The Nature of Scholarship in Computing Education: An Approach from *IEEE Transactions on Education*

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New review criteria for *IEEE Transactions on Education*, adopted in 2013, will significantly impact the future of scholarship in computing education.

Scholarship in computing education, like scholarship in engineering education more broadly, is an emerging multidisciplinary field, and, as in any emerging field, scholars face challenges describing the nature of their work. In his 1990 book *Scholarship Reconsidered: Priorities of the Professoriate,* Ernest Boyer, president of the Carnegie Foundation for the Advancement of Teaching from 1979 to 1995, described a framework identifying four categories of educational scholarship—discovery, application, integration, and teaching—that has proved influential across many different fields. I find that applying Boyer's framework provides a productive approach to addressing questions about the nature of scholarship in computing education.

Since its inception in 1957 as *IRE Transactions on Education*, *IEEE Transactions on Education* has published original scholarly contributions spanning considerable intellectual territory. When in 2013 the editorial board decided to revise the review criteria for the *Transactions*, it seemed important to develop guidelines that matched the breadth of these contributions, and Boyer's framework, with its encompassing scholarly scope, provided an excellent foundation on which to base our efforts. Because the *Transactions* has historically focused on matters of education in electrical engineering, computer engineering, and other fields within the scope of IEEE, teaching as a category of scholarship didn't seem necessary, so the board considered in detail contributions involving Boyer's three remaining areas of scholarship: discovery, application, and integration. In all three areas, scholarly contributions can take a variety of forms.

THREE AREAS OF SCHOLARSHIP

For *IEEE Transactions on Education*, scholarship of discovery emphasizes contributions of new knowledge in the pertinent educational fields. One scholar might develop a tool or process for assessing learning in electronics, computer architecture, or robotics, for example. Another might explain difficulties that students encounter when learning one or more concepts. Others might contribute findings about what motivates students interested in learning about communications, networking, databases, or other topics. Whatever its focus, to be considered for publication in *IEEE Transactions on Education*, a paper asserting a contribution of new knowledge requires a thorough understanding of past contributions in related areas.

Scholarship of application emphasizes contributions that apply findings from research on learning and teaching (either general research or research in a specific knowledge domain, such as compilers) to create or design educational activities in fields appropriate for the *Transactions*. Such educational activities may include courses,

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course segments, curricula, laboratory experiments, course projects, capstone courses, and outreach activities. Academic professionals worldwide design activities like these for their students, but to be published in *IEEE Transactions on Education*, a paper describing this work must both demonstrate the application of published educational research in the activity's design and provide a cogently articulated rationale for its key design decisions.

Scholarship of integration emphasizes multidisciplinary contributions that integrate, interpret, synthesize, coalesce, or otherwise organize prior research to identify patterns, themes, trends, needs, and opportunities upon which other scholars can build. Such scholarly contributions often take the form of review articles. The increasing importance of this area of scholarship can be seen in the rapidly growing field of systematic review (M. Borrego, M.J. Foster, and J.E. Froyd, "Systematic Literature Reviews in Engineering Education and Other Developing Interdisciplinary Fields," to be published in *J. Eng. Education*, vol. 103, 2014), a discipline offering review methodologies designed to address specifically articulated questions, rather than the more generalized approaches that characterize traditional review articles. Scholarship of integration is aided by Scopus, ERIC, the International Bibliography of the Social Sciences (IBSS), and other databases that offer powerful search tools to extract relevant content.

These three areas of scholarship comprise virtually all the scholarly contributions submitted to the *Transactions*.

COMMON REVIEW CRITERIA

For *IEEE Transactions on Education*, all three areas of scholarship—discovery, application, and integration—are reviewed according to six basic criteria:

- *Organization and clarity.* How well is the manuscript organized and written?
- *Illustrations.* How well do illustrations, figures, tables, and so forth enhance and support the intended contributions of the manuscript?
- *Relevance.* To what degree will the global readership for the *Transactions* be interested in the manuscript under review?
- *Context.* To what degree have the authors situated their intended contributions within the body of existing work? How well have the authors related their work to prior scholarship?

Each of the three areas of scholarship has distinctive review criteria, with those for scholarship of application being the most detailed.

- *Findings.* How well have the authors analyzed and summarized their data, evidence, artifacts, and other elements of their presentation?
- *Conclusions.* How well have the authors connected their findings to implications for practice, policy, future research, and other issues of concern to the field?

The first two review criteria emphasize overall qualities of communication and presentation, while the remaining four focus on more distinct qualities that differ somewhat according to the contribution's specific area of scholarship. Details about relevance, context, findings, and conclusions specific to scholarship of discovery, application, and integration, along with more information about review criteria for *IEEE Transactions on Education*, can be found at http://sites.ieee.org/review-criteria-toe.

SPECIFIC REVIEW CRITERIA

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Scholarship of application

Essentially, for the *Transactions*, scholarship of application is the scholarship of design in an educational context. Authors making contributions to scholarship of application are offering a "good" design; that is, they've applied, implicitly or explicitly, existing knowledge well. In large part, this area of scholarship involves making more explicit the application of existing knowledge, including, most basically, knowledge of the disciplinary subject. For example, authors presenting their design for all or part of a course on electromagnetics must demonstrate that they used accurate technical knowledge regarding electromagnetics and that they applied this knowledge in an expert manner.

In addition to content knowledge, authors should also apply knowledge from research on learning and teaching. Consider, as an illustration, a key principle emerging from current research: prior knowledge of relevant material influences acquisition of new knowledge (S.A. Ambrose et al., *How Learning Works: Seven Research-Based Principles for Smart Teaching*, Jossey-Bass, 2010). Authors applying this principle should, therefore, demonstrate that they've taken into account the need for instructors to adapt course designs to students' knowledge of prerequisite topics at the beginning of a course.

More specifically, evaluating the quality of the authors' design in scholarship of application requires considering intended outcomes and application design.

Intended outcomes. Applying existing knowledge requires that authors know in advance what their instructional design is intended to achieve. Review of intended outcomes involves evaluating how well authors have articulated these outcomes and how well they reflect community-wide understanding of appropriate outcomes. Research has shown that, in general, designers create more effective designs when their intended outcomes are clear, explicit, and stated at a functional level (that is, designers state design requirements before they generate embodiments or physical realizations for those requirements).

Similarly, authors should articulate their intent (What is the course trying to achieve?) before describing their design (What is the sequence of course topics?). So before they describe how a specific segment of a course has been designed or redesigned, for example, they should articulate what students will be expected to demonstrate after completion of the course segment. Articulation of specific outcomes simplifies the task of showing how well the design achieved its intent. In other words, stating outcomes is a prerequisite for developing and implementing an evaluation plan.

Application design. In designing lab experiments, instructional software, courses, or other educational contributions, authors make multiple design decisions: they choose specific topics, specific ways to organize and present material, specific assignments for students to work on, and so forth. In addition to describing the results of these key design decisions, authors should explain their rationale for having made them—that is, why did they choose particular alternatives among different possibilities? While in the past many articles published in *IEEE Transactions on Education* have offered a particular approach to teaching a subject, far fewer have laid out the rationale underlying the key decisions that led to the approach. The application design review criterion is intended to place greater weight on evaluating such rationales.

Scholarship of discovery and scholarship of integration

The distinctive review criterion for both scholarship of discovery and scholarship of integration is methodology. To address this criterion, authors must articulate an explicit methodology, show that it's both appropriate for the questions they've selected to consider and consistent with accepted practice, and document that the methodology was implemented as described. While a treatise on research methodologies is beyond the scope of this column, many articles and books provide substantive resources on methodologies for both scholarship of discovery (see, for example, M. Borrego, E.P. Douglas, and C.T. Amelink, "Quantitative, Qualitative, and Mixed Research Methods in Engineering Education," *J. Eng. Education*, vol. 98, no. 1, 2009, pp. 53–66) and scholarship of integration (see Borrego, Foster, and Froyd, above).

The nature of scholarship as an emerging field is influenced, in part, by what will be published in relevant journals. For computing education, the framework and review criteria for *IEEE Transactions on Education* may shape conversations among participating scholars across the globe. Because the framework and review criteria were revised in 2013, I hope this brief discussion based on those revisions can contribute to this ongoing conversation.

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