The Contribution of Qualitative Research towards the issues affecting Female Undergraduate Engineering Students

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Abstract This article explores the use of qualitative research methods towards our understanding of the issues affecting female undergraduate engineers. As outlined in this article female engineering students face many challenges during their undergraduate studies. Qualitative research methods provide an opportunity to gain a deeper understanding of the issues affecting female undergraduate engineering students. Qualitative research provides an opportunity to gain rich data that simply would not be possible using quantitative methods. This article critically appraises three qualitative articles discussing the issues affecting the female undergraduate engineer and highlights the contribution that each article makes towards our overall understanding of the undergraduate female engineering experience. This article concludes that qualitative research methods provide invaluable data and has the potential to uncover new phenomenon.

Keywords qualitative research, female, undergraduate, engineering

Introduction

Qualitative research is primarily concerned with understanding phenomena in depth and in its natural environment. Denzin and Lincoln (2005) define qualitative research as 'a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible' (p 3). The very nature of this definition emphasizes the importance of the setting or the context of the phenomenon under investigation. Similarly, Hatch (2002) describes some of the recurring characteristics of qualitative research, particularly the natural environment, prolonged contact, emphasis on meaning, inductive data analysis and emergent design. Erickson (1986) also states that in order for the qualitative researcher to gain an understanding from the participants' perspective in the natural environment, it is imperative that the researcher spends a significant amount of time with these participants in this natural environment in order to fully capture the phenomenon under investigation. Extended engagement on the part of the qualitative researcher is one of the trademarks of high-quality qualitative research (Hatch, 2002).

The purpose of this article is to evaluate three qualitative articles addressing the major issues affecting female undergraduate engineering students. The first article is a dissertation investigating why women enter into undergraduate engineering study and why they persist in engineering academia. The second article is a paper addressing gender biases women may experience during their undergraduate engineering studies, and the third article is also a paper addressing retention factors especially for first year engineering women. Qualitative research is ideal for this type of investigation, as an important objective is to gain an understanding of these issues from a female perspective. Each of these articles was analyzed to determine the purpose of the research, the methodology employed, and the findings of the research. An overview of the philosophical perspectives which underlie qualitative research is provided, followed by a discussion on validity and reliability. An analysis of each of the three articles is provided and is then followed by a discussion on ethical issues. The contribution of qualitative research towards our understanding of the female undergraduate engineering experience in university based on the three articles is provided and finally the conclusion to this investigation is given.

Philosophical Perspectives

Most individuals in the engineering profession are aware of the terms positivism and post positivism, and accept the notion of an absolute truth, (Chism et. al. 2008). Quantitative research is based on positivism. The ontological position of quantitative research is the existence of a single reality, which is highly objective in nature, and a reality that can be studied without any influence of the researcher (Guba and Lincoln, 1994). Epistemologically, Guba and Lincoln (1994) state that the researcher and the researched are independent of each other; 'inquiry takes place as through a one way mirror' (p 110). This allows the researcher to study the phenomenon without placing any undue influence on it. A key characteristic of quantitative research is the use of large sample sizes, this is such that the findings of the research can be generalized to the wider population. Common methods used in quantitative research include the use of surveys, and questionnaires.

In comparison, the qualitative paradigm is a form of inquiry that is based on interpretivism (Chism et. al., 2008) and constructivism (Guba and Lincoln, 1994). Interpretivism emphasizes that the truth is contextual in nature, is dependent on the situation, as well as the individuals being observed and the researcher carrying out the observations, while constructivism examines the meanings which people attach to situations. Crotty (2003) states that constructivism dismisses the concept of human knowledge, and refuses to accept the notion that truth is already in existence in the world and that it is waiting to be discovered. Truth or meaning attached to it is only possible through engagement with the world around us. Meaning therefore is constructed and different people can attach different meanings even to the same phenomenon (Crotty, 2003). The ontological position of qualitative research presumes the existence of multiple realities which are continually changing (Kelle, 2010). It is highly subjective in nature and epistemologically requires close interaction between the researcher and the researched. Qualitative research is characterized by the use of small sample sizes, as the primary motivation is on meaning. Common methods used in qualitative research include interviews, focus groups and participant observation.

The decision as to whether to use qualitative or quantitative methods is largely dependent on the purpose of the research (Creswell, 2002). Quantitative research is ideal for answering questions beginning with how many? or how much? or when trying to determine the existence of a relationship between specific variables. Conversely, qualitative research is ideal for answering questions which begin with how and why (Leech and Onwuegbuzie 2007). According to Castellan (2010) a quantitative investigation is suitable for determining the effectiveness of a cause and effect relationship while a qualitative investigation is suitable when trying to gain insight into a particular situation. Once the decision has been made to conduct qualitative research, the researcher must then decide which approach to use.

