122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #11687

A thematic analysis comparing critical thinking in engineering and humanities undergraduates

Ms. Amy Elizabeth Bumbaco, University of Florida

Amy Bumbaco is a PhD candidate in the Materials Science and Engineering Department at University of Florida, USA. She is working on engineering education research as her focus. Her current research interests include first year engineering education, critical thinking, qualitative methodologies, and peer review. She received her BS in Materials Science and Engineering at Virginia Tech. She founded an ASEE student chapter at University of Florida and is currently an officer of the chapter and continues sharing engineering education research with fellow members.

Dr. Elliot P. Douglas, University of Florida

Elliot P. Douglas is Associate Professor of Materials Science and Engineering, Dean's Fellow for Engineering Education, and Distinguished Teaching Scholar at the University of Florida. His research interests are in the areas of active learning pedagogies, problem-solving, critical thinking, diversity in engineering, and qualitative methodologies.

A thematic analysis comparing critical thinking in engineering and humanities undergraduates

Abstract
This paper examines the meaning and enactment of critical thinking for engineering and humanities undergraduate students. We address the following research question: What are the similarities and differences between humanities and engineering students in their perceptions and enactment of critical thinking? Semi-structured interviews were conducted with four to five undergraduate Materials Science & Engineering and English students. Interviews were analyzed using thematic analysis. English and Materials Science & Engineering students differed in the specific way critical thinking was viewed. A major theme that arose for engineering students was that critical thinking was often similar or equivalent to problem solving. However, English students saw critical thinking as a way of forming opinions, forming and defending an argument, and making connections. Common themes for both groups included aspects such as broadening ideas, needing deeper understanding, and needing reflection and metacognition. Both groups utilized the concepts common throughout their major classes as the physical representation of critical thinking. The embodiment of course concepts as critical thinking may be supported by the idea of engineering identity and self-efficacy. Students may choose engineering, and stick to it, because they relate to the concepts and to how engineers think. However, faculty may influence how students in either discipline comprehend the meaning of critical thinking. Thus, critical thinking style may be considered a part of engineering identity or may be influenced by faculty.

Introduction

Critical thinking is considered an important attribute in engineers, and there is a desire to graduate engineers with the ability to think critically.[1,2] However, humanities departments believe that they are a key contributor to fostering creative and critical thinking.[3–5] In *Academically Adrift*, Arum and Roska reveal that neither humanities or engineering programs are fostering critical thinking as they desire, and overall student gains in critical thinking during their undergraduate years are minimal.[6] This leads to the question of what is critical thinking and how can it be fostered within the higher education curriculum.

First, it is important to briefly detail how scholars view and define critical thinking. The definition of critical thinking differs throughout literature.[7–19] One of the commonly used expert definitions was created by a group of scholars, educators, and leading figures in critical thinking using the Delphi method. The consensus from this process defined critical thinking as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based."[9,10] Most definitions of critical thinking are not empirically based, and they are rarely specific to engineering. More recently scholars have developed guides on critical thinking within specific areas, for example Paul and Elder's *Guide to Engineering Reason*.[20] These guides also are founded on scholarly and philosophical definitions that were not based on empirical research. The empirically based critical thinking principles that do exist are founded upon expert and faculty beliefs, rather than student beliefs.[9,21–24]

In order to foster critical thinking in the undergraduate curriculum for humanities and engineering students, it is important to study what critical thinking means to these students and how they perceive their enactment of critical thinking. How can we teach critical thinking without understanding how students see critical thinking in the classroom? It is also valuable to understand the possible differences between critical thinking in these two disciplines. This could allow a foundational understanding of teaching and learning differences and similarities for the two disciplines and open possibilities to further existing pedagogies.

Thus, in this paper we seek to provide an initial exploration of the similarities and differences of what critical thinking is for humanities and engineering students. We address the following research question: What are the similarities and differences between humanities and engineering students in their perceptions and enactment of critical thinking? For the purpose of this paper, the focus will be on one of the major categories discovered between the two groups of students: how students use and perform critical thinking.

Methodology

This study is the pilot phase of a larger project aiming to understand critical thinking for students and faculty in humanities and in engineering. As a pilot, four to five students each from Materials Science & Engineering and English were selected. Selection was based on requesting senior students from both departments to respond to an interest email and/or in-class visit. Semi-structured interviews were conducted with five senior year undergraduate Materials Science & Engineering students and four senior year undergraduate English students. The interviews focused on the perception of students on the meaning of critical thinking and their use of critical thinking. In order to provide a starting point for the discussion, students were asked to bring an assignment that they felt required them to use critical thinking. Interviews followed an interview guide which contained a few broad questions asked within each interview such as "Can you describe the assignment in which you thought critically?"; "What does critical thinking mean to you?"; and "How do you see teachers implementing critical thinking in their classrooms?". The interviewer then asked further, unstructured questions to gain a deeper understanding of concepts introduced by participants' answers to the structured questions.

Interviews were analyzed using interpretivist thematic analysis. Statements in the interview transcriptions were coded with descriptive labels through emergent coding, and these codes were then categorized into themes. Constant comparison, first within each interview and then within each cohort, was used to continually sort the data until a robust set of themes that explained the data was developed for each cohort. Then each cohort's themes were compared in parallel, through the use of tables with sub-themes, to address similarities and differences. Coding and sorting was conducted by the first author. Trustworthiness, as defined by Borrego et al., was assured through conversations among peers, including the two authors and two other researchers not involved in the project.[25] In these conversations, themes, codes, and data were discussed and compared and then suggestions were made for revising the coding scheme and how the themes were organized.

Findings

The thematic analysis presented a comprehensive look at the similarities and differences between these sets of students. This examination revealed the following main categories: how students use and perform critical thinking, resources students use for critical thinking, values and dispositions of students to think critically, influence of background and time on student thinking, and why students use critical thinking. For this paper, we focused on the category of how students use and perform critical thinking.

Shared Meaning of Critical Thinking for Materials Science & Engineering and English Students

Both groups expressed certain traits of critical thinking in similar ways. The following themes were broad representations of specific aspects of the use of critical thinking.

Broadening Ideas

Students believed that thinking more broadly and being more open to ideas demonstrated an ability to use critical thinking. They valued this ability to be flexible in their thinking style, as shown by the following engineering student:

> *You know, you focus on something and then you look back and you go well, you know, what else could I look at? That could be kind of your trial and error process if you want to call it that or even talking to a client and they tell you to do something and then you try doing it, it doesn't work, and they want you to do something totally different. Or it does work but they still want you to do something totally different.*

English students expanded on this idea of broadening views by also allowing ideas to change through interaction with people and materials, as discussed by this English student:

> *Ah, I always think because it's one thing to have an opinion by whichever way you get it but then it's kind of like just a stick to your own opinion. I feel like you don't mature that way. Like you've got to have a way to mingle with other people so you can understand how they feel because the world is so big. Like you have to be able to communicate and be able to take in other people's opinions so that you can be like a mature person.*

Connecting Work

On top of being open to others' ideas, students needed to be able to connect previously learned ideas, life experiences, and concepts heard from others. These tasks included connecting: concepts, personal experiences, aspects of problems, and their own and others' ideas. Students also expressed applying ideas to new contexts. For example, the following engineering student discussed the importance of utilizing concepts in multiple contexts: "It's not some ridiculous mechanism, it's something very basic or simple or something that we've heard somewhere else in some other principal or some other phenomenon. And this same concept with slightly different consequences."

Often English students emphasized making connections, as one student said, "There's still like, yeah, it's still making connections and I think that as, yeah, I think that's all it [critical thinking] is really." This emphasis suggests that making connections represents a core part of their conceptualization. While Materials Science & Engineering students focused on making connections within problems, with others' ideas, and to the real world, English students had a deeper and broader way of making connections. The specific aspects on the idea of making

connections for the English students will be discussed more thoroughly in Relating Critical Thinking to English Course Concepts.

Reflection and Metacognition

Both sets of students also discussed the importance of metacognition and understanding their own thinking. For example, this engineering student discussed asking yourself questions, not just having the teacher ask you, by stating:

> *You're, like it's not so much of a teacher asking you but sometimes it's you yourself asking like okay, well, what did I think about this? Okay, well, how do I think the author was wrong or right? You know, and then as you, you don't even realize like you're developing your understanding of what you read or what you heard.*

Engineering and English students also both mentioned thinking and/or working independently. One of the English students discussed this important trait: "Just like being independent, like being able to think independently is important. Because, um, even though it's important to get the con—like when you are attacking text it's important to try and attack it from every possible aspect." The groups also both commented on the value of being guided and coached into independent thought. As one Materials Science & Engineering student stated: "Exactly, exactly. And so it's important to kind of help them along…if you give them something abstract but they actually kind of work at it and you help them along then that's a gain."

Gaining a Deeper Understanding

Often, students emphasized critical thinking as understanding concepts on a level deeper than just the initial information. This was often expressed as connecting, discussing, or reflecting on ideas. As an English student explained: "In order to even start the first one to raise their hand and start the conversation you have to be thinking deeper than just what did we read last night or like what was the main plot." English students explained thinking deeper in an abstract way as going beyond surface thinking. However, the idea of having a deeper understanding for engineering students focused on truly understanding what they are doing and why something works as it does. For example, "And making sure you understand that [real world context], too, because you know, sometimes I feel like engineers can get so bogged down in the numbers that they don't even realize what they're actually doing."

Differences Between students: Relating Critical Thinking to Course Concepts

Though both sets of students shared these general ideas of critical thinking, there were differences in the finer levels of their expression of critical thinking. The primary ideas of both student groups' definitions focused on course concepts particular to each respective discipline.

Relating Critical Thinking to Engineering Course Concepts

The findings discussed in this section on relating Critical Thinking to Engineering Course Concepts are based on previously discovered findings that were originally presented by the authors at a prior conference and are reviewed here for comparison to the English student findings.[26] Engineering students related critical thinking to engineering concepts they deal with in the classroom. These engineering course concepts included: applying a framework/plan; weighing, selecting, and testing options (in materials science this is known as selection and

design); using background knowledge; and using problem solving. For instance, one student explained the critical thinking process in a design course as:

> *There's a coach but no one tells you what to do or how to solve the problem. You're expected to understand the problem, come up with possible solutions, select those solutions, or select the best couple solutions, test them and you know, at the end of the year design the products.*

Every Materials Science & Engineering student directly mentioned needing and applying knowledge or background information. For example:

> *I guess you know, one of the interesting things about just materials classes in general is that again a lot of this, sometimes the assignments we get are more kind of out of the box thinking or critical thinking studies that you apply what you do know to some physical phenomena that no one has really come up with an answer to but like based on the knowledge that you have why do you think this occurs.*

These course concepts highlight that to these students critical thinking was similar or equivalent to problem solving. Though students believed in many different styles of problems and answers, including a right answer and an opened-ended problem with many or no answers, problem solving in general was unanimously mentioned. As one student explained, "Well, I thought about it and my, the thing that it really means to me is like problem solving and a method to problem solving." Problem solving included five sub-concepts: figuring out what the problem is, figuring out why something is happening, solving in an orderly way, applying to a real world context, and reaching a conclusion/solution. Students found defining the problem as the first step:

> *I think it requires a broader scope. Where you basically have to decide more things ah, for yourself and prioritize, what is important to, like if it's open-ended you kind of have to define the problem in the first place as well.*

Many students mentioned the importance figuring out why something occurred as part of the problem solving process. For example:

> *I like to think of the bigger picture because at least in my, what I'm going to be doing, I won't be doing that much science but a lot more engineering which is um, you know, more of a critical thinking than it is of like the actual science behind. It's, it's what is happening or how is it happening rather than why is it happening.*

Students' felt the final step to critical thinking involved reaching a conclusion or solution. As one student stated, "Well, I would define critical thinking as the employment of reason in order to reach a conclusion especially in regards to problem solving."

<u>Relating Critical Thinking to English Course Concepts</u>

English students' core definition was broader than the engineering students. For many of these English students, critical thinking was necessary in their major. As one student expressed, "English, it's like one of those subjects and like topics where there's not ever really a wrong answer as long as you could think critically about what you're reading and support it." Due to the nature of how English is for the students, they used the term critical thinking less than the engineering students, and usually just described their classes, discussion, and writing to define critical thinking.

These students also related the main ideas of critical thinking as concepts frequently discussed or emphasized in the classroom environment. The main concepts English students related to thinking critically included: developing opinions, finding and understanding themes, forming an argument and supporting with evidence, and making connections. For example,

> *That's what [English] is. It's, it's you're given a text and it's the, it's the art of analyzing text but it's also the art of analyzing the text and then having your own opinion on that. So it's as much enjoying the books and writing about them as it is arguing your own standpoint or arguing a standpoint. It doesn't even have to be what you believe in if you think you can find enough evidence…*

All the English students mentioned making specific types of connections including connecting: text/themes to contexts, contexts to contexts, past to present, text to own ideas, ideas to background knowledge, ideas to larger themes, ideas to their own past and current life and others', texts and books to one another, and others' ideas to their own ideas. For example, this student discussed using critical thinking as follows:

> *I guess critical thinking is taking a subject and then writing what you know about it and then taking a step past that of really connecting that to the larger themes of not only what this class is for because I think it's important that even though I wrote this paper for a children's literature class I wasn't just looking at the lens of children's literature, I was looking at, you know, maybe even discussing this to someone who knows nothing about literature and analyzing.*

Some students also stated directly that English was highly focused on making opinions, "Well, yeah, I'd say most English major, it's not, it's getting a major in English as much as it's getting a major in having an opinion." Students talked about not only forming opinions but supporting them and forming an argument. For instance:

> *Well, the author's not here anymore or even if they were you didn't meet them so I could either look at their arguments and look at their, their evidence and their support and I could decide that I agree with them, um, based on their evidence and based on evidence of my own or I could decide that I don't agree with them and due to whatever, as long as I have the evidence to support it.*

Conclusions

Many of the broad embodiments of what critical thinking is remain consistent for both sets of students. These findings also share a connection with common definitions that already exist in critical thinking including the concepts of broadening ideas or finding alternatives[8,10,11,15,21,21,23,27] and using reflection and metacognition.[7,17,27] However, the idea of a deeper understanding is presented differently in literature. Literature discusses having knowledge, clarity, or credibility,[15–17,19,23,28] but does not address the concepts of needing a deeper understanding of the particular issue or knowing what you are doing in a physical and real world way.

As shown by students connecting critical thinking with course concepts, English and Materials Science & Engineering students did differ in the specific way critical thinking occurred. For Materials Science & Engineering students, critical thinking was often similar or equivalent to problem solving, with many of the underlying categories within this theme reflecting steps in the

problem-solving process. The key points Materials Science & Engineering students mentioned mirror those traits defined by scholars as problem solving. For example, Woods describes problem solving to include Engage: I want to and I can, Define-the-stated problem, Explore, Plan, Do it, and Look back.[29] Literature emphasizes a complex relationship between problem solving and critical thinking.[7,19,21] Even so many components of the Materials Science & Engineering students' expressions are similar to those within critical thinking literature including: identifying problems, comparing ideas, evaluating, discovering alternatives, drawing a conclusion, supporting with relevant and adequate evidence, and involving content knowledge.[9,10,15–17,19,21,23,27]

The main components of the English students' definitions also relate to ideas commonly present in literature for critical thinking including connecting ideas[15,17,19,23] and forming an argument and supporting with evidence.[8–10,15,17,19,21,27] These emphasized areas relate closely to how Literacy is often defined for the English discipline. One scholar describes English students as needing the abilities of textual analysis, interpretation, and appraisal.[30] The concept of analysis deals with the rules of composition and applying analytical concepts to the rules. The idea of interpretation includes understanding the text's meaning based on the knowledge from the analysis as well as from the interplay of socio-historical circumstances.[30] The idea of interpretation for the broader discipline of humanities "entails inquiring, evaluating, judging, finding, and articulating meaning" and is a key point shared amongst its sub-disciplines.[31] Both textual analysis and interpretation parallel the students' discussion of connecting ideas, especially among texts, and supporting arguments with evidence. Relating specifically to arguing ideas, the literature also expresses that students need to be able communicate persuasively in English.[30]

Though the components of critical thinking for both disciplines relate to concepts of critical thinking in literature, a difference persists between what is expressed by the two groups. Another aspect that may explain these findings is the social concept of identity. Academic identity, or student identity, may be influenced through the interplay of the individual, discipline, profession, and institution.[35] As one form of these interactions, the faculty-student encounter is believed to influence student development. For students of any discipline, faculty interaction and being taught by student-oriented faculty influence students' affective, personal, and cognitive development.[36,37] There is also evidence showing that student-faculty interaction has a positive influence on the likelihood of students choosing academic and scientific research careers,[38] and that informal interaction affects the development of problem-solving skills.[39] Faculty may also influence student gains in general education when emphasizing higher-order activities.[40] The principle of faculty affecting problem solving and cognitive development may mean faculty influence critical thinking specifically. However, counter to this principle, one study found lecturers in humanities conceptualized critical reading very differently from their students.[41] Therefore, this leads to an area for further study within both disciplines.

A specific concept of identity that is important in engineering is that of engineering identity. One study found that students defined engineering as improving or helping the world, using math, science, and/or technology, solving problems, and applying knowledge.[32] The last three of these were also mentioned as critical thinking by students within our study. The engineer often has a technical world identity to connect to, and those ideas may influence how these students define critical thinking.[33] Students who persist in engineering tend to understand what engineering is,

are intrinsically motivated towards engineering, and feel like they belonged.[34] These ideas may reflect why the senior undergraduate students, those who persisted, may be so inclined to define critical thinking as professors and professionals do. They identify with the already set ideals of engineering and engineering thought.

Another possible influencing principle is that of self-efficacy for engineering students. If students believe they can perform and think like an engineer, they can persist and succeed in engineering.[42,43] Understanding and learning, having problem solving abilities, and interest and satisfaction in what they are doing impacts students' connection with engineering, usually positively.[44] These three self-efficacy factors in particular could help explain the connections that Materials Science & Engineering students make to the class concepts based on whether or not these concepts are something they enjoy, understand, and are interested in.

The impact of identity, faculty influence, and self-efficacy on the students raises the question of where their approach to critical thinking derives from: Are students' critical thinking ideas being shaped by their experiences in college and what critical thinking means to their professors? Or do students tend towards disciplines with a thinking style that they share an identity with already? It is possible that students who entered engineering and stayed already thought as engineers 'should' and felt like they belonged. This also could be true of English students thinking as one 'should' for the area of literacy leading them to English or they may have stayed because they connected with the principles of literacy. The students may have shared a common view on what thinking is already before entering their discipline. However, there is still a potential that critical thinking is not just based on identity but deeper principles, existing definitions, and personal tastes.

Future work will attempt to answer some of these questions. It will expand upon this study to include a four way comparison of thematic analysis between critical thinking in engineering and humanities for both students and faculty. This future work may help to understand the relationship of faculty members' meaning of critical thinking and students' views. This pilot study was limited to two disciplines; however, the future work will include surveying students in other disciplines.

Acknowledgements
Funding was provided by NSF Grant EEC-1159016 and the Materials Science & Engineering Department at the University of Florida. We also acknowledge QuaLab Research Group Members for their support.

Bibliography

1. ABET. ABET - Criteria for Accrediting Engineering Programs, 2013 - 2014. at <http://www.abet.org/DisplayTemplates/DocsHandbook.aspx?id=3149>
2. National Academy of Engineering. *The engineer of 2020: visions of engineering in the new century*. (National Academies Press, 2004).
3. How Humanities Changed My Life. at <https://revelle.ucsd.edu/academics/hum-life.html>
4. Why do the humanities matter? | Stanford Humanities. at <http://shc.stanford.edu/why-do-humanities-matter>
5. Critical Thinking and the Humanities. at <http://public.wsu.edu/~gened/orpheus/critical_thinking.html>

6. Arum, R. & Roksa, J. *Academically Adrift: Limited Learning on College Campuses*. (University of Chicago Press, 2011).
7. French, J. N. & Rhoder, C. *Teaching Thinking Skills: Theory and Practice. New York Garland Pub*. (Inc, 1992).
8. Willingham, D. T. Critical Thinking: Why Is It So Hard to Teach? *Arts Educ. Policy Rev.* **109,** 21–32 (2008).
9. Facione, P. A. *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction. Research Findings and Recommendations.* (1990).
10. Facione, P. A. Critical thinking: What it is and why it counts. *Millbrae CA Calif. Acad. Press Retrieved April* **1,** 2004 (2011).
11. Norris, S. P. Synthesis of research on critical thinking. *Educ. Leadersh.* **42,** 40–45 (1985).
12. Norris, S. P. *The generalizability of critical thinking: Multiple perspectives on an educational ideal*. (Teachers College Press, 1992).
13. Yinger, R. J. Can we really teach them to think? *New Dir. Teach. Learn.* **1980,** 11–31 (1980).
14. Paul, R. W. Critical Thinking: Fundamental to Education for a Free Society. *Educ. Leadersh.* **42,** 4 (1984).
15. Walsh, D. & Paul, R. W. The Goal of Critical Thinking: from Educational Ideal to Educational Reality. (1986).
16. Mason, M. Critical thinking and learning. *Educ. Philos. Theory* **39,** 339–349 (2007).
17. Ennis, R. H. A taxonomy of critical thinking dispositions and abilities. (1987).
18. Watson, G. B. & Glaser, E. M. *Watson-Glaser Critical Thinking Appraisal: Manual*. (Psychological Corporation, 1980).
19. Beyer, B. K. *Practical strategies for the teaching of thinking.* (Allyn and Bacon, 1987).
20. Paul, R., Niewoehner, R. & Elder, L. *The thinker's guide to engineering reasoning*. (Foundation Critical Thinking, 2006).
21. Stein, B., Haynes, A., Redding, M., Ennis, T. & Cecil, M. Assessing critical thinking in STEM and beyond. *Innov. E-Learn. Instr. Technol. Assess. Eng. Educ.* 79–82 (2007).
22. Stein, B. *et al.* Faculty Driven Assessment of Critical Thinking: National Dissemination of the CAT Instrument. *Technol. Dev. Netw. Educ. Autom.* 55–58 (2010).
23. Jegede, O. J. & Noordink, P. The Role of Critical Thinking Skills in Undergraduate Study as Perceived by University Teachers across Academic Disciplines. (1993).
24. Ahern, A., O'Connor, T., McRuairc, G., McNamara, M. & O'Donnell, D. Critical thinking in the university curriculum – the impact on engineering education. *Eur. J. Eng. Educ.* **37,** 125–132 (2012).
25. Borrego, M., Douglas, E. P. & Amelink, C. T. Quantitative, qualitative, and mixed research methods in engineering education. *J. Eng. Educ.* **98,** 53–66 (2009).
26. Bumbaco, A. E. & Douglas, E. P. in *A thematic analysis on critical thinking in engineering undergraduates.*
27. Mayhew, L. & Dressel, P. *General Education Explorations of Evaluation*. (American Council On Education, 1954).
28. Ennis, R. H., Millman, J. & Tomko, T. N. *Cornell Critical Thinking Tests Level X & Level Z: Manual*. (Midwest Publications Pacific Grove, Ca., 1985).
29. Woods, D. R. An Evidence-Based Strategy for Problem Solving. *J. Eng. Educ.* **89,** 443–459 (2000).
30. Chambers, E. & Gregory, M. *Teaching and Learning English Literature*. (SAGE, 2006).
31. Helm, T. E. What Are You Assessing? General Education and the Humanities Curriculum. *Coll. Teach.* **48,** 90–94 (2000).
32. Mena, I., Zappe, S. & Litzinger, T. Examining the Experiences and Perceptions of First-Year Engineering Students. in *Proceedings of the 2013 American Society for Engineering Education* (2013). at <file:///D:/Users/Amy/Downloads/Examining%20the%20Experiences%20and%20Perceptions%20of%20First-Year%20Engineering%20Students-Mena.pdf>
33. Korte, R. in *Philosophy and Engineering: Reflections on Practice, Principles and Process* (eds. Michelfelder, D. P., McCarthy, N. & Goldberg, D. E.) 39–50 (Springer Netherlands, 2013). at <http://link.springer.com/chapter/10.1007/978-94-007-7762-0_4>
34. Pierrakos, O., Beam, T. K., Constantz, J., Johri, A. & Anderson, R. On the development of a professional identity: engineering persisters vs engineering switchers. in *39th IEEE Frontiers in Education Conference, 2009. FIE '09* 1–6 (2009). doi:10.1109/FIE.2009.5350571
35. Välimaa, J. Culture and identity in higher education research. *High. Educ.* **36,** 119–138 (1998).
36. Astin, A. W. *What matters in college*. (San Francisco: Jossey-Bass, 1993).
37. Hu, S. & Kuh, G. D. The Effects of Student-Faculty Interaction In the 1990s. *Rev. High. Educ.* **24,** 309–332 (2001).
38. Pascarella, E. T. & Terenzini, P. T. *How College Affects Students: A Third Decade of Research*. (Wiley, 2005).

39. Endo, J. J. & Harpel, R. L. The effect of student-faculty interaction on students' educational outcomes. *Res. High. Educ.* **16,** 115–138 (1982).
40. Umbach, P. D. & Wawrzynski, M. R. Faculty do matter: The role of college faculty in student learning and engagement. *Res. High. Educ.* **46,** 153–184 (2005).
41. Weller, S. Comparing Lecturer and Student Accounts of Reading in the Humanities. *Arts Humanit. High. Educ.* **9,** 87–106 (2010).
42. Lent, R. W., Brown, S. D. & Larkin, K. C. Relation of self-efficacy expectations to academic achievement and persistence. *J. Couns. Psychol.* **31,** 356 (1984).
43. Lent, R. W., Brown, S. D. & Larkin, K. C. Self-efficacy in the prediction of academic performance and perceived career options. *J. Couns. Psychol.* **33,** 265 (1986).
44. Hutchison, M. A., Follman, D. K., Sumpter, M. & Bodner, G. M. Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students. *J. Eng. Educ.* **95,** 39–47 (2006).