An examination of web-based P-12 engineering curricula: Issues of pedagogical and engineering content fidelity

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***Abstract**: When introducing engineering into P-12 classrooms, teachers' preparation and support becomes a crucial factor. The advent of the Internet brought a shift and an extension of how teachers receive professional development and how they prepare for courses. While the professional development offered by universities and school districts provides the majority of formal options accessed by teachers, many informal sources are utilized on a day-to-day basis. A preliminary web search for P-12 engineering materials revealed a wide variety of curriculum and lesson plans indicative of equally diverse definitions and perspectives on engineering and engineering education concepts. This potential relationship warrants further analysis. This study is a first attempt to examine these web-based P-12 Engineering curricula, present the existing landscape of this field and address emerging pedagogical and engineering fidelity issues.*

The background

Engineering education for the precollege years is an emerging academic discipline addressing the need to further understand and improve the ways that engineers are formally educated. One of the fundamental research questions brought to light by the emerging discipline involves identifying opportune times and approaches in introducing students to engineering, starting perhaps from the early ages. Indeed, as evident by the large number of web based material available today, such an early exposure trend seems to be taking place.

The early exposure hypothesis will inevitably rely on the motivations, knowledge and skills of teachers and parents who might find the topic of engineering interesting but intrinsically difficult because of its specialized content. During these early stages of the diffusion process, the use of the internet can extend how teachers receive professional development, prepare for coursework and access more traditional ways of learning new content and acquiring new expertise (Smerdon & Cronen, 2000). While the professional development offered by universities and school districts provides the majority of formal options utilized by teachers, many more informal sources are utilized on a day-to-day basis. The main informal model of collegiality, "asks your colleague" saw growth and extensions into virtual worlds: teachers using physical and online communities for support and exchange of ideas. In addition, teachers are more likely to just "go online" to find entire lesson plans, ideas, assessment material, or worksheets for their students (O'Dwyer et al., 2004).

While the current polyphony in ideas and suggestions about early exposure might eventually give rise to comprehensive curricula for younger children, an on line grass root culture is proliferating. Faculties of university, educational institutes, non-profit organizations, along with many teachers, produced materials to be used in classrooms and post their materials online, contributing to an online *grass-roots* culture of engineering education resources. Trying to address these needs, a large number of web sites containing "P-12 engineering curricula" already exist. The number of the web sites along with the popular interest in informal learning seems to be increasing very frequently.

An initial review of the resources revealed a broad array of materials, ranging from curriculum to individual lesson plans and activities, and brought to light that there exist many different definitions and perspectives regarding engineering and engineering education concepts on the web that respectively lead to a large variety of "engineering curriculum" results that should be further analysed. As a result of this first web survey we have identified three broad areas of interest with embedded questions to be addressed. These are: the use of online interactive applications as a new learning modality, the nature of the content and the way it is presented, and the enhancement of informal education through the web material development.

When examining how students learn, the use of digital interactive applications in online educational activities is relatively new as a learning modality, and brings one more option besides reading, listening, discussing or participating in hands-on activities in labs. While the power of the web has in the last decades been used to deliver content, current trends toward interactivity are greatly enhanced through technological advancement. This knowledge transfer is still pretty much realized within a framework with characteristics of advanced industrial and post-industrial settings that leaves a lot of other issues and perspectives out.

Second, when it comes to the content delivered, the US is leading in an effort to establish the boundaries of engineering content knowledge and the academic community seeks to understand how the scholarly process of research can embrace the "new content" in and apart of STEM interdisciplinarity (Schuman et al.2002).

Lastly, interest on informal, by this meaning out of classroom, learning settings as an emerging research area is increasing. While the full educational potential of such settings is not well understood (Gorard, Fevre & Rees, 1999), we suspect that such potential could be great (Willoughby &Wood, 2008). Significant differences between formal and informal settings such as access, familiarity, informality and community could be contributing to lasting learning effects originating on those settings.

The research questions

The present study addresses the following questions:

- Through which working definitions are the engineering concepts and the proposed curriculum presented on the web? Are the P-12 engineering curricula differentiated from science, technology and math curricula?
- Is there a bigger trend towards formal or informal P-12 engineering curriculum?
- What seems to be the nature the web based K-12 engineering education curricula as currently developed and presented?
- What media are used to present web-based P-12 engineering education curricula?
- What are the criteria for assessing the pedagogical (cultural/developmental) and content (engineering) fidelity of web based K-12 engineering education curricula?

Methodology

We began with a thorough Internet survey, using the following key words, "P-12 engineering curriculum" material, using the Google and Yahoo search engines. Our aim was to create a chart of present engineering curricula material offered on the Web in relation to the age of the target group. Since the concepts and definitions regarding young engineering are very new and get remoulded very often, trying to find their place among the already existing working definitions, to increase the validity of the survey, our sample is limited to web sites and digital material offered from universities, museums, foundations, institutions and other such entities formally recognized to be relevant to educational and curriculum issues.

Results of the survey include 29 web sites, all American and one British, and the most recent updates were made in January 2009. The data is stored in a database containing information collected from the web sites and their embedded applications.

The categories of the data collected and their definitions are presented in Table 1.

Table 1: Category names and their definitions regarding the data collected from the websites

Name	**Url**	**Status**	**School Level**	**Statement**
Web-site's name	Web-site's url	Owner's relevance to education	Student's school level (according to the American Educational System)	Owner's declaration regarding the curriculum presented (Engineering, Science, STEM, ect.)
Form	**Assessment**	**Curriculum**	**Students Assessment**	**Media**
Formal (to be used in classroom) / Informal (to be used out of classroom)	Report of assessment for the curriculum presented on the web-site	Existence of curriculum (according to definitions)	Type of info regarding student's assessment tools/methods provided	Media used to present the curricula (Text, Images, Audio, Video(interactive or not?)

In the "School Level", "Statement", "Form" and "Assessment" fields we have collected the data as they are declared and reported by the web-site's developers. Since there have been numerous discussion regarding what curriculum is, to classify whether the content was a formal educational curriculum we used Toombs' & Tierney's (1993) and Haywood's (2006) definitions. According to Toombs and Tierney, following a framework on design analysis, "*The curriculum is an intentional design for learning negotiated by faculty in light of their specialized knowledge and in the context of social expectations and students' needs*" and "The essential qualities are all there: *faculty responsibility, specialized knowledge, intended outcomes, negotiated relationships*, and a *learning plan for students*." Haywood complements that by saying that curriculum is "*the formal mechanism through which intended education aims are achieved*". According to this we did not considered sporadic individual projects not mentioning any specific learning goal, implementation instructions, or relevance to previous or future engineering knowledge as curriculum. A literature review was conducted, in order to develop criteria that can facilitate the evaluation of web based proposed curricula designed to engage younger students and their teachers in interest development and knowledge acquisition around engineering education related content. Quantitative analysis followed for all data categories.

Findings and Conclusions

Our analysis led to the following findings regarding the landscape of the web-based P-12 engineering education curricula. 8 out of the 29 web-sites (27.58%) are in fact directories or portals to other websites that present links to educational material. These directories have only been included in the analysis of statements regarding their content, and the choice of terminology presented in Figure 2. The remaining of the findings comes from the analysis of the 21 websites that actually present engineering activities and/or curriculum. Out of these 21 web-sites universities and colleges developed the 33.33%; museums developed the 14.28%, engineering societies or agencies the 9.52%, 14.28% are educational mass media production, 4.76% were developed by national agencies, and 14.28% were developed by other educational institutes or foundations.

Starting by mapping the landscape of the School Levels (Figure 1) targeted by the 21 web-sites we can see how underdeveloped web curriculum regarding PreK engineering still is, since only scattered activities are presented in just the 10.3% of the web-sites analyzed. This percentage reflects back to the fundamental about the optimum time to introduce students closer to engineering. Proceeding with the rest of the educational levels, kindergarten activities can be found in 58.62% of the web-sites, elementary school activities can be found in the majority of the web-sites, namely in 86.2%, and a little less refer to middle and high school, these percentages being 75.86% and 72.4% respectively.

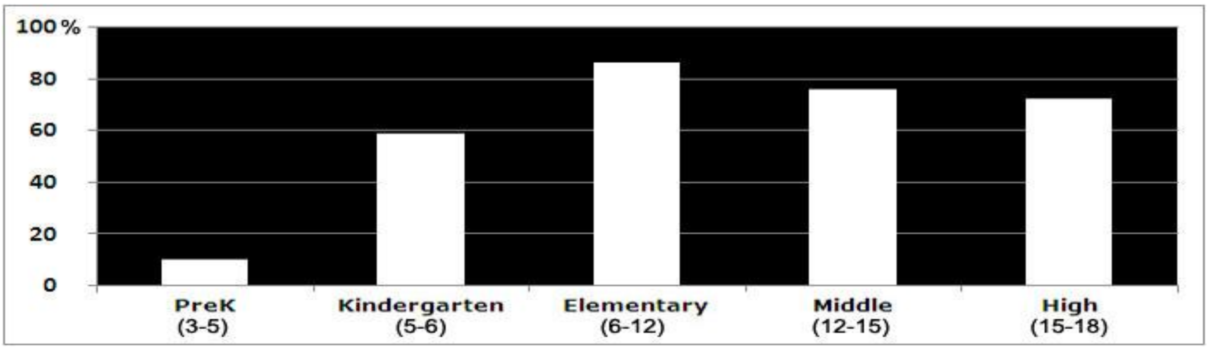

Figure 1: Students' School Level

Observing how the engineering curriculum is defined and presented (Figure 2), what definitions are implicit and whether there is a differentiation from science, technology or math education, terminology used in the 29 web sites, we have come across the following terms used. Although we have come across the web-site looking for "P-12 engineering curriculum", the terms Engineering, Technology, Science, STEM, and their combinations are used by the web-site content developers, so the curriculum is placed under various categories even within the same web site. This fact can be interpreted as an indicator that shows that the developers have not clear boundaries regarding the engineering discipline in the PreK-12 grade level yet.

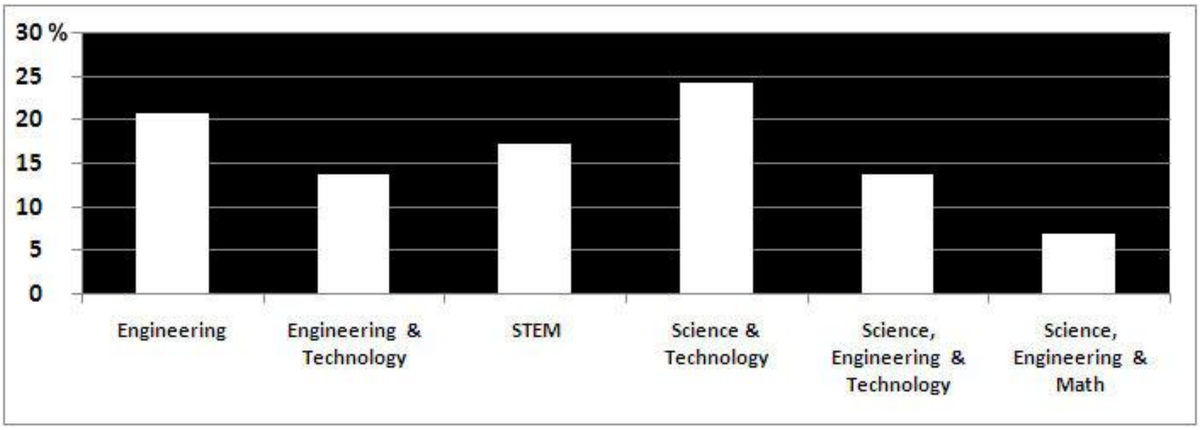

Figure 2: terms used by the web-site's content developers.

Regarding the form of the curriculum, our analysis shows that it is not perceived as a content that should be strictly taught in class, but it can also be implemented in a variety of out of classroom settings. Out of the 21 web-sites analysed, in the 38.09% of them the content developers refer to the activities presented as activities or curriculum to be used by the teacher in a formal classroom setting during class, 9.52% of them are referred to as activities parents and students, or students alone, can do in an informal classroom setting, e.g. at home after class, on vacation, in an extracurricular summer workshop etc., and the 52.38% of them are referred to as activities that can be used both in a formal and an informal setting as described above.

When it comes to the nature of web-based curriculum, by that we are referring to the engineering curriculum presented to an end-used, that being the teacher, the parent or the student, instructions regarding the implementation methods and the assessment of the learning outcomes, all of them presented though a digital environment that allows for the user's interactivity and collaboration both with the digital application and with other end-users. For the time being analysis shows that the attention has mostly been focused on the development of activities, them either being scatter or placed within the framework of a curriculum, but not as much on the development of the assessment methods and tools or the users' collaboration. All 21 web-sites analysed contain at least some sporadic activities. The percentage of web sites containing curriculum, this being defined according to Toombs' & Tierney's (1993) and Haywood's (2006) definitions, reaches 62%. Out of that the 50% presents some kind of student's assessment tool, and just the 4.76% is allowing for end-users' interaction and collaboration through the implementation of a teacher's forum. Furthermore out of the 22 web-sites presenting engineering curriculum, the 28% is reporting the curriculum to have actually been used in a formal or informal setting.

Regarding the media used to present the content 76.2% of the web sites use text and sketches while presenting activity instructions or assessment tools, 4,7% use online videos, and 23,8% use both instructional text, sketches and online video. There is only one case that the video contained a narrative regarding engineering content, while all the other video cases contained interactive video games presenting engineering problems' simulations.

Bellow are the titles of the web sites, which appear more than once in the 8 web sites we have categorized as directories linking to the web sites that contain the activities. These are : Engineering is Elementary (www.mos.org/eie), Teach Engineering (http://teachengineering.org/), Teacher's Domain (www.teachersdomain.org), NASA - For Educators (http://www.nasa.gov/audience/foreducators/), Engineering the Future: Science, Technology, and the Design Process™ (www.mos.org/etf), and Discover Engineering (www.discoverengineering.org)

When it comes to evaluation criteria, while reviewing current literature, criteria exist regarding evaluation of pedagogical content, of learning modalities, of digital applications and of feedback and assessment processes. Due to the compound nature of the web-based curriculum discussed though, we propose fidelity of the web-based curriculum to be examined in parallel based on all following categories, since all of them reflect via different ways on the final desired learning outcome:

- Evaluation of content: engineering validity, mode of content presentation and organisation (Georgiadou & Economides, 2000).
- Evaluation of learning: proposed evaluation methods, assessment presentation(ISTE , 2007)
- Technical evaluation: usability, learning potential, efficiency, ability to memorize, bugs (Avouris, 2000)
- Evaluation of interactivity, collaboration and feedback feasibility: allowance for interactivity with the application, and feedback provision, type of feedback (summative and/or formative (NRC, 2001)) provided or requested, allowance for user-to-user interactivity and/or collaboration

Recommendations

The preliminary findings of this study make two conclusions possible. First, we can establish with certainty that interest in early engineering has started to develop increasingly, taking as evidenced for this the number of websites that already exist. Second, as almost all of the websites are part of the outreach arm of various entities, the quality of the proposed early engineering curricula vary greatly. Currently, the lack of coherent standards makes it impossible to ascertain the quality of the proposed engineering curricula and assorted activities. On the other hand, the wide open field of the web encourages a certain kind of dialogue as the various entities are all eager to contribute to the discussion on early engineering. Our results show that the road ahead is long in that out of this highly generative phase, issues of developmental and cultural fidelity will have to be examined for a long time. On the other hand, the contributions of these websites to the sustained interest in early engineering are immense. In the future and as more formal settings undertake the adaptation of engineering curricula, the conversation is likely to be more intensely focused on what is early engineering curriculum and how best to integrate it in current practices.

Future Plans

Future plans of this study include expanding the data base to include web sites with international origin, in order to capture the global perspective on P-12 engineering curricula, and how it is perceived among diverse engineering cultures and schools of thought.

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