Phenomenology, an approach described by Guest et. al. (2013) as 'the study of the conscious experience' (p 10), seeks to uncover the individual's lived experience. Guest et. al. (2013) also suggests that much qualitative research is phenomenological in nature since it attempts to gain an understanding of the lived experience and the meaning that such experiences have for the individual. The researcher must set aside or "bracket" their own preconceptions of what the experience is (Chism et. al., 2008). The very nature of open ended questions and interviews which are commonly used in qualitative enquiry allows the individual freedom to talk about an issue in their own words without placing an undue influence on an answer which is characteristic of fixed response questions common in quantitative enquiry. Adopting a phenomenological approach to research suggests that the researcher must be committed fully as it can be quite demanding. The researcher is essentially documenting the human experience which suggests that they must gather vast amounts of data and catalogue this data in such a manner that trends or themes emerge. A phenomenological approach allows the researcher to examine the individuals lived experience which can then be used to better explain the individuals' reality.

Hermeneutics is not a qualitative approach as is phenomenology, but is rather an approach typically concerned with interpretation and meaning of qualitative data especially the textual data produced for example from a phenomenological approach. The central idea is to recover any trends or patterns which are embedded in the lived experience descriptions. This aids human understanding thereby making sense of the written data. Kinsella (2006) suggests that qualitative enquiry is informed through hermeneutics. Kinsella (2006) also states that hermeneutics seeks to provide understanding and not to offer an explanation.

Weber (2004) mentioned the hermeneutic circle, which basically suggests that interpretation is a continuous cycle of reinterpretation in regard to the text. Schwandt (2000) states that in the hermeneutic circle, in order to understand a certain part of a text, the whole text must be understood, and equally the researcher cannot gain the meaning of the text as a whole without understanding the individual parts. Weber (2004) states that the interpreter has their own pre-conceptions of the phenomenon initially and that this forms the basis for making sense of the phenomenon, however as interpretation proceeds the interpreter must re-evaluate their own pre-conceptions. The hermeneutic circle suggests that there is essentially no one true meaning in relation to the text and new meanings can be discovered which may not have been envisioned originally. This is consistent with the ontological position of qualitative research.

Social constructionism is similar to constructivism, and may be considered as a subset to it. The perspective adopted by social constructionism suggests that meanings are socially constructed rather than individually constructed as is the case in constructivism. Meanings are created in the social context, and through direct interaction with other individuals. Schwandt (2000) suggests that we construct a model to make sense of an experience, but that this model is continually tested and modified in light of a new experience. Language and culture play an important role in the construction of new knowledge (Schwandt, 2000). Social constructionists believe that reality is not known but rather it is negotiated socially, and is dependent on how individuals conjointly elaborate their ideas. In this regard, there is an infinite amount of socially constructed realities. Symbolic interactionism focuses on how meanings are produced by individuals through their interaction with symbols, the most popular symbol being that of language (Berg and Lune, 2012). The focus of symbolic interactionism is on understanding the interactions between the individual and their world, based on meanings that the individual attaches to their world. These meanings are the result of communication between people and can be modified through communication and collaboration (Savin-Baden and Howell-Major, 2013). Meaning in this regard is socially constructed and this coincides with the ontological and epistemological assumptions of the qualitative paradigm, that there is no objective meaning but rather meaning is created through interaction (Joniak, 2005).

Feminist research is research that is conducted by women for women, the aim of which is to study the social conditions of women in a 'sexist' society. Feminist research aims to empower women and provide them with a voice to describe life socially and from their perspective. It also seeks to enlighten the world to the factors that have attributed to the situation under investigation and propose solutions to help alleviate the problem, and ultimately it contributes towards social change (Sarantakos, 2005). Gender is central to social enquiry, and is based on the theoretical proposition that women because of their experiences both personally and socially are much better placed than men to study the world of women. Feminism is based on the realist ontology and a modified objectivist epistemology (Sarantakos, 2005). Feminist research advocates that knowledge is socially constructed, and the information that is generated by the women must be recognized and valued. Feminists believe that there are multiple realities that can be observed and experienced, and feminists must respect the "truth" as provided by the research participants (Rose, 2001).

Action research is a collaborative form of qualitative investigation that provides participants with the means to take action in an effort to solve a particular problem (Berg and Lune, 2012). The primary aim of action research is change and improving professional practices for those affected. Action research has been a common method of research used in an educational setting, the aim of which was to improve class room practices (O'Connor et. al., 2006). Action research requires active engagement of the participants, and also requires the participants to be empowered in order to discuss the issues which affect them. It is a cyclical process involving thinking, acting, gathering data and reflecting. Action research is ideal for researchers who seek to solve real world problems. Researchers adopt this technique when they wish to examine a practical situation, make a change and investigate the consequences of this change (Savin-Baden and Howell-Major, 2013). Action research follows an objectivist ontology and subjective epistemology.

