authenticity and/or authentic experience in the literatures in our database. To achieve this goal, several steps were taken.

We developed a rubric to summarize the findings and to standardize the search across different individuals working on the project. First, each article was read and evaluated using the evaluation rubric shown in Table 2, focusing on the description of authenticity or authentic experience.

Table 2. Evaluation sheet for articles.

<table>
<tr><td>RECORDER/ DATE</td><td colspan="2"></td></tr>
<tr><td>CITATION:</td><td colspan="2"></td></tr>
<tr><td rowspan="2">COPY & PASTE

Open pdf in adobe, and select text are with snapshot tool, then paste in document</td><td>ABSTRACT: at beginning of paper

abstract : (0, 1, 2)
0- no mention
1- unsure
2- mention</td><td></td></tr>
<tr><td>DEFINITION:
authenticity is…

definition: (0, 1, 2)
0- no mention
1- unsure
2- mention</td><td></td></tr>
<tr><td rowspan="2">Term used:
0- no mention
1- unsure
2- mention
3- main focus</td><td>“authenticity”: (0, 1, 2, 3)</td><td></td></tr>
<tr><td>“authentic”: (0, 1, 2, 3)</td><td></td></tr>
<tr><td>CONFIDENCE SCALE
(CIRCLE ONE)</td><td colspan="2">0= Focus of Article 1= ☺ sure 2= 😐 somewhat sure 3= ☹ not at all sure!</td></tr>
<tr><td>RECORDER COMMENTS:</td><td colspan="2"></td></tr>
</table>

Second, articles were grouped based on the confidence scales. The group of “Focus of Article” contains papers that clearly focus on authenticity studies; the “Sure” group contains papers that have sufficient description data of authenticity and/or authentic experience; the “Somewhat Sure” group includes papers that have limited information on authenticity and/or authentic experience; and the “Not at All Sure” group have papers that mention “authenticity” and/or “authentic”, but no definition/description of study or experience in this area.

Finally, 11 papers in the "Focus of Articles" group were selected and researched to extract definitions of authenticity. Six of them are in the engineering education domain, while the other five are in general education studies. As a result, 59 descriptions and definitions of "authenticity" and "authentic experience" were extracted.

Data Synthesis

After careful reading and discussion of the 59 descriptions and definitions, we categorized them as "Context Authenticity", "Task Authenticity", "Impact Authenticity", and "Personal/Value Authenticity" (Table 3 shows key definitions and characteristics for each type of authenticity). The common theme of all the different authenticity definitions is their relation to real-world experiences.

Context Authenticity answers the question, *What makes a context authentic?* This type of authenticity should take place in authentic contexts and resemble daily life experiences. For example, the activity should contain a suspension of disbelief process, such as when watching a movie. Task Authenticity answers the question, *What makes a task authentic?* This type of authenticity focuses on constructivist type learning environments in which students may be challenged to make decisions in practical contexts. Impact Authenticity focuses on what impacts an authentic experience can deliver in an informal learning setting. Impact authenticity asks, *What impacts can an authentic experience deliver out of school?* Finally, Personal/Value Authenticity asks, *What makes an experience authentic on a personal level?* Personal/value authenticity includes actions that make an experience authentic on a personal level such as self-exploration.

Table 3. Key definitions and characteristics for each type of authenticity.

Categories	**Key Definitions and Characteristics**
ALL in common	Real world (RW) related
Context Authenticity *(What makes a context authentic?)*	***Curriculum should…*** **Key Definitions** 1. Be similar to the real-world work environment or future professional situations 2. Resemble challenges or social interactions in daily life 3. Bring real world experience to the classroom 4. Be a situation similar to 'in-the-wild' 5. Make students control the process, gain hands-on experience, or apply study content in the real world 6. Include everyday experiences and students' interest and professional target* 7. Align school and professional outcomes **Characteristics** 1. Be a complete task-environment 2. Contain a suspension-of-disbelief process

	3. Be open in forming and solving the problem and outcomes 4. Be a complex problem-solving context and interdisciplinary context 5. Have situations of collaboration, access to tools and resources, discretion and ownership, or flexible use of time
Task Authenticity (*What makes a task authentic?*)	***Curriculum should…*** **Key Definitions** 1. Be of real world relevance and related to the study 2. Reflect and develop professional skills students need after graduation 3. Challenge students in decision-making in practical contexts **Characteristics** 1. Contain ill-structured problems, no pre-specifications 2. Let students problematize the subject matter** 3. Contain open-ended creative activity 4. Promote disciplined inquiry 5. Ask students to interpret ambiguous data
Impact Authenticity (*What impacts can an authentic experience deliver out of school?*)	***Link curriculum to…*** **Key Definitions** 1. Justification of actions in cultural practices 2. Events and issues in society 3. Participation as effective citizens in a technology-based society 4. Impact of project is not exclusively only within the classroom **Characteristics** 1. Professional community standards in relative area 2. Cultural significance 3. Minorities' experiences in the role of engineers and scientists
Personal/ Value Authenticity (*What makes an experience authentic on a personal level?)*	***Let students …*** **Key Definitions** 1. Produce knowledge with value in students' lives and studies beyond simply proving their competence 2. Experience everyday life and their interest and belief* 3. Include their professional target in the experience* 4. Make a personal version of sociocultural practice, integrate personal interests and cultural values 5. Build community for learning and communication 6. Conduct self-exploration 7. Develop a sense of identity and sense of confidence **Characteristics** 1. Problematize the subject matter** 2. Perceive relations between the practices and the value of them 3. Pursue personally relevant goals and interests and have personal choice 4. Exercise creativity engaging in personal construction of new knowledge 5. Defend their position in objective terms 6. Develop self-learning skills benefiting them throughout life

Note. * Overlap between *Context* key definition and *Personal/Value* key definition, **Overlap between *Task* characteristics and *Personal/Value* characteristics.

Key factors were those which appear frequently when educators/researchers discuss authenticity (Table 4 summarizes the key factors). Key factors were noted when reading the first group of papers in the literature search. When the authors of articles that discussed authenticity described or referred to the authentic problem, environment, or activity, these factors were used as descriptors of what authenticity meant in that context. These factors provide additional information about different characteristics that may describe an authentic situation.

Table 4. Factors of authenticity.

Factors	**Key factors of authentic problems** 1. Real-world context/Future professional situation 2. Complete task-environments 3. Ill-structured, non contrived problems with ambiguous data 4. Suspension of disbelief 5. Interaction among learners 6. Decision-making in practical contexts 7. Value beyond school 8. Values defensible in objective terms 9. Provide information/data that is from or mimics real-life or skills 10. Classroom-professional community balance 11. Complex problem transcending the borders defined by disciplines **Key outcomes or appeal of authentic problems/situations** 1. Promote disciplined inquiry 2. Active self knowledge construction 3. Higher-ordering thinking 4. Self exploration 5. Openness/diversity of forming the problem, solving the problem, and outcomes 6. Personal interest, school goal and professional goal combination 7. Students' interest, belief, and value

Validation and Modification

The rubric needed to have an acceptable inter-rater reliability (i.e. 80% using liberal measurements) before it could be used to classify the types of authenticity. While more liberal criteria (e.g. .70 agreement coefficient) are typically used for indices that are more conservative or for exploratory research,[30] Neuendorf's[31] review of typical cutoffs for inter-rater reliability found that .90 is an acceptable criteria for all types of situations, and that .80 or greater is acceptable for most situations.

We calculated the percentage of agreement using two independent raters to establish inter-rater reliability. For the overall rubric, we selected a 5% sample to calculate inter-rater reliability using two independent raters; the percentage of agreement ranged from 88% to 100% for each category following two rounds of discussion and minor modifications to the rubric.

Round 1: (percentage of reliability and modifications to the rubric)

In first round of the literature search with a total pool of approximately 500 journal articles, conference proceedings, and books, we selected a 5% (n = 25) sample of papers to test the reliability of the rubric in the first round.

By avoiding errors introduced by human factors, the results show that the reliability of the key definitions and characteristics in the rubric (Table 5) reached as high as 0.88, which means that the lowest agreement coefficient was 0.88 (occurring once). Table 5 shows the reliability numbers.

Table 5. Reliability for the first round of interrater reliability.

	Key Definition							**Characteristics**					
	1	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**
Context Authenticity	0.96	0.96	0.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-
Task Authenticity	1.00	1.00	1.00	-	-	-	-	1.00	1.00	1.00	1.00	1.00	-
Impact Authenticity	1.00	0.96	1.00	-	-	-	-	1.00	1.00	1.00	1.00	1.00	-
Personal/Value Authenticity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00

After discussion and careful examination on the areas with lower reliability, the rubric was revised to its final form (Table 3).

Round 2: (percentage of reliability)

For the second round of reliability, a total number of 1,004 full papers were read and a total of 154 full papers were cross-read between the two raters (15.3% of the total). For this round of reviewing, the two raters read the abstract, searched for sentences with "authentic" or "authenticity" in the paper, and read one sentence before, the "authentic"-contained sentence and one sentence after.

The reliability for this round was lower than the first round, with: context authenticity: 70%, task authenticity: 78%, impact authenticity: 90%, and personal/value authenticity: 84%. There were two main reasons for the lower reliability rate: (1) In this round we combined the differences in all the key definitions and characteristics together (i.e. if in the first round we combined the total differences in Context together, the difference number should be (1-0.96)*25+(1-0.96)*25+(1-

0.88)*25=5. Therefore, after combining, the reliability rate should be 1-5/25=80%; and (2) this round of reliability was a rough reading of the abstract and several sentences, which introduced more errors due to human factors. The second round of reliability demonstrated that if we read a paper roughly and try to categorized it by our rubric, the accuracy will be not less than approximately 70%.

Examples

Table 6 provides examples of types of activities for each type of authenticity that could be appropriate for the K-12 classroom setting. The table shows examples of learning activities that are authentic in some aspects or settings and then in aspects or settings where the learning activity would not be authentic.

Table 6. Examples of authentic and non-authentic learning activities.

Type of Authenticity	Examples
Context authenticity	***Authentic Activities*** 1. In a mathematics class, the teacher not only delivers theories, principles and equations to students, but also involves students in designing a toy where the principles and equations should be applied. 2. In an engineering class, the teacher asks students to choose their own topics for final project. ***Non-Authentic Activities*** 1. In a mathematics class, the teacher only delivers theories, principles and equations to students. 2. In an engineering class, the teacher decides the topic for final project.
Task authenticity	***Authentic Activities*** 1. In a high school engineering learning module, the students are responsible for collecting data from the local factory and using the data to do their projects. 2. In a high school engineering learning module, the students are trained to use AutoCAD which is a popular tool used in the industry where the students may eventually work. ***Non-Authentic Activities*** 1. In a high-school engineering learning module, the students do imaginary projects which are not relative to the engineering industry at all. 2. Balancing a checkbook in the elementary classroom.[17] Students at the elementary level will not find this activity relevant to their daily lives
Impact authenticity	***Authentic Activities*** 1. In an environmental engineering learning module, the teacher leads a discussion about possible reasons for global warming. 2. For a civil engineering learning module, the teacher discusses with students about the standards of a national civil engineering project. ***Non-Authentic Activity*** 1. For a civil engineering learning module, students are not given professional or safety standards as design constraints.
Personal/ value authenticity	***Authentic Activities*** 1. Students conduct interviews with individuals in their neighborhoods to design a transportation system. 2. Students conduct a project about biodiversity in the forest nearby. ***Non-Authentic Activities*** 1. Students conduct a literature search for transportation needs across the country. 2. Students conduct a project on the biodiversity of a rainforest when students attend an urban school.

Demographic Findings

Authentic curriculum design has various characteristics and influences on students in different demographic groups. In this section, we summarized the frequency of papers regarding the authenticity study or authentic curriculum design for all education levels, from kindergarten to graduate school. The papers were based on availability and were counted only if one of the grade levels were mentioned. Table 7 shows the grade levels with the numbers of authentic studies or curricula. There is a great degree of overlap in educational levels as shown in the vertical lines of the figure.

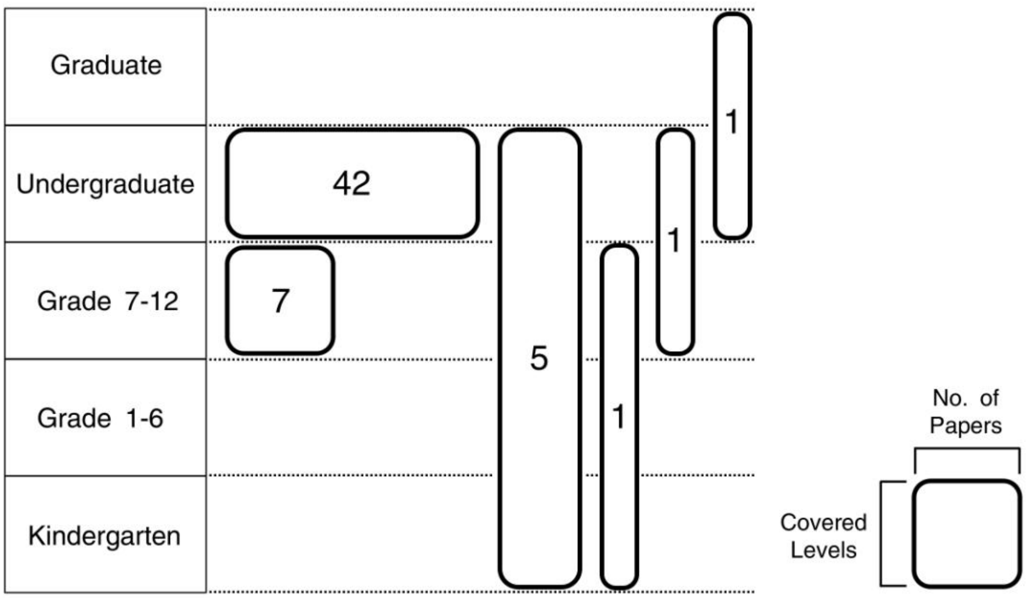

Figure 1. Demographic findings of authenticity by educational level.

Next, we categorized the papers with the type of application fields (e.g. engineering, science, management). Context authenticity (*n* = 28), personal authenticity (*n* = 28), and task authenticity (*n* = 25) were the most frequent types of authenticity. The least frequent type of authenticity was impact authenticity (*n* = 12). In grades K-12, authenticity was most frequently seen in the field of science. Table 7 shows the frequency analysis of the types of authenticity and in what areas they were found.

Table 7. Frequency analysis of types of authenticity.

	Total No. of Papers, % of Total, and Area Represented (s=science, e=engineering, t=technology, m=math, a=all, mg=management, or STEM)					
Type of Authenticity	**Undergrad** 46 papers (75.4%) s (3), e (30), a (4), e,s (4), e,t (1), STEM (3), mg (1)	**Grades 7 – 12** 7 (11.5%)	**Grades K – 12** 1 (1.6%) m,s (1)	**Grades 7 – undergrad** 1 (1.6%) e (2), s (2), a (2), e,s (1)	**Grades K – undergrad** 5 (8.2%) a (3), e,s (1)	**Undergrad – graduate** 1 (1.6%) e (1)
	Total No. Related to Authenticity					
Context	20	5	0	0	3	1
Task	21	3	0	0	0	0
Impact	11	0	0	1	0	0
Personal/ value	22	3	1	1	1	0

Publication trends (statistics stop in August 2011)

The following table shows the publication trends from prior to 1981 until August 2011. The majority of papers that mention authenticity are found more recently in the year 2010. Prior to 1981, there was only one paper found that mentioned authenticity (Table 8).

Table 8. Publication trends of authenticity by year of publication.

Year	**<1981**	**1981-1990**	**1991-2000**	**2001-2008**	**2009**	**2010**	**2011**
No. of papers	1	2	128	796	99	144	3
No. of papers / year	0	0.2	12.8	99.5	99	144	3

Discussion and Implications

The purpose of this paper was to critically examine the current conceptualizations of authenticity as principles to design curricula. To do this, we conducted a systematic literature review of books, journal articles, and conference proceedings in engineering education.

The majority of papers discussed authenticity at the undergraduate level, which is not surprising given that engineering has yet to become widespread in K-12. However, authenticity in K-12 engineering education has the potential to impact students' learning in engineering, science, and mathematics. Engineering design activities, for example, can be used as an integrative context to learn mathematics and science in K-12 and interest more students in engineering from an earlier age. For example, the Boston Museum of Science's *Engineering is Elementary* curriculum utilizes various themes, such as designing water filters to learn about environmental engineering, or designing windmills to learn about mechanical engineering.[32] These units may be categorized by types of authenticity and teachers can utilize them in different contexts or situations depending on the student population.

Next, results showed that impact authenticity was discussed less frequently in authentic learning studies and curricula. Impact authenticity focuses on cultural significance and events or issues in society. This type of authenticity may be especially important for underrepresented students in engineering. Research has shown that there are several critical factors that motivate students to pursue a particular activity and later on a career, once of which is that the experience is authentic, meaningful, and connected to their own real-world understanding.[33] With performance disparities in mathematics and science among students from disadvantaged populations, both underrepresented minorities and females, who lag behind their peers,[34] increasing impact authenticity may help achievement and interest in STEM areas.

We recommend that curriculum designers and professional development providers examine these types of authenticity to ensure that engineering activities are actually authentic in a given situation. Future directions should examine if different types of authenticity affect learning outcomes differently, or if using more than one type of authenticity at a time is more beneficial for K-12 students.

Implications include the use of different types of authenticity to provide more appropriate and promising principles for better design of engineering curricula and standards. Authenticity is situated in a long history of reform pedagogy and student-centered learning theories and would additionally address the reported shortcomings of traditional K-12 classroom education and how existing STEM curricula are positioned.

Conclusion

K-12 standards and curricula in science and mathematics are influenced by historical developments over the time span of their existence – growing content, political influences, different pedagogical models and different values and beliefs about what science and mathematics are and how they should be taught. The K-12 engineering community is in a unique position to explore different frameworks, not just to decide what to teach (concepts, processes and competencies), but also to decide and discuss the governing principles of K-12 engineering standards and curricula. Currently, "authentic" experiences are widely used in all K-12 curricula and across undergraduate/graduate curricula in engineering; our developed model of authenticity encompassing workplace engineering components and individual learners' concerns might serve as a model which could help design engineering experiences for K-12 students. The model does not prescribe the exact activities or content to be taught; rather, the model introduces considerations for the context around which we create learning modules and curricula. More research is necessary about which authenticity dimensions are more beneficial for the desired learning outcomes and program goals.

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