Monster Chips and Multimedia: Impact on Engineering Design and Education

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Abstract: The tools and resources available to an engineer will determine both the scope and scale of projects that may be reasonably attempted and also the design approaches that will be considered. Since engineering education should prepare students to use resources efficiently and effectively to satisfy human needs and desires, it is important that educators incorporate the current context and future trends in the process of education. Although the various fields of engineering have achieved different levels of maturity, there are identifiable stages that most pass through. Superimposed on that dynamic are current advances in two enabling technologies that impact almost all fields of engineering. One is the ability to design and produce electronic components of increasingly higher levels of integration and complexity on physically smaller devices. The second is the growing capability to learn and teach using interactive dynamic visual presentations with less reliance on verbally oriented textbook education. Both the "monster chips" and growing wealth of multimedia resources have great potential to increase the productivity of engineers and to reduce the limitations of geography on engineering education and engineering practice. However both also pose great challenges to engineering education to use new resources effectively in the process and content of education. The increasingly high levels of integration allow students to do more sophisticated designs at an earlier stage in their education, but there is a danger that elimination of the traditionally earlier "tedious steps" also eliminates a necessary stage of development of understanding for many students. The increasing availability and use of multimedia materials enriches the educational process, but although materials can now be updated more frequently, there is also correspondingly less time spent verifying content of material that is expected to be more transient than archival. The focus of this paper is on the impact of these forces in the electrical engineering curriculum, but these issues are readily extended to other fields of engineering such as electromechanical control systems or environmental monitoring.

Keywords: multimedia, complexity, testability, tutorials, electrical engineering curriculum

1. Introduction

Engineering progress has always been supported by a combination of scientific advances and technological development. Historically the formal educational process for engineers has emphasized the engineering science component for both philosophical and practical reasons. However, the tools and resources a practicing engineer can draw upon and understand will determine both the scope and scale of what is considered possible or reasonable. For that reason it is important that educators incorporate at least the current context, if not current methods, in the process of education so students will learn to design on an appropriate scale. Many physical and software tools in common commercial use are not generally made available to students because of either a high financial cost or a steep learning curve for both faculty and students. These tools and methods are designed to make the frequent user more productive, so the financial or time investment of a commercial enterprise can be justified.

An example of this tension between teaching fundamentals and teaching current technologies can be found in the curriculum content for digital design where there are theoretical closed form optimizations at low levels of complexity, but a wealth of more empirical tools and methods at the level used in actual design. The cycle of development of more complex circuits begets more complex design tools which are in turn used to design even more complex circuits.

2. Current Trends

The maturity of different fields of engineering can have a strong impact on the curriculum content. Although the various fields of engineering have achieved different levels of maturity, there are identifiable stages that most pass through [1]. Software is now estimated to be passing from the "craftsman" stage to the stage of more formal and structured design methodologies [1] and similar observations may be made about some aspects of highly integrated dynamically reconfigurable digital hardware design.

Superimposed on that dynamic are current advances in two enabling technologies that impact almost all fields of engineering. One is the ability to design and produce electronic components of increasingly higher levels of integration and complexity on physically smaller devices [2,3]. The second is the growing capability to learn and teach using interactive dynamic visual presentations with less reliance on verbally oriented textbook education. Both the "monster chips"[3] and growing wealth of multimedia resources have great potential to increase the productivity of engineers and to reduce the limitations of geography on engineering education and engineering practice. However both also pose great challenges to engineering education to use new resources effectively in the process and content of education

2.1 Highly Integrated Components

The challenge of designing and testing the highly integrated circuits requires use of very sophisticated components that have detailed functional and performance specifications rather than underlying fundamental models. For very complex designs it makes more sense to use parts already developed by others whenever possible, but that adds another layer of specification so that these parts can be verified to be correct. Design for internal test is essential as the bandwidth for the connections continues to fall behind the internal bandwidth. Incorporating this style and approach to complex design and integration is problematic in an environment that tends to isolate small areas of knowledge for detailed theoretical study.