Validity and reliability

Qualitative researchers are concerned with ensuring that the findings of their research are defensible (Weber, 2004), and that the findings are 'true' and certain (Guion, 2002). It must be such that colleagues who examine the evidence collected also agree with the claims made by the researcher. They do not have to necessarily agree with these claims, but they should come to the same conclusion as the researcher who

conducted the research (Weber, 2004). Researcher bias is considered a major threat to validity in qualitative research and therefore it is important that the researcher engages in reflexivity, which means that the researcher must critically self reflect and be self aware about their own predispositions (Johnson, 1997). In order to increase validity, the researcher can use triangulation, which is regarded as the combination of approaches or methods when dealing with a particular research problem. Berg and Lune (2012) describe triangulation as the use of "several lines of sight", implying that each method can produce a different line of sight when dealing with the same phenomenon (p 6). This will lead the researcher to a much deeper understanding, and a more complete picture of the phenomenon under investigation.

Dependability is a term often used to describe reliability in qualitative research (Guba and Lincoln, 1994). The concept of dependability suggests that the exact procedures followed by the researcher should be documented in detail, and it is with such detail that the reader of the research can be assured that the correct research practices have been followed (Shenton, 2004). Bryman (2012) suggests that researchers should implement an "auditing approach" (p. 392). Colleagues or peers would then act as the auditor, the purpose of the auditor would be to determine if the proper procedures were followed. Bryman (2012) does suggest that this can be very demanding for the auditor due to the copious amounts of data which qualitative research tends to generate. Qualitative researchers also believe that their interpretative awareness is an important characteristic of reliable research. Interpretative awareness means that the researcher is aware of the subjectivity that they bring to the research process and that the researcher has taken the necessary steps to address this issue (Weber, 2004).

Article 1: Smith (2012)

Purpose: This thesis investigated the reasons and motivations for women entering undergraduate engineering study and why these women decide to persist in engineering academia. The purpose of this investigation was to determine the possible existence of common themes that may influence women to study engineering. This information provided valuable feedback for management, career teachers at secondary schools, and the colleges and universities directly involved in this study so that they are much better informed as to the reasons why women choose to study engineering and why they decide to persist in engineering academia.

Methodology: The theories on which the conceptual framework for this study were based upon the self-efficacy theory, expectancy-value theory and Gottfredson's theory of circumscription and compromise. This study primarily focused on 17 women enrolled in various engineering courses at 4 different colleges and universities. This research was conducted based on phenomenological perspective and the data collection technique employed was interviews. The interview questions were chosen carefully to fully reflect the conceptual framework which in turn was guided by the literature review. The interviews were designed to last between 45 and 60 minutes, and were carried out at the institution which the female attended. The interviews were conducted with the current cohort of freshman students and junior students. The researcher made clear her own propensity, a female engineer in this case. The interviews were recorded, transcribed, analyzed and coded to ensure no loss of data.

Research findings: Specific themes emerged from this research. The influence of a family member, a friend or a teacher has a major impact on the decision to study engineering. This is consistent with Gottfredson's theory which emphasizes that family members have an influence on career aspirations particularly in young women (Gottfredson, 2002). Females' self-efficacy regarding their mathematics and science ability plays a major role in their decisions to continue with their studies in engineering. This finding is consistent with self-efficacy theory, which states that a persons' belief in their abilities has a major influence on the action that they take and the path that they choose (Betz and Hackett, 1997). Some of the interviewees also reported the prestige of obtaining an engineering degree, and these findings support the expectancy value theory, which states that people are very much goal oriented. Peer support was also deemed instrumental for academic success. This coupled with working collaboratively in teams contributed to the reasons why females decide to persist in engineering academia. Smith also reported that the findings of this research were consistent across all four institutions.

This was an extremely comprehensive piece of literature, well written and presented in a coherent manner. The researcher demonstrated a level of reflexivity however as a female engineer this may be considered a drawback of the research, since this research was conducted from the phenomenological perspective and not the feminist perspective. The researcher may in fact hold baggage which is placing bias within the data. It may have been advantageous for the interviews to be conducted by someone not directly involved in the engineering profession. Also since this research focused only on the current cohort of freshman and junior students, the researcher left out a body of students and by eliminating students in later years of study, the researcher has effectively lost a valuable source of information.

Article 2: McLoughlin (2005)

Purpose: This article introduced the notion of "spotlighting", which is to single out women in such a way as to make them feel uncomfortable. The purpose of this research was to propose a conceptual framework in order to understand the different types of biases that can occur within engineering schools and to suggest changes which would increase the "comfort level" for women in engineering. The theoretical perspective was not stated explicitly but it was also quite apparent that this research was conducted from a feminist perspective with the statement 'It is with the goal of supporting the voices of women undergraduate engineering students that this research is undertaken' (p 374).

Methodology: The data collection technique employed in this research was longitudinal interviews. This investigation was carried out over a two and half year period, a total of 28 undergraduate female engineers were interviewed. 22 of these females were interviewed longitudinally, 9 of which were from a large university, and 13 of the females attended a small private engineering college. Each female was interviewed for approximately 1 hour on three separate occasions. This resulted in 63 longitudinal interviews in total, two students did not complete the interview cycle. On a few occasions, email had to be used to gain access to certain students. The data obtained from the large university and the small private engineering college was compared with data collected from 6 students enrolled in an engineering class at a private women's college. This produced a further 6 interviews, therefore a total of 69 interviews were conducted from three different types of school. Each of these 69 interviews were fully transcribed and excerpts from the interview data were placed into three separate categories: including academics, student life and relationships. Specific phenomenon emerged from this analysis.

Research findings: While type I (overt sexism) which is to single out women with the intention of causing them harm and type II, which is to single out women with absolutely no intention to cause them harm or to help them in any manner were mentioned, this research specifically identified type III spotlighting, which is to single out women in such a way as to help them. It was reported that this can cause anxiety to women. However, McLoughlin reported that spotlighting can be effective provided it is done correctly. McLoughlin discussed how women in engineering programs can have a negative impact on women and in a way contribute towards spotlighting by further emphasizing it. It was stated however, that engineering programmes for women be made available to all students, and be based on academic criteria and not demographic criteria. McLoughlin also stated that it is the responsibility of institutions to expand the opportunities for women in engineering programmes and provide engineering programmes that emphasise the pre-emption of non-professional behaviour.

While this paper was extremely interesting and identified the new phenomenon of type III spotlighting, an obvious limitation of this research was the lack of the transparency between the theory and the method. There was no mention of how the observational data which would have resulted from the interviews was used and if this data complemented or even contradicted the interview data. The fact that a relatively small sample size was used and that this enabled the researcher to conduct a more inductive, in-depth analysis should have made the issue of transparency easier to address.

Article 3: Hornback et. al. (2012)

Purpose: This paper emphasized the fact that many colleges and universities face disturbing trends concerning the retention, underrepresentation and socialization of females in the engineering profession. The primary aim of this investigation was the retention of first year female students enrolled at a large

engineering college. It was stated that only 20% of Bachelor's degrees are earned by females, and that women are often socialized to enter more feminine careers. It was also stated that there has been a major decline in the number of females entering the STEM[1] workplace.

Methodology: Six research questions were proposed in order to investigate the drop in retention of females. The research questions specifically addressed areas such as loss of interest during first year, the presence or absence of the "chilly climate", self-efficacy levels, academic performance, support structures, and the structure of the academic program in promoting career awareness. Focus groups were the principle method involved for data collection. A total of eight hour long focus groups were conducted, with a range of four to ten females participating. All of the participants were first year female engineering students. The focus groups were video recorded and transcribed to ensure no loss of valuable key information.

Research findings: It emerged through this research that the professor plays a major role in engaging females during their first year of study. It was found that professors who were passionate and involved with the class had an extremely positive impact on the female students. In relation to the "chilly climate", it emerged that male peers in the team were the main source and that special attention must be given in order to ensure that women have a positive experience when it comes to working in teams. In relation to the self-efficacy of females, it was found that females reported a high self-efficacy regarding their college work, however self-efficacy decreased significantly when extracurricular activities were considered. It was concluded that a mentoring program would be beneficial in assisting females with balancing outside interests with their college work.

Academic performance was deemed to have a major impact on how women define success, and it was reported that this can place major stress on females, which in turn can have an impact on the retention of these females. It was also reported that women felt that support structures were important, however, many of the women felt uncomfortable due to the gender-specific nature of the support groups which tended to further emphasize women as the minority. Regarding career awareness, females reported the importance of the introduction class and the first year engineering project as particularly beneficial in helping them to understand what they would be doing in their future careers. Guest speakers were also reported as being extremely beneficial in promoting career awareness. It was suggested that more of these types of classes would be beneficial in promoting career awareness which in turn could increase retention.

While the literature review was most interesting, it could be felt that it did not substantially vindicate the research questions proposed in this research. The research questions were clearly derived from the literature review, but there was a clear lack of literature to support these research questions. Also, the lack of ethical considerations may be deemed to have a negative impact on the findings of this research. While focus groups are a great method for eliciting information from a group of individuals, individual interviews could also have been used to further increase the validity of the data gathered. The use of individual interviews may also result in the discovery of new information. Also, since the biographies of the authors were not provided in this research, this may be seen to introduce author bias in terms of the results.

Ethical issues

The primary focus of qualitative research is on exploring people in their natural environment in order to gain an understanding of some phenomenon. Embedded in this is the concept of the relationship and power between the researcher and the participants (Orb et. al., 2000). Punch (1994) