Guest Editorial: A Practical Approach to Understanding—and Applying!—the Scholarship of Application

I. INTRODUCTION

AS MANY as 80% of papers published by the IEEE TRANSACTIONS ON EDUCATION fall within an area known as the scholarship of application [1].[1] Recently, the TRANSACTIONS established a new set of criteria to evaluate manuscripts submitted in this area. This guest editorial is intended to demystify these new criteria and to help writers avoid some common mistakes. The guidelines given here suggest systematic ways for researchers to design their studies and present their findings that will increase the likelihood of their papers being accepted by the IEEE TRANSACTIONS ON EDUCATION.

The TRANSACTIONS' "Description and Review Criteria" describe the scholarship of application as follows:

> *Scholarship of Application*: "Contributions within this area of scholarship will often describe how prior research on learning and teaching (either general research, or research in a specific knowledge domain such as engineering) has been applied to create or design educational activities in electrical engineering (EE), computer engineering (CpE), and other fields within the scope of interest of IEEE. These activities include, but are not limited to, courses, course segments, curricula, laboratory experiments, course projects, capstone courses, and outreach activities. Faculty members across the world design these activities for their students, but to be published in the IEEE TRANSACTIONS ON EDUCATION a paper describing this work must (a) demonstrate application of published educational research and (b) provide a cogently articulated rationale for key design decisions" [2].

One way to think about this is that, much as all other forms of scholarship, the scholarship of application often means making a claim, laying out a hypothesis, or setting out a goal to be evaluated. Frequently, the assertion that the application is effective at achieving its stated goals is implicit (although it is better to make this claim explicit). Specific examples of the scholarship of application and their associated claims, taken from recent IEEE TRANSACTIONS OF EDUCATION manuscripts, might include the following:

- implementation of a new organic electronics laboratory in a graduate curriculum—the explicit claims of this manuscript are that the new laboratory enhances student learning and improves satisfaction [3];
- development of a hands-on lab project with the explicit claims that it improves interest in the course and encourages students to learn the topics required in designing real embedded systems [4];
- integration of hardware and software design instruction using a cryptography application—the explicit claims of this manuscript are that the course teaches both hardware and software design, along with skills in decision-making, presentation skills, teamwork, and design creativity, skills generally overlooked in engineering [5];
- comparison of the effectiveness of a flipped classroom and a traditional classroom in an upper-division engineering course—the explicit claims are that the new approach allows the instructor to cover more material than the traditional classroom and increases students' performance on in-class assessments [6].

In contrast, examples that might be classified as more representative of the scholarship of discovery or of the scholarship of integration include the following:

- study of the factors that influence dissemination in engineering education (scholarship of discovery) [7];
- examination of the effects of anonymity in group discussion on peer interaction and learning achievement (scholarship of discovery) [8];
- review and synthesis of various perspectives on plagiarism (scholarship of integration) [9];
- description of the 10-year evolution of bullfighting robotics to help teach engineering at the Universidad Politecnica de Madrid (scholarship of integration as well as scholarship of application) [10].

II. DIVING DEEPER INTO THE SCHOLARSHIP OF APPLICATION

The TRANSACTIONS' new review criteria for the scholarship of application comprise eight elements [2]:

1) the *relevance* of the described efforts;
2) the clarity and significance of *intended outcomes*;
3) the *context* of the work (within the prior research);
4) the *application design* of the project;
5) the presentation of the *findings*;
6) the contributions as described in the *conclusions*;
7) the overall *organization and clarity* of the manuscript;
8) the meaningfulness of the *illustrations*.

Digital Object Identifier 10.1109/TE.2014.2313036

[1]As background information, Ernest Boyer developed a model for scholarship that was divided into four areas—the scholarship of discovery (obtaining new knowledge), the scholarship of integration (synthesis), the scholarship of application, and the scholarship of teaching. There are obviously a variety of ways to categorize the many types of scholarship, but many have found Boyer's model to be useful. In Boyer's discussion of the scholarship of application, he made clear that he was describing activities where theory and practice interact. Clearly, the areas of scholarship can overlap—development of a novel lab project is an application, but it also involves applying something novel, which is a discovery.

