2015

Influence of Collaborative Learning on Women's Experiences of Engineering Education

Shannon Chance
Technological University Dublin, shannon.chance@tudublin.ie

Brian Bowe
Technological University Dublin, Brian.Bowe@TUDublin.ie

Influence of Collaborative Learning on Women's Experiences of Engineering Education

Shannon M. Chance
CREATE, Dublin Institute of Technology, Dublin, Ireland
shannon.chance@dit.ie

Brian Bowe
CREATE, Dublin Institute of Technology, Dublin, Ireland
brian.bowe@dit.ie

***Abstract**: In a study of 55 electrical engineering students, Yadav, et al., found learning gains among students in Project-Based Learning (PBL) to be twice the gains of those taking traditional lecture courses. Du and Kolmos indicate group-based PBL is more supportive and appealing to women than traditional lecture formats. Savin-Baden posits that female and minority students are more likely to ask questions in non-competitive PBL environments. This study interrogates the claim that PBL is particularly supportive to female and minority students. This work-in-progress uses a phenomenological research methodology to investigate how collaborative learning (in formal as well as non-formal settings) influences women's experiences of engineering education. Our intention is to help teachers and educational leaders create environments and policies that effectively support women and diverse groups of students.*

Introduction

Problem-Based and Project-Based Learning (PBL) is believed to increase student engagement and improve learning outcomes in engineering (Marra, Rodgers, Shen, & Bogue, 2012; Kokkelenberg & Sinha, 2010). In fact, by studying learning gains among 55 electrical engineering students, Yadav, Subedi, Lundeberg, and Bunting (2011) found those who experienced PBL had twice the gains of students in the control groups, who encountered the traditional lecture format. Proponents of experiential learning assert that female and minority students are more likely to ask questions in non-competitive PBL environments (Savin-Baden, 2004a, 2004,b). They describe group-based PBL as more inclusive, supportive, and appealing to women than traditional lecture/lab formats.

If such pedagogies do indeed hold appeal for women (as identified by Du & Kolmos, 2007, 2009), they may help educators address some of the reasons women cite for avoiding science, technology, engineering, and mathematics (STEM) subjects (Marra, *et al*., 2012; Kokkelenberg & Sinha, 2010). Some authors suggest that women avoid technical subjects that they see as overly theoretical, non-experiential, or lacking hands-on activity (Kelly, 2007; Richter & Grottke, 2007). Engineering curricula that integrate PBL may hold greater appeal for such women.

Although Yadav *et al*. (2011) provided straightforward evidence to support the claim that PBL promotes learning, there is a need for more direct evidence to back the claims that PBL is particularly supportive to female and minority students. This paper reports a research project, currently underway, that investigates the experiences of female engineering students who are engaged in collaborative learning formats in three different countries. The study uses phenomenological approaches to uncover issues of highest concern to these women.

Our aim is to identify ways to improve the learning environment/culture in engineering. We will develop recommendations for others (and ourselves) to use in planning and conducting groups-based learning activities. In the verbal presentation of our work-in-progress, we will report preliminary findings from the interviews conducted during the 2014-15 academic year with 45 women (11 Irish, 12 Polish, 9 Portuguese, and 13 foreign to their country of study).

Context

This study draws from, and contributes to, four main bodies of literature: (1) student development theory, (2) gender diversity in engineering education, (3) collaborative learning in engineering, and (4) phenomenology in engineering education research. We intend this work to help teachers and administrators develop policies and create learning environments that support women, and demographically diverse groups of students, in increasingly effective ways.

Student Development Theory

Scholars of 'student development' provide evidence to support the claim that women and minority students find experiential-learning environments to be more supportive than traditional lecture formats. Their prior research has documented tendencies that are more common to women than men, such as the desire to learn in interpersonal, inter-individual, and connected ways (Baxter Magolda, 1992; Belenkey, Clinchy, Goldberger, & Tarule, 1986). Respectively, at the same stages of cognitive and epistemological development, men tend to value impersonal, individual, and separate ways of learning and knowing (Love & Guthrie, 1999). The aim of student development theorists is to help students—female and male—develop ways of thinking that is epistemologically sophisticated. This type of thinking has been described as "contextual" (Baxter Magolda, 1992), "constructed" (Belenkey, Clinchy, Goldberger, & Tarule, 1986), "reflective" (King & Kitchener, 1994), "cross-categorical" and "trans-systems" (Kegan, 2009). Regardless of the name, all of these require synthesis and metacognition. They are all "generative" ways of knowing and learning (Love & Guthrie, 1999) that require students to take a leap of faith (Parks, 2000) and give up both 'black and white' thinking and radical subjectivism—which are common among students at the second, and even third level, of education.

Gender Diversity in Engineering Education

Much traditional pedagogy and many seminal research studies were normed to white males (Kohlberg & Hersh, 1977; Perry, 1970). Conducting research about how women learn engineering is important—particularly because science and engineering fields cannot seem to attract enough female students. Engineering programs need to retain the women they do attract, by keeping them fully engaged and professionally fulfilled. Educators need to create a culture for learning and working in engineering that appeals to more people.

There is also a need for sound research on the topic. Beddoes and Borrego (2011) comprehensively analysed the literature on gender in engineering education, and identified a need for methodological and philosophical rigor. In analysing three major engineering education journals over a 14-year period (1995-2008), they were able to locate just 88 articles on gender in engineering education (57 authored in North America and 25 in Europe). They found that up through 2008, gender was a marginalized issue in engineering education. They noted that 22% of all gender-related articles appeared in special focus issues, not mainstream publications. Beddoes and Borrego emphasized among the articles that did get published, few used *any* form of theoretical framework. They asserted, overall, "engineering education scholarship is still characterized by a lack of explicit and consistent theoretical engagement" (p. 283). We seek to help overcome this historic deficit.

Collaborative Learning in Engineering

In a study by Stump, Hilpert, Husman, Chung, and Kim (2011), women reported greater use of collaboration than men. Use of such strategies was positively associated with course grade and feelings of self-efficacy related to learning course content. At Denmark's Aalborg University, collaboration underpins all curricula. Engineering students there cited PBL pedagogies and regional access/location as what drew them to the program (Du & Kolmos, 2007). Surveys conducted at Aalborg by Du and Kolmos (2007, 2009) found that while both genders benefitted from PBL, the collaborative hands-on format was more of a consideration for women than for men in selecting this university. Overall, students identified the most

important things they learned as being: technical knowledge, skills related to planning/ management/organization, and teamwork/collaboration. They described peer learning as the primary distinction between PBL and traditional formats. Overall, women were "more positive towards project and team work than men, and those women prefer to have more time for project work and more dialogue with project supervisors" (p. 433). Students indicated that, through group work, they developed better ways to collaborate and that they frequently received support from peers. Students described group work as a means "to keep women who had a strong wish to study engineering from dropping out" (p. 433).

There is a widespread perception in education that peer learning holds strong students back (Beichner, *et al*., 2007). New research indicates this isn't the case. Among those working in teams, individuals from the top of the class—who often provide the most instruction to others—actually achieve the highest learning gains when placed in small groups of mixed ability. Such gains have been measured in many different institutions at the undergraduate (Beichner; Topping, 2005) and post-graduate (Lin & Hsu, 2012) levels.

Phenomenology in Engineering Education Research

As a research methodology, phenomenology has been used successfully in other studies related to engineering education. In keeping with this particular study, Charity-Leeke (2012) used phenomenology to study 'sociocultural contextual meaning' related to gender roles in engineering. Lin and Hsu (2012) published a phenomenological study of 12 doctoral students in science and engineering who experienced collaborative learning as peer mentors. Their "findings suggest doctoral peer mentors served instrumental, psychosocial, buffering, and liaison roles; they passed on their social, professional, and academic knowledge to their mentees and tried to assist them in adapting to the culture of the lab and academia" (p. 563).

In engineering, phenomenology has also been used to investigate students' learning strategies (Lawanto & Santoso, 2013), feelings of dissatisfaction during graduate school (Lin, 2012), use of textbooks during problem-solving activities (Lee, *et al*., 2013), and experiences of working as a designer in various fields (Eckert, *et al*., 2010). Phenomenologists have studied students' experiences in acquiring "the discourse of engineering" (van Heerden, 2001, p. i) and finishing degrees and entering the engineering profession (Feutz & Zinser, 2012). Phenomenologists have studied how first-generation college students found their way into engineering (Trenor, 2009) and teachers' experiences using tablet PCs to teaching engineering (Kyu Yon, 2011). With this nascent yet strong foundation, phenomenology provides an ideal framework for exploring how collaborative learning influences women's experiences of engineering education.

Theoretical Framework and Research Questions

The term 'phenomenology' refers to both a philosophy and a research methodology (Aleksander, 2010). Creswell (2014) identified it as one of five distinct strategies for conducting qualitative research (along with ethnography, narrative research, grounded theory, and case study approaches). As a research methodology, phenomenology involves the study of consciousness and of how people perceive specific phenomena. Using phenomenology, a researcher team does not aim to test a specific hypothesis, because the findings must emerge from the data rather than from an existing theory or any other pre-determined idea of what might be found. Although the researcher must have familiarity with the literature in order to develop a focus and a plan of study, it is only after generating results and establishing a credible interpretation of data that the researcher can accurately situate the findings within existing literature. This step is, nevertheless, essential because it serves to connect the new work to the larger body of knowledge.

In making our selection of which phenomenological approach to use, we evaluated and considered the descriptive approach developed by Giorgi (2009) and two interpretative

approaches: the highly structured approach created by Moustakas (1994; 2001) and a cyclical approach to hermeneutic interpretation established by Van Manen (1997, 2014).

Giorgi's (2009) psychology-based method aims to develop a rich description of the phenomena as experienced by multiple individuals. It aims to simply describe commonalities among experiences, rather than interpret them. Descriptive phenomenology is thus appropriate for answering some—but not all—of our research questions. Specific questions we have that can be answered using descriptive phenomenology include:

- *What is it like to experience engineering education as a young woman?*
- *What is it like to experience group-based learning as a woman in engineering?*
- *Does formal and informal collaboration help women stay in engineering?*
- *How and when do women develop the sense that they belong in engineering?*

Due to the high number of research questions and the inherent complexity of our topic, Giorgi's (2009) method proved inadequate. Giorgi's example phenomenon—the experience of jealousy—was complex, yet the interviews he analysed were much shorter and more clearly contained. We had much more data to interpret. Moreover, a number of our research questions seemed to require inference. These questions ultimately prompted us to use interpretive phenomenology:

- *Is Problem-Based Learning as supportive and inclusive as the literature suggests?*
- *Are there aspects of formalized team projects deter woman from persisting?*
- *How can engineering educators create more supportive learning situations for women?*

As a result, we carefully considered two interpretive methodologies that could be used to decipher broad phenomena. Both of these phenomenological methods have been described as 'hermeneutic' because they involve making interpretations of narrative descriptions. The first of these, developed by Moustakas (1994, 2001), offers a systematic approach to reorganizing and coding data (Creswell, 2007). The second involves using 'hermeneutic circles' or cycles to code data. It was developed by Van Manen (1997, 2014) and described with helpful clarity by Chari (2014). For this study, we will employ Van Manen's approach.

Methodology

The project itself involves interviewing approximately 45 female engineering students from technical institutes: 23 first-year students studying engineering and applied physics in Ireland, 10 undergraduate students studying engineering technologies in Portugal, and 12 undergraduate and post-graduate students studying engineering and applied physics in Poland. Of these 45 students, 13 are non-native in their place of study. As such, our sample contains demographically diverse women and includes people who are of ethic majority and ethic minority status in their place of study.