2.2 Computational Tools and Multimedia Resources

Before convenient personal computation was readily available, engineering practice moved from heavy dependence on precomputed tables to more reliance on mathematical modeling using continuous linear systems and approximations. As computers and then calculators became part of the engineer's toolbox, finite element methods and nonlinear simulations extended the scope and complexity of problems that could be solved. Now with increasingly higher levels of integration in the basic components used for design, there is more emphasis on new design validation techniques for systems composed of complex components and less emphasis on reinventing the individual components [2,3]. Over that same time span, materials used for education have changed from handbooks to verbally oriented basic textbooks to more narrowly focussed example oriented textbooks to computer based computational and design tools and interactive web-based tutorials. While materials are now updated more frequently, there is correspondingly less time spent verifying content.

Multimedia resources provide a solution to many problems. Dynamic interactive tutorials can be used to present course material in a variety of different styles to better match the diversity of learning styles of students [5.6]. The dynamic interactive format is familiar to students who enjoy video games, and visualization aids can help students at all levels visualize relationships and concepts. Some issues: However, the overly empirical approach needed to be successful at many video games can also make it difficult for students to learn in a structured way. As it always has been with students, the most immediate goal is to achieve the *correct result*. The instructor designs problems so that the student learns the *process* of achieving the correct result. If the multimedia tutorials and modern design tools allow students to find the desired answer by a sequence of empirical steps that can not be readily reproduced, the lessons will not have obtained their objectives.

Many factors have combined to drive student learning styles toward empirical methods of trial and search rather than toward fundamental principles. Popular culture emphasizes short attention span events, reading is more difficult for many students due to lack of practice, video games reinforce a quick decision "try it and see" approach without a sanity check at the end, and previous education may have emphasized memorizing recipes rather than understanding concepts.

There is a challenge for assessment and program evaluation if web based resources are used to a substantial extent as course materials. The web based materials have a more transient existence than paper text or reference books. While this has the desirable effect of reducing the overhead for updating and improving content, it has the corresponding undesirable effect of less initial proofreading. Far less quality control goes into a newspaper for example than a reference book. A second problematic effect is that there may be no way to know what was used in a class if the class is assessed over a period of several years. The dynamics of the web based resources make the experience of using them different over time.

3. Impact on the Curriculum

In this modern context we try to determine what we *can* teach students, what we *should* teach students, *how* we should teach students, and *when* we should teach which topics. All of the question are currently subjects of serios debate in academic communities. For example, there is a challenge for assessment and program evaluation if web based resources are used to a substantial extent as course materials. The web based materials have a more transient existence than paper text or reference books. While this has the desirable effect of reducing the overhead for updating and improving content, it has the corresponding undesirable effect of less initial proofreading. Far less quality control goes into a newspaper for example than a reference book. A second problematic effect is that there may be no way to know what was used in a class if the class is assessed over a period of several years. The dynamics of the web based resources make the experience of using them different over time. A third issue is that in addition to being costly and complex to use, many design tools have a relatively short useful lifetime, and this may further discourage academic investment. In general the tolls and manufacturing processes for highly integrated circuits have developed faster than our ability to create formal design and verification methodologies.

Development of engineering curricula is often seen as a balance between teaching fundamental principles that will be the basis for future learning and teaching current technology which will have immediate commercial value but may also rapidly become obsolete. However, when planning new educational programs for the increasingly global workplace, it is important to consider that these two objectives do not necessarily conflict, and that the balance between them migrates as technology evolves. Since the design tools and the components used in design are very much dependent on current and emerging technology, it is essential that this technology be included in educational programs without fear of converting "educational programs" into "training programs" [6].

Engineering education is certainly some mixture of science, current practices, structures and standards, current enabling technology, and cultural perspectives. In recent years several different trends have shifted the balance more toward an unstructured empirical approach that is not efficient in the long run and increases the difficulty of consolidation of learning. Often introductory software and hardware courses unintentionally reinforce these tendencies because the courses start by teaching a specific language or design tool and repeated trial and error methods work well. This paper will describe some interactive software designed for use in the lower division which attempts to reinforce a concept oriented approach as a supplement to existing courses. It presents concepts of logic design visually along with text explanations and structured sequences of examples. The HTML text supporting the applets is easily modified for customized use [4,7].

3.1 First Courses

The trends described above have led to a wide range of experiments in curriculum reform and renovation. Electrical engineering programs have traditionally been built on a firm foundation of mathematics and physics, followed by circuits, fields, electronics and systems with a strong dependence on mathematical modeling. Mathematical tools are especially powerful in electrical engineering because of the linear behavior of analog components over many orders of magnitude.

The focus on the "first course" is both an issue of curriculum progression and also an issue of philosophy [7, 8, 9, 10]. Should the first electrical engineering course remain the traditional circuits course? If it is replaced, should it be replaced with something more interesting or should it be replaced with something more fundamental? Proposals have included comprehensive freshman design projects, a basic concepts of the field course [7], digital signal processing [8], analog filtering [9], and basic communications and information theory [10]. These options are some mixture of content designed to be attractive and interesting to students early in their education and content that is fundamental to the field. No clear agreement about the "right" first course seems imminent due to different perspectives on education, the cost of components and assistants for the courses, and the lack of portability of some classes that can be effective at very selective universities but are difficult when the student mix is more representative.

3.2 Between the First Courses and the Capstone Design …

The middle part of the curriculum is now in need of appropriate updating, but there are strong disagreements within most faculty about what should remain and what should change. This is the level at which the conflict between the learning fundamentals and basic concepts using simple components is confronted with the short term objective of specific commercially desired skills on one side and the need for the development of new methodologies appropriate for design and test of complex systems. There is still a strong tendency to keep coursework focused on smaller units with good mathematical models. However, then when the students get to their capstone design courses the units they learned to design with are beyond their reach, deeply embedded in highly integrated components and boards. However teaching students to design with modules at the board level is of seen as "nonacademic".

4. Conclusions

The purpose of this paper has been to focus on the important questions that need to be asked about the curriculum in the modern context. How do we keep the academic content that will have long term value to the student and still teach content that will have the immediate relevance demanded by the current workplace? In almost all cases there is strong debate and a wide range of proposed solutions. It is important to define the problems before effective solutions can be created. New types of educational resources have to be developed which bridge this gap and teach the fundamental principles of a field in the context of current practice. Since there is little commercial market for such tools beyond educational institutions, it can be expected that a wide range of independent efforts by educators will develop in parallel. The communication that makes these efforts visible to all involved will be essential to bringing these new resources together for use by educational institutions.

7. References

[1] Gibbs, W. Wayt, "Software's Chronic Crisis", *Scientific American*, Vol 271, No. 3, pp86-95, September, 1994.
[2]Taur, Yuan, "The Incredible Shrinking Transistor", *IEEE Spectrum*, Vol 36 No. 7 pp25-29, July 1999.
[3] Zorian, Yervant, "Testing the Monster Chip", *IEEE Spectrum* Vol 36 No. 7 pp54-60, July 1999.
[4] Wood, Sally L., "A New Approach to Interactive Tutorial Software for Engineering Education," *IEEE Transactions on Education*, 39(3), pp. 399–408. 1996.
[5] Wood, Sally L., and Ronald L. Danielson, "Curriculum Evolution: Integration of Web-based Resources, Tutorial Software, and Commercial Design Tools", *Proc. ICEE99*, Ostrava, Czech Republik, 10-14 August, 1999.
[6] Wood, Sally L., "An Introduction of Programmable Gate Arrays into an Introductory Logic Design Course" *Proc. Frontiers in Education 24th Annual Conference*, pp388-392, San Jose, California, Nov. 2-6, 1994.
[7] Wood, S., "A Concept Oriented Freshman Introductory Course Utilizing Multimedia Presentations and Group Laboratory Experience," *Proceedings of the 1998 Frontiers in Education Conference*, IEEE Press, Nov. 1998.
[8] Munson, David C. Jr. and Douglas Jones, "Analog Signal Processing First", *IEEE Signal Processing Magazine*, Vol. 16, No. 5, pp24-29, September 1999.
[9] McClellan, James H, Ronald Schafer, and Mark Yoder, "Digital Signal Processing First", *IEEE Signal Processing Magazine*, Vol. 16, No. 5, pp29-34, September 1999.
[10] Johnson, Don H., and J. D. Wise, "A Different First Course in Electrical Engineering", *IEEE Signal Processing Magazine*, Vol. 16, No. 5, pp34-37, September 1999.