Most of the review criteria form a straightforward checklist that authors can use to ensure their manuscript is properly constructed. The difficulty for many researchers lies in the subtleties of the fourth criterion, *application design*, which the TRANSACTIONS defines as follows:

> *Application design*: "In the scholarship of application, a key focus is on decisions that authors made as they applied existing knowledge and research. This criterion focuses on these decisions. What were key decisions that needed to be made in the process of designing approaches, strategies, tactics, activities, behaviors, and structures to achieve the outcomes? Have the authors identified and explained the key decisions that were needed for their approach? For each decision, what are alternatives drawn from the literature that were, or should have been, considered? To what extent have the authors considered possible alternatives, including alternatives described in prior research? For each decision, what were the criteria used to guide prioritization among the alternatives? To what extent have the criteria that the authors use in making their decisions been clearly and adequately explained? How did the authors prioritize their alternatives, based on their criteria? Did they describe how they arrived at their decisions? Were the descriptions clear and the reasoning solid?"

It is well known that science is subject to considerable biases. A study by Stanford University's John Ioannidis, for instance, has provided compelling evidence that more than half of all published research findings are false [11]. Another major study found that 88% of 53 "landmark" cancer studies could not be replicated, even despite assistance from those who produced the original study [12]. It is as easy to fall prey to biases and problematic study designs in scholarship of application as it is in other types of research [13]. The application design criterion describes many factors to be considered in order to prevent misdirected and potentially false findings. It also lays out the many considerations underlying a study publishable by the IEEE TRANSACTIONS ON EDUCATION. To clarify these issues, two contrasting approaches to undertaking such a study will be discussed here.

III. SCHOLARSHIP OF APPLICATION EXAMPLE

This section illustrates two very different ways in which a faculty member could approach planning, implementing, and reporting an experiment to "flip" his or her classroom. Study #1, conducted by Dr. Humdrum, is unlikely to be published in the IEEE TRANSACTIONS ON EDUCATION. Study #2, on the other hand, conducted by Dr. Dig-Deeper, has a high potential for publication. For purposes of simplicity, we represent both Dr. Humdrum and Dr. Dig-Deeper as male professors.[2]

Note that these two fictitious situations are exaggerated to provide insight into good (and bad) ways to approach the scholarship of application. While we all would hope to make more informed decisions than those of Dr. Humdrum, we cannot all expect to achieve the superhero status of Dr. Dig-Deeper. He applies so many good practices that he may appear intimidating, but there have been many strong application papers published by the IEEE TRANSACTIONS ON EDUCATION that have been more modest in their approach. The key idea is to address all eight elements of the review criteria, designing the study such that the methods for evaluating the claims align with stated goals, presenting a clear rationale for the design decisions while acknowledging the inherent limitations.

A. Study #1

Dr. Humdrum reads an article in *The Chronicle of Higher Education* about the flipped classroom, and he decides to implement the approach in his own class. He is teaching Electric Circuits again this year, as he did last year; he designs an experiment to compare the flipped class with his conventional lecture approach. Last year, he videotaped all of his class sessions for Electric Circuits, so this year he posts his videos online for students to review before class. Then, he uses the class period for students to work homework problems. He writes a final exam for the class that is equivalent to last year's. He finds no difference in the average exam score for last year's traditional course and this year's flipped classroom, and his students complain that the video lectures are dry and dull. He concludes that the flipped approach is a poor substitute for traditional approaches to teaching and writes up his observations and conclusions for the TRANSACTIONS. To his surprise, the manuscript is rejected.

B. Study #2

Dr. Dig-Deeper has heard the buzz about the flipped classroom. He reads an article extolling the benefits of the flipped classroom, and he wants to see if he can replicate the results in his class. He does a thorough review of the research literature—he even reads some recent books and online articles and forums on the phenomenon of flipped classes—and he begins to formulate his project. (Although he did not realize this until much later, his preliminary exploration of the literature applies to the scholarship of application's review criteria for *relevance* and *context*.)

For the *application design* element of the project, Dr. Dig-Deeper enlists a team of two fellow faculty with complementary backgrounds. His team includes an educational psychologist with a good grasp of statistics and a new mechanical engineering professor who is eager to apply his recent pedagogical training from his teaching assistant work. Early on, Dr. Dig-Deeper sets up a meeting with a member of his Institutional Review Board (IRB) to ensure he has understood the appropriate considerations for collecting and compiling data. Then, he starts to plan a flipped class experiment, actually drafting tentative sections of the manuscript the team intends to submit. He realizes that the process of writing will force him to carefully evaluate and lay out the choices he and his team are making as they conduct the study. (The team addresses the review criteria of *organization and clarity* of the manuscript, presentation of the *findings*, and even the contributions as described in the *conclusions* as they wrestle with getting their preliminary ideas down on paper. Even the element of meaningfulness of the *illustrations* is brought into play at this early stage as the team realizes that certain key factors could ultimately result in a

[2]We carefully considered the gender options for our two professors, especially given the male-dominated nature of the engineering faculty profession. Because Dr. Humdrum is not a very good model, we did not want to be accused of practicing gender discrimination by making him female. On the other hand, we thought it would be a clear case of reverse discrimination to make the superhuman Dr. Dig-Deeper a female. Making both characters women would have created an unrealistic scenario that would be too unrepresentative of typical engineering professors to be believable. Every alternative had drawbacks, and we finally decided to settle for the least of all evils by making both professors male.

valuable graphical display of the study's contributions.) Writing the literature review proves especially valuable as, during the process of finalizing that section, Dr. Dig-Deeper finds some papers he had missed earlier that give him a better idea of how others have flipped their classrooms. He even contacts some of the authors of the papers to ask a few questions about their findings. As Dr. Dig-Deeper digs deeper, he begins to realize that this study has the potential for significant impact, and that it is going to take several years to complete the work. He begins to look for funding to support his team's work in this area.

Dr. Dig-Deeper's developing manuscript focuses on *application design* decisions in two areas: design decisions made about the pedagogy of the flipped classroom, and design decisions made about the evaluation of the impact of the flipped classroom.

1) Classroom Design (How Dr. Dig-Deeper Enacts the Flipped Classroom).: Dr. Dig-Deeper discovers that the "flipped classroom" is a buzzword used haphazardly to define a myriad of pedagogical innovations. He begins by working with his team to clearly define their approach to the pedagogy (this relates not only to the *application design* element of the project, but also to the element of clarity and significance of *intended outcomes* and the *context* of the work). They opt to use a definition that characterizes a flipped classroom as one in which three key things happen [14]: 1) the first exposure to course content occurs prior to each class; 2) students complete a pre-class assessment to ensure preparation; and 3) class time is used for processing, practice, group learning, and other active learning techniques.

As a way of providing first exposure to course content, Dr. Dig-Deeper decides to use videos and pre-class readings. He has read the research on attention span, and he knows that shorter videos will be far more conducive to learning than standard 2-hour lectures. Therefore, he creates a series of short informational videos to describe some of the more complicated concepts in his class. He then requires his students to watch select videos before each class; he also assigns relevant portions of the course textbook.

Dr. Dig-Deeper hears from some students that they are frustrated and uncomfortable at having to assume responsibility for their own learning by completing the pre-class work. Therefore, he provides support that helps students improve their self-learning ability by detailing clear expectations for what they should know and by providing practical resources on learning more effectively (e.g., [15]) accessible through the course Web site. He also addresses effective self-learning in class.

Consistent with the definition of his pedagogy, Dr. Dig-Deeper designs and administers a series of pre-class quizzes using his university's learning management system. These quizzes contribute a small portion to the students' grade and help him ensure that students prepare for class. In addition, by reviewing student responses before class, Dr. Dig-Deeper is able to ascertain students' level of understanding about key ideas and adjust his class plan each day.

Dr. Dig-Deeper begins each class period by briefly reviewing the topics that, based on the pre-class quizzes, are giving the students the most difficulty. Then, he has students engage in active learning. On a typical day, he has students work individually on an initial problem using the concepts they studied prior to the class. Following that, he has the individual students turn to a neighbor to compare their answers and refine their solutions. Finally, he has students work together in groups of four to solve a second, more complex problem. Throughout the process, he roams around class offering suggestions and feedback because he knows that personalized guidance, interaction, and encouragement are important ways to foster student success.

2) Design of the Evaluation (How Dr. Dig-Deeper Evaluates the Flipped Classroom): Dr. Dig-Deeper works with his team to outline three main claims about the flipped classroom study. First, he has read that the flipped class can increase student learning, so he plans the bulk of his study around evaluating learning gains students make in his flipped class and comparing them to those in his traditional course. (Note that this relates to the element of clarity and significance of *intended outcomes*.) His first/primary claim is that: *As a result of engaging in the flipped classroom, students will have greater conceptual understanding of the course objectives*. Dr. Dig-Deeper plans to invest considerable effort in making students responsible for learning some material on their own, and he hopes this will result in improvements in their confidence. Accordingly, his second claim is that: *Students who participate in the flipped class will have increased confidence in their ability to succeed*. Finally, because this is a new endeavor for him, he decides to compare student perspectives about both versions of the class to explore other ways in which the flipped classroom is better (or worse). His third claim is that: *Students will have positive perspectives about their learning in the flipped class*. Dr. Dig-Deeper is wary of his own claims, however, because he knows they reveal his implicit bias, so he continues to work with his team to refine his claims and design a fair evaluation of them.

To study the impact of his flipped classroom experiment, Dr. Dig-Deeper decides to teach the course in the traditional way one year and use the flipped method in the next year. (He realizes that an alternative approach might have been to enlist another professor to teach one of the courses during the same timeframe. However, he considers the tradeoffs and concludes that, in his opinion, having the same professor provides a better control experience.) He chooses to use the same textbook, same weekly homework assignments, and same testing methods for each of the two years—he carefully describes all these considerations in the paper. Sometimes, to his chagrin, he writes up a few paragraphs for the draft manuscript describing his plans, but then the plans change after discussion with his team, and he has to delete and rewrite. Ultimately, he redrafts much in the manuscript as the study develops, but he is grateful that the manuscript provides a continuing means for him and his team to focus their thoughts.

To evaluate the primary claim for his course, *greater conceptual understanding*, Dr. Dig-Deeper decides to compare student performance on two separate instruments: 1) homework problems, and 2) a validated concept inventory. First, for the homework problems, he works to carefully ensure that the assignments used in the two different versions of his course are matched by soliciting two independent reviews. He asks both the teaching assistant for the course and one of his colleagues to help revise the problems. He then pilots the two versions of the problems with some undergraduate researchers in his lab.

Dr. Dig-Deeper also considers relative time in the semester when each problem is assigned—he tries to maintain the same schedule in order to eliminate inadvertent bias. (The team's psychologist was very helpful in pointing out potential sources of bias.) Second, Dr. Dig-Deeper finds the Electric Circuits Concept Inventory [16], a validated, multiple-choice instrument that measures students' understanding of DC circuits, and notes that the concepts addressed in the inventory are well matched with the ones he teaches in his Electric Circuits course. Dr. Dig-Deeper decides to administer the instrument on the first day of class and then again as part of the final examination for both versions of his classes.

To evaluate his second claim, *increased student confidence*, Dr. Dig-Deeper and his team review the literature on confidence and self-efficacy and identify several potential self-report survey instruments. After considering the pros and cons of three of these instruments and contacting the developers of each, they decide to use the Longitudinal Assessment of Engineering Self-Efficacy (LAESE), a validated instrument that has been used previously in engineering classes [17]. Dr. Dig-Deeper administers the LAESE in both versions of his class during the first week of class and again at the end.

Finally, to evaluate his third claim, *positive student perspectives*, Dr. Dig-Deeper decides to enlist the assistance of his campus's center for teaching and learning to collect student feedback about both classes. He has worked with the center's professional staff before, when they had administered a Small Group Instructional Diagnosis [18] in the middle of the term for his Signals and Systems class; the anonymous student feedback he received allowed him to make small changes to this teaching that resulted in large improvements. An objective consultant visits his flipped class in the middle of the term and then meets with Dr. Dig-Deeper to share student perspectives of the class. This candid student feedback provides Dr. Dig-Deeper with some good insight.

In writing about his efforts, Dr. Dig-Deeper begins by showing that students enrolled in both courses had similar background characteristics and ability prior to taking the courses. He compares the GPAs of entering students for both courses, as well as self-efficacy scores and concept inventory data. He finds and reports minor differences. Then, he and his team conduct careful statistical analyses to show that the flipped group performed statistically better on many problem sets as well as on the concept inventory items. They also present a comparison of student perspectives in both courses, noting both the strengths and weaknesses of each approach.

Dr. Dig-Deeper takes great care to ensure that the methods used to evaluate the goals of the study *align* with what he is evaluating. He is aware that his claim that his students learn more deeply cannot be substantiated by, for example, survey data on the students' satisfaction with the course. Underlying the design of both his new initiative (the flipped classroom) and his evaluation of it, there is a careful, thorough discussion of the design decisions, reasons, rationales, evidence, justification, and tradeoffs so that readers can clearly understand why the approaches were chosen. In this way, all eight elements of the review criteria for the scholarship of application come into play.

Despite his busy schedule, Dr. Dig-Deeper has taken the time to watch a massive open online course (MOOC) on how to improve his writing for research [19]. Then, he and his team finalize the draft manuscript and send it to a few colleagues from other disciplines for a "pre-review." When they receive the feedback, they find they can do a final review with fresh eyes. They make several revisions, rewriting one section of their paper to invite less controversy and also responding to the edits of a writer-friend who is not an academic [20], [21]. They are confident that the final draft they submit to the IEEE TRANSACTIONS IN EDUCATION is their best work, and they wait anxiously for feedback from the editor.

IV. Putting it all Together—Pointers for Successful Publication

Dr. Dig-Deeper and his team learned a lot in completing their project and writing it up for the IEEE TRANSACTIONS ON EDUCATION. They read the TRANSACTIONS' review criteria and framed their project using the guidelines. They reflected on the scholarship of application criteria that emphasized the inclusion of both: 1) the application of published research, and 2) a well-articulated rationale for key design decisions. Here is a quick synopsis of ideas used by Dr. Dig-Deeper and his team that may help you toward successful publication in the IEEE TRANSACTIONS ON EDUCATION.

- *Pick an area that is of broad interest.* If you cannot easily imagine colleagues at other institutions being interested in your findings, or if the context of your research is too narrow to allow generalizing the findings to other situations, consider looking for something different to study.
- *Thoroughly review the literature and link your work to appropriate prior research.* You cannot design a fair or appropriate study if you do not understand the current "state of the art," so take some time to learn about other published research and use that to shape your research plans.
- *Consider forming a multidisciplinary research team.* Partnering with faculty in education, psychology, business, or statistics, for example, or working with professionals from your campus center for teaching and learning can help you explore the research in a more comprehensive way that provides a better chance for successful publication.
- *Identify significant and relevant claims.* The claims that underscore your project should be stated explicitly and framed as testable hypotheses. Central to the idea of any hypothesis is that the outcome is not predetermined.
- *Beware of your potential biases.* Be objective as you plan your work—avoid designing your project in a way that simply confirms your gut feeling. Similarly, be aware that the disciplinary biases inherent in traditional engineering research may require you to design your project and write about your findings in ways that appeal to a variety of audiences.
- *Collect and analyze the data using proven methodology that is aligned with your research questions, goals, or claims.* Keep in mind that a well-designed study might include quantitative data as well as qualitative data—both can yield strong, rich findings. Be aware of over-relying

on student opinion data—students can be predisposed to telling you what they think you want to hear. However, do not dismiss insights you might be able to get from a well-designed self-report survey or from data collected by objective colleagues.

- *Report findings that are clearly supported by your data.* Be sure that your evaluation data matches with your claims and with the study design and that it provides sufficient evidence (e.g., an ample number of students, cohorts, etc.) from which to draw worthwhile conclusions.
- *Clearly articulate the practical implications of your findings.* Helping the reader understand how your findings might extend to other settings can be an important way to increase the impact of your work.
- *Describe the limitations inherent in your work.* Manuscripts that describe the scholarship of application inevitably have limitations. Acknowledge them and discuss their potential impact on results and conclusions.
- *Consider the ethical implications of working with human subjects.* Different institutions in different countries can have very different requirements in relation to institutional review of your research. It is a good idea to establish a relationship with your IRB officials and to interact with them regularly.
- *Get feedback on your draft.* Good writing allows your work to be broadly cited and appreciated. "Pre-reviews" by colleagues from other disciplines, and even from outside academia, can dramatically improve the clarity and quality of your writing.

V. Conclusion

It is very likely that the paper you are planning for the IEEE Transactions on Education falls into the category of the scholarship of application. If that is the case, do your homework. You want to be able to support and describe the many carefully researched decisions you made in laying out a claim and attempting to prove it. Remember that, in some sense, you are working as a detective who has made an important claim and is now trying to prove that claim using all the wit and intelligence at your disposal. This editorial is meant to guide you in your work.

Acknowledgment

The authors would like to thank Rebecca Brent, Jeff Froyd, the Associate Editors, and Kirsty Mills, IEEE Transactions on Education Editorial Administrator. These individuals reviewed drafts of this editorial and offered insightful comments, suggestions, and criticisms.

Barbara Oakley
Oakland University
Rochester, MI 48309 USA
(e-mail: Oakley@oakland.edu)

Cynthia J. Finelli
University of Michigan
Ann Arbor, MI 48109 USA
(e-mail: cfinelli@umich.edu)

References

[1] E. L. Boyer, *Scholarship Reconsidered: Priorities of the Professoriate*. Princeton, NJ, USA: Carnegie Foundation/Jossey-Bass, 1990.
[2] IEEE Transactions on Engineering, "The scholarship of application: Description and review criteria," 2013 [Online]. Available: http://sites.ieee.org/review-criteria-toe/application/
[3] N. Bednar and G. Stojanovic, "An organic electronics laboratory course for graduate students in electrical engineering," *IEEE Trans. Educ.*, vol. 56, no. 3, pp. 280–286, Aug. 2013.
[4] L. Sousa, S. Antao, and J. Germano, "A lab project on the design and implementation of programmable and configurable embedded systems," *IEEE Trans. Educ.*, vol. 56, no. 3, pp. 322–328, Aug. 2013.
[5] L. Uhsadel, M. Ullrich, A. Das, D. Karaklajic, J. Balasch, I. Verbauwhede, and W. Dehaene, "Teaching HW/SW co-design with a public key cryptography application," *IEEE Trans. Educ.*, vol. 56, no. 4, pp. 478–483, Nov. 2012.
[6] G. S. Mason, T. R. Shuman, and K. E. Cook, "Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course," *IEEE Trans. Educ.*, vol. 56, no. 4, pp. 430–435, Nov. 2013.
[7] B. T. Hazen, W. Yun, and C. S. Sankar, "Factors that influence dissemination in engineering education," *IEEE Trans. Educ.*, vol. 55, no. 3, pp. 384–393, Aug. 2012.
[8] B.-S. Jong, C.-H. Lai, Y.-T. Hsia, and T.-W. Lin, "Effects of anonymity in group discussion on peer interaction and learning achievement," *IEEE Trans. Educ.*, vol. 56, no. 3, pp. 292–299, Aug. 2012.
[9] D. Chuda, P. Navrat, B. Kovacova, and P. Humay, "The issue of (software) plagiarism: A student view," *IEEE Trans. Educ.*, vol. 55, pp. 22–28, 2012.
[10] M. Hernando, R. Galán, I. Navarro, and D. Rodriguez-Losada, "Ten years of cybertech: The educational benefits of bullfighting robotics," *IEEE Trans. Educ.*, vol. 54, pp. 569–575, 2011.
[11] J. P. A. Ioannidis, "Why most published research findings are false," *PLoS Med.*, vol. 2, p. e124, 2005.
[12] C. G. Begley and L. M. Ellis, "Drug development: Raise standards for preclinical cancer research," *Nature*, vol. 483, pp. 531–533, 2012.
[13] R. M. Felder and R. G. Hadgraft, "Educational practice and educational research in engineering: Partners, antagonists, or ships passing in the night?," *J. Eng. Educ.*, vol. 102, pp. 339–345, 2013.
[14] Center for Research on Teaching and Learning, University of Michigan, Ann Arbor, MI, USA, "Flipping your class," 2014 [Online]. Available: http://www.crlt.umich.edu/node/58368
[15] B. Oakley, *A Mind for Numbers: How to Excel at Math and Science*. New York, NY, USA: Penguin, Jul. 2014.
[16] T. Ogunfunmi and M. Rahman, "Concept inventory assessment instruments for circuits courses," in *Proc. Amer. Soc. Eng. Educ.*, Vancouver, BC, Canada, 2011.
[17] R. M. Marra, K. A. Rodgers, D. Shen, and B. Bogue, "Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy," *J. Eng. Educ.*, vol. 98, pp. 27–38, 2009.
[18] C. J. Finelli, T. Pinder-Grover, and M. C. Wright, "Consultations on teaching: Using student feedback for instructional improvement," in *Advancing the Culture of Teaching on Campus: How a Teaching Center Can Make a Difference*, C. E. Cook and M. L. Kaplan, Eds. Sterling, VA, USA: Stylus, 2011, pp. 65–79.
[19] K. Sainani, "Writing in the Sciences," Stanford University, Stanford, CA, USA [Online]. Available: https://www.coursera.org/course/sciwrite, massive open online course (MOOC), accessed through Coursera.
[20] T. Becher and P. Trowler, *Academic Tribes and Territories*, 2nd ed. Philadelphia, PA, USA: Open Univ. Press, 2001.
[21] R. Toor, "Bad writing and bad thinking," *Chronicle Higher Educ.* Apr. 15, 2010 [Online]. Available: http://chronicle.com/article/Bad-WritingBad-Thinking/65031/

Barbara Oakley (M'98–SM'02) received the B.A. degree in Slavic languages and literature and the B.S. degree in electrical engineering from the University of Washington, Seattle, WA, USA, in 1973 and 1986, respectively, and the Ph.D. degree in systems engineering from Oakland University, Rochester, MI, USA, in 1998.

She is currently an Associate Professor of engineering with the Department of Industrial and Systems, Oakland University, and is a licensed Professional Engineer in the State of Michigan. Prior to her academic career, she rose from Private to Captain in the US Army, worked as a Russian translator on Soviet trawlers in the Bering Sea, and served as a Radio Operator with the South Pole Station in Antarctica. This varied background provides unconventional insight to her work. Her most recent book is *A Mind for Numbers: How to Excel at Math and Science (Even If You Flunked Algebra)* (Tarcher-Penguin, 2014). She is interested in translating research findings from neuroscience and cognitive psychology to instructors and students so that these findings can have a practical impact on people's ability to learn effectively. Her foundational research, published in the *Proceedings of the National Academy of Sciences*, involves pathologies of altruism and altruism bias.

Cynthia J. Finelli earned the B.S.E., M.S.E., and Ph.D. degrees in electrical engineering from the University of Michigan, Ann Arbor, MI, USA, in 1988, 1989, and 1993, respectively.

She currently serves as Director of the Center for Research on Learning and Teaching Engineering and Research Associate Professor with the College of Engineering, University of Michigan. In these roles, she leads faculty development initiatives in engineering, actively pursues research in engineering education, and assists other faculty at the university in their scholarly endeavors. She leads a national initiative to create a taxonomy/keyword outline for the field of engineering education research. Her current research interests include studying faculty motivation to change classroom practices, evaluating methods to improve teaching, and exploring ethical decision-making in undergraduate engineering students.

Dr. Finelli is an American Society of Engineering Education Fellow. She is Past Chair of the Educational Research and Methods Division of the American Society of Engineering Education.