Each interview begins with an open-ended question to allow the participant to raise the topics of greatest concern to her. We typically start with questions like: *How are you enjoying being here at this college? Are you settling in all right? How are you getting on with your classmates?*

In most cases, the interviewee herself raises topics related to the research questions. Although we bring a list of specific questions into the interview, we typically only need to ask a few of the pre-planned questions (since most have emerged naturally by the end of the hour). In the unusual case that an interviewee is very brief in her responses, the interviewer draws from the list of questions and follow-up probes.

By the end of the interview, we begin to introduce more specific topics if they haven't appeared. If, for instance, the student has not yet mentioned much to do with feelings of belonging—which studies have shown to be important in retaining women (Gill, Mills, Franzway, & Sharp, 2008; Marra, *et al*., 2012)—the interviewer may ask: *Can you tell me about a time when you felt like you really belonged here, in engineering? When you felt like*

you were already an engineer? And alternatively: *Was there a time when you felt like you might not belong?* Or, if she had considered leaving engineering: *Can you tell me about what was causing you stress at that time?*

We are establishing a case file for each participant that includes a fully transcribed interview. Our method of analysis will follow these steps:

1. Personally transcribe each interview that was conducted in English to become more acutely aware of nuances.
2. Select one single interview transcription to study at a time and read it in its entirety several times before proceeding.
3. Close the transcription and describe, in detail, how that person experienced engineering. Tell the story in first person (i.e., from her perspective).
4. Recount the overall experience and its various facets with as much detail as possible. Do not try to relate it to other transcripts yet.
5. At the end of this new narrative, make a list of themes related to the specific interviewee's experience.
6. Complete steps 1 to 6 for each interviewee.
7. Review the entire set of interpretive summaries and search for common themes.
8. Start grouping these themes into sub-sets.
9. Review each original transcript again, one by one, with regard to the proposed themes. Consider if the themes hold true for the individual interviewee. Ask if there is more in the interview that should be elaborated upon. In the process, identify quotes in the original transcript to use in reporting.
10. Proceed to write results, formulating findings and considering implications.

Emerging Findings

A large-scale qualitative study of this kind requires a great deal of time and energy, but the benefits of in-depth research and cross-cultural comparison are high. The following observations, noted in the process of collecting data but prior to phenomenological analysis, have implications for practice and future research. First, there is clearly a need to locate and interview women who considered joining engineering but ultimately chose a different field for study. Doing so will prove difficult, however, because even getting students who selected engineering to provide interviews was a time-consuming challenge.

Recruitment Issues

In Ireland, we were able to gather a highly representative sample that reflects comprehensive coverage of one, very specific, target population. Here, we managed to interview 20 of the 24 women who started the four-year Bachelor of Engineering degree program in the fall of 2014 (in addition to one girl who returned after considering a new major, and two students of applied physics). Three girls declined our requests for interviews, and one had left the program mid-year. The primary researcher served as an observer in the students' design projects module for the year in order to build rapport. Interviews spanned the school year.

Interviews in Poland were completed in one week. There, female students were eager to participate. They were much more diverse in age and experience than the Irish and Portuguese participants. Those who responded to our invitations (emailed to them by a Polish association for women in STEM) were those able and willing to communicate in English and enthusiastic enough to go out of their way to speak with us. They do not, therefore, necessarily represent the population of women at their institution or elsewhere.

Girls at the selected technical institute in Portugal were reticent. The lack of a language shared by participants and researchers prove difficult. Their participation was solicited in class, by their teachers, for interviews to be conducted either in English or by teachers from their programme. Initially, only a few agreed to participate. We broadened the parameters, and over the course of ten weeks, their language teacher was able to recruit and interview 11

participants. The lead researcher was not present for most interviews and only one interview has been translated to date. This means there is low familiarity and immediacy with this data.

Commonalities Regarding Collaboration

All English-speaking participants described learning collaboratively in informal settings and all had worked in pairs or small teams for lab assignments. All participants in Ireland had experience of formalized group learning with teacher-selected as well as self-selected teams. Only a few Polish women had taken courses that required formalized group work (other than standard labs where equipment is shared for the sake of cost and efficiency).

The lead researcher observed several commonalities among the Irish- and Polish-born girls who were studying engineering in their native land. Cultural natives consistently expressed high satisfaction and comfort in working with boys while learning engineering. Many appreciated having fewer worries about dress, physical appearance, and social drama than they encountered when working with girls. This was true even for those Irish girls who had attended girls-only schools. In contrast, some foreign-born girls (from both co-ed and single-sex schools) experienced discomfort in working with boys who ignored their ideas, didn't leave adequate time, or failed to contribute. Native students also encountered such issues, but it appeared to bother them less.

One clear commonality among all participants has been the central role of the Internet in their studies. Many women used search engines and YouTube to solve tough problems, and Facebook provided almost all participants with a ready source of connection to their peers. They communicate using Facebook groups (or WhatsApp) to master concepts, organize study meetings and social events, and help solve homework problems—often posting photos of handwritten equations and notes. Most students also have a few peers they can rely on to answer questions and provide advice, typically via text, when they get stuck while studying at home. Most also have a group they like to study with prior to a test or exam.

Observations from Ireland

More than half of the girls in the Irish sample were born in the Middle East, Asia, or America. The primary and secondary schools they attended (in Ireland and Middle East) were often single-sex/non-co-ed. In fact, most girls in the Irish institution had to take a stand somewhere along the way—to gain access to high-level maths and physics in high school and/or to travel abroad to study. This begs the question: *What about all the others who faced resistance and didn't take a stand or didn't succeed with their pleas for adequate preparatory classes?*

Overall, language was more problematic than gender for the girls studying in Ireland. Girls who had made it into this program had already overcome many barriers; they described being diligent in their studies, which sometimes created difficulties when working in groups with less-dedicated students. Experiences working in groups or pairs varied. Problems were most pronounced when another teammate (a) didn't seem to care, (b) decided to let the girl/interviewee do most of the work, (c) waited until the last minute to contribute and then required a high-level of hand-holding in order to complete required tasks, or (d) altogether ignored the ideas and contributions of the girl. As a result of these interviews, we realized that composition of each group is important (and we developed methods for creating teams). Through this study, we also realized foreign students could benefit from targeted support and we are currently developing recommendations for their teachers. For instance, women described a strong sense of support from program coordinators but frustration with some forms of instruction (via lecturing) and tutoring (when assistance was lacking in labs).

Girls in the Irish study appreciated gaining exposure to multiple fields prior to selecting a specific major. Most appreciated working groups on the design projects, which were offered for the first time this year as part of the new common first-year engineering programme.

Observations from Poland

By conducting Polish interviews in rapid succession and comparing them with Irish interviews, some interesting observations about Polish education appear. For instance, the primary and secondary schools attended by Polish women were co-ed, with physics included in the curriculum starting in middle school. This facilitated a natural transition into maths and physics-based high schools. In both Poland and Ireland, many interviewees had accepted leadership and project management roles and/or organized their own study groups. By the second or third year of engineering study, many of the Polish women perceived that their peers saw them as skilled organizers of people and information.

Polish participants expressed high levels of desire to continually learn, challenge, and 'develop' themselves. Most enjoyed working with girls and boys alike and many had emerged as leaders among their peers. Most felt that they were treated differently as a result of being girls—that they were more visible and received more opportunities than their male peers. Most had been part of an awkward exchange with one or two older male teachers who were uncomfortable working with girls, but the women asserted change was underway and individuals with out-dated views would retire. Gender-wise, they had faced much more difficulty during internships, where they felt as capable as their male counterparts but believed they were given less meaningful and less challenging tasks. In such cases, their requests for more technically challenging work were often ignored.

A significant finding that was immediately apparent upon completion of the Polish interviews is the lack of both the concept and practice of mentorship in Poland. The head of the women's organization that solicited participation confirmed this observation and indicated she is working to establish mentoring activities. Conversations with four other educational leaders at the institute further confirmed this is not yet part of the culture in Poland.

