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**A VIRTUAL HEMODIALYZER DESIGN PROJECT FOR FIRST-YEAR ENGINEERS:
AN EPISTEMIC GAME APPROACH**

**Naomi C. Chesler^{1,2}, Elizabeth Bagley², Eric Breckenfeld³, Devin West³
and David Williamson Shaffer²**

¹Department of Biomedical Engineering
University of Wisconsin Madison
Madison, WI 53706
USA

²Department of Educational Psychology
University of Wisconsin-Madison
Madison, WI 53706
USA

³Department of Engineering Physics
University of Wisconsin Madison
Madison, WI 53706
USA

ABSTRACT

Engineering institutions nationwide are pursuing first-year engineering design courses to attract and retain nontraditional students. However, these courses often have high enrollment rates and can be resource intensive. Virtual design projects offer a potential solution to the physical resources requirements but often result in an overly constrained design space, creating uninteresting or non-challenging design problems. We are developing a design problem within a novel virtual environment (i.e., a game) that provides first-year engineering undergraduates with a more authentic engineering design experience and a more complete and accurate understanding of the engineering profession. The design problem presented challenges students to incorporate carbon nanotubes and chemical surfactants into a hemodialysis ultrafiltration unit. Our approach seeks to provide students with experience in the skills, knowledge, values, identity, and epistemology of the engineering profession, which is the *epistemic frame* of the profession. The virtual environment also provides a uniquely comprehensive platform for assessing the students' epistemic frame development over time. We anticipate that this approach will be highly engaging to first-year undergraduate engineering students and will help engineering instructors understand how engineers-in-training learn to become engineers.

INTRODUCTION

Prior work has shown that a key step in developing the skills, knowledge, values, identity and epistemology (way of knowing) – that is, the epistemic frame – of many professions, especially those that require innovation, is some form of *professional practicum* [1,2]. In a practicum environment, a learner takes professional action in a supervised setting and then reflects on the results with peers and mentors. Skills and knowledge become more closely tied as the

student learns to see the world using the epistemic frame of the profession. Examples of professional practica include capstone design courses in undergraduate engineering programs, medical internships and residencies, and almost any graduate program in science, technology, engineering and mathematics disciplines. Prior work has also shown that *epistemic games* - learning environments where students role-play as professionals-in-training to develop the epistemic frame of a profession - increase students' understanding of and interest in the profession [3-5].

Here, we present the development of *Nephrotex*, a novel epistemic game for the engineering profession. Our approach is novel in several ways. First, our game, which has aspects in common with more traditional first-year design courses [6,7], is offered not in isolation but as part of a simulated workplace environment for established professionals in practice. Thus, the learning develops in context [7] and the experience has the potential to more realistically mimic the engineering experience. Second, all activities take place in a virtual environment with some automation to interactions, which reduces demands on the instructors' and design clients' (if present) time and enhances the potential for scale-up to more and larger institutions. Third, we incorporate a data collection platform that has the potential to dramatically improve assessment of learning outcomes through qualitative and quantitative formative and summative evaluation.

METHODS

In *Nephrotex*, students are welcomed as early career hires into the fictitious company *Nephrotex*, whose core technology is the ultrafiltration unit, or dialyzer, of a hemodialysis machine. The students' assigned task is to design a next-generation dialyzer that incorporates carbon nanotubes and chemical surfactants into the

hollow fibers of the dialyzer unit. This task is assigned to them by the head of research and development, a virtual non-player character, and explained to them in depth by their engineering manager, a non-virtual (i.e., real – potentially one of their instructors) non-player character, who also supplies some introductory background material. To redesign the dialyzer unit, four aspects of the hollow fiber material can be altered (Figure 1): the base polymer, percent carbon nanotubes, material processing method and surfactant. If they choose to test a combination of these parameters, their choices serves as the input to a “black box” that yields the following outputs or performance characteristics: biocompatibility, marketability, reliability, ultrafiltration rate and cost.

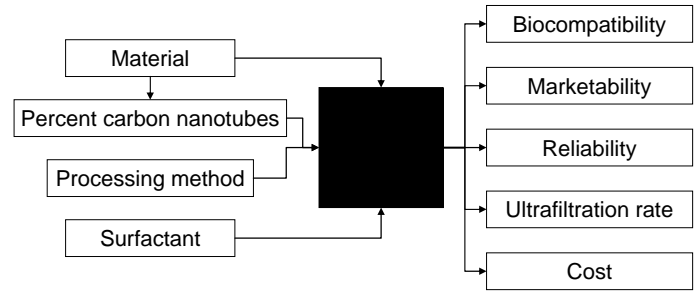


Figure 1. *Nephrotex* inputs and outputs for virtual design. The “black box” represents the physical principles and assumed relationships that govern hemodialysis ultrafiltration.

Students begin by familiarizing themselves with the virtual environment (by taking an entrance interview, writing a staff page biography, reading others’ staff pages, etc.) and a portion of the design space (by performing a preliminary data analysis of variations in output parameters for one material based on changes in surfactant) (Figure 2). Students are guided in small groups through Design-Build-Test (DBT) cycles first with just one material and then with all materials including all possible values of all input parameters. Stakeholder feedback – the responses of those with interest in the project - is key to the DBT cycles. In *Nephrotex*, the stakeholders are a clinical engineer, a manufacturing engineer, a focus group liaison, and representatives from marketing and product support, all of whom are virtual non-player characters programmed to express approval or disapproval based on the player’s design choices. At the end of each design phase, students must make a recommendation and justify their choice based on how it satisfies the competing demands of the stakeholders. One key element of the game is that there is no optimal solution. That is, there is no solution for which cost is minimized and the other performance criteria are maximized.

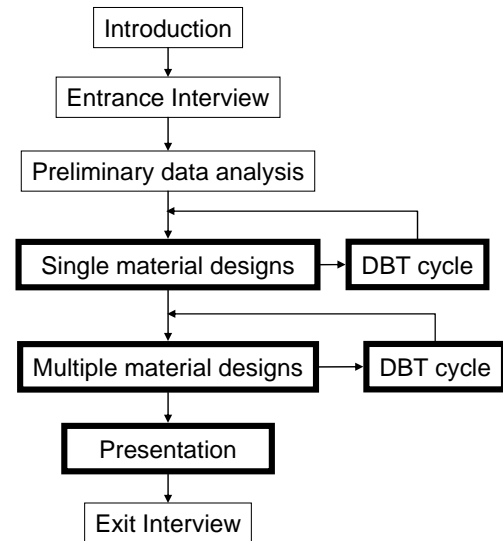


Figure 2. *Nephrotex* workflow diagram. Boxes outlined with light lines indicate individual work; heavy lines indicate team work. DBT = design, build, test cycle.

We plan to incorporate this game into an existing first-year engineering design course as a module of eight to nine 50-minute in-class activities plus out-of-class small group and individual activities (e.g., keeping an electronic notebook). The activities will focus students on developing engineering skills (e.g., graphical, written and oral communication, literature search and interpretation, working within teams), knowledge (e.g., of basic manufacturing, nanotechnology, tradeoffs in design), identity (promoted through interaction with clients [8]), values (potentially by attempting to meet the conflicting demands of various stakeholders) and epistemology (through all of the above). We anticipate piloting the game in Fall 2010 and using the data collected to refine the game for broader distribution.

CONCLUSION

This approach to first-year engineering design reduces the faculty- and client-time demands, which may allow scale up to larger classes at institutions with few resources. In addition, the virtual environment provides a platform where student work output can be analyzed for evidence of development of epistemic frame elements at multiple times. We predict that this approach will be highly engaging to first-year undergraduate engineering students and provide a wealth of data for assessment of learning and professional development.

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