Conclusion

The findings described above constitute preliminary observations. We will set them aside as we transcribe and analyse the data. We believe that becoming phenomenologists requires a high level of self-reflection and self-critique. To avoid bias, it is crucial for phenomenological researchers to 'bracket' their assumptions in some way or other. While our research team believes it is impossible to bracket out all prior experience when making interpretations, we agree that one must consciously identify, analyse, and seek to and mitigate assumptions. Thus, prior to coding, the primary researcher is reflectively writing her personal opinions on the topics of: PBL, first year engineering and design education, the specific schools where we conducted interviews, and the context in which the interviews took place. By explicitly stating assumptions, we are trying to avoid the tendency to seek confirmation of our own pre-conceptions. As a phenomenological researcher, one can never assume to easily know what the interviewee is talking about. When that happens, the researcher is likely to start thinking about his/her own experiences and beliefs instead of listening closely to the interviewee.

Acknowledgements

We are indebted to Drs. Bill Williams and Bianka Siwinska for their assistance setting up interviews in Portugal and Poland and to the European Union's FP7 programme for supporting this project with a Marie Skłodowska-Curie International Incoming Fellows grant.

References

Aleksander, I. (2010). The engineering of phenomenological systems. *Philosophy of Engineering: Volume 1 of the proceedings of a series of seminars held at The Royal Academy of Engineering*.

Baxter Magolda, M. B. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development*. San Francisco: Jossey-Bass.

Beddoes, K., & Borrego, M. (2011). Feminist Theory in Three Engineering Education Journals: 1995-2008. *Journal Of Engineering Education*, *100*(2), 281-303.
Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J., Deardorff, D., Allain, R. J., ... & Risley, J. S. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project. *Research-based reform of university physics*, *1*(1), 2-39.
Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice, and mind*. New York: Basic Books.
Chari, D. (2014) What is Nanoscience?' - A Hermeneutic Phenomenological Study of Nanoscience Researchers' Experiences, Doctoral Thesis, Dublin Institute of Technology.
Charity-Leeke, P. (2012). *Women In Engineering: A Phenomenological Analysis of Sociocultural Contextual Meaning of Gender Roles.* (Electronic Thesis or Dissertation). Retrieved from https://etd.ohiolink.edu/
Creswell, J.W. (2007). *Research design: Qualitative, quantitative and mixed methods approaches.* (2nd ed.). Sage.
Creswell, J.W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches.* (4th ed.). Sage.
Du, X., & Kolmos, A. (2007). *Gender Inclusiveness in Engineering Education - Is Problem Based Learning Environment a Recipe?* American Society for Engineering Education.
Du, X., & Kolmos, A. (2009). Increasing the diversity of engineering education – a gender analysis in a PBL context, *European Journal of Engineering Education, 34*:5, 425-437.
Eckert, C. M., Blackwell, A., Bucciarelli, L. L., & Earl, C. F. (2010). Shared conversations across design. *Design Issues, 26*(3), 27-39.
Feutz, M., & Zinser, R. (2012). Following engineering graduates. *Journal of Technology Studies, 38*(1), 12-22.
Gill, J., Mills, J., Franzway, S., & Sharp, R. (2008). 'Oh you must be very clever!'High-achieving women, professional power and the ongoing negotiation of workplace identity. *Gender and Education*, *20*(3), 223-236.
Giorgi, A. (2009). *Descriptive Phenomenological Method in Psychology: A Modified Husserlian Approach*.
Kegan, R. (2009). What "form" transforms. *A constructive-developmental approach to transformative learning. Teoksessa K. Illeris (toim.) Contemporary theories of learning: learning theorists in their own words. Abingdon: Routledge*, 35-54.
Kelly, J. F. (2007). *Lego Mindstorms NTX-G Programming*. Guide. Computer Bookshops.
King, P. M., & Kitchener, K. S. (1994). *Developing Reflective Judgment: Understanding and Promoting Intellectual Growth and Critical Thinking in Adolescents and Adults. Jossey-Bass Higher and Adult Education Series and Jossey-Bass Social and Behavioral Science Series*. Jossey-Bass, 350 Sansome Street, San Francisco, CA 94104-1310.
Kohlberg, L. & Hersh, R.H. (1977). Moral development: A review of theory. *Theory into Practices*, 16, 53-59.
Kokkelenberg, E.C., & Sinha, E. (2010). Who succeeds in STEM studies? An analysis of Binghamton University undergraduate students. *Economics Of Education Review*, *29*(6), 935-946.
Kyu Yon, L. (2011). What does the Tablet PC mean to you? A phenomenological research. Innovations In Education & Teaching International, 48(3), 323-333. doi:10.1080/14703297.2011.593708
Lawanto, O., & Santoso, H. (2013). Self-regulated learning strategies of engineering college students while learning electric circuit concepts with enhanced guided notes. *International Education Studies, 6*(3), 88-104.
Lee, C., McNeill, N., Douglas, E., Koro-Ljungberg, M., & Therriault, D. (2013). Indispensable resource? A phenomenological study of textbook use in engineering problem solving. *Journal of Engineering Education, 102*(2), 269-288.
Lin, Y. (2012). Life experiences of dissatisfied science and engineering graduate students in Taiwan. *College Student Journal, 46*(1), 51-66.
Lin, Y., & Hsu, A. (2012). Peer mentoring among doctoral students of science and engineering in Taiwan. *Asian Pacific Education Review, 13*(4), 563-572.

Love, P. G., & Guthrie, V. L. (Winter 1999). *New direction for student services*. (88). San Francisco: Jossey-Bass.
Marra, R.M., Rodgers, K.A., Shen, D., & Bogue, B. (2012). Leaving engineering: A multi-year single institution study. *Journal of Engineering Education*, *101*(1), 6-27.
Moustakas, C. (1994). Phenomenological research methods. London: Sage Publications.
Moustakas, C. (2001). Heuristic research: Design and methodology. In K. J. Schneider, J. F. T. Bugental, & J. Fraser Pierson (Eds.), *The handbook of humanistic psychology*. London: Sage Publications.
Parks, S. D. (2000). *Big questions, worthy dreams: Mentoring young adults in their search for meaning, purpose, and faith*. San Francisco: Jossey-Bass.
Perry, W. (1970). *Forms of ethical and intellectual development in the college years: A scheme*. (1st ed.). New York: Holt, Rinehart, and Winston.
Richter, T., & Grottke, S. (2007). AC 2007-1733: Learning Abstract Information Theory on Visual Data: An Integrated Course on Wavelet-Based Image Compression.
Savin-Baden, M. (2004a). *Foundations of Problem-based Learning*, Open University Press, Buckingham.
Savin-Baden, M. (2004b). *Challenging Research in Problem-Based Learning*, Open University Press, Buckingham.
Stump, G. S., Hilpert, J. C., Husman, J., Chung, W. T., & Kim, W. (2011). Collaborative learning in engineering students: Gender and achievement. *Journal of Engineering Education*, *100*(3), 475-497.
Topping, K. J. (2005). Trends in peer learning. *Educational psychology*, *25*(6), 631-645.
Trenor, J. M. (2009). A phenomenological inquiry of the major choice processes of an overlooked demographic: First generation college students in engineering. In *Proceedings of the 2009 Research in Engineering Education Symposium*.
van Heerden, K.I. (2001) *A phenomenological investigation into undergraduate students' experience of acquiring the discourse of engineering.* PhD thesis, Rhodes University, South Africa.
Van Manen, M. (1997). *Researching lived experience*, Ontario, Canada: The Althouse Press.
Van Manen, M. (2014). *Phenomenology of practice: Meaning-giving methods in phenomenological research and writing* (Vol. 13). Left Coast Press.
Yadav, A., Subedi, D., Lundeberg, M. A., & Bunting, C. F. (2011). Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course. *Journal of Engineering Education,100*(2), 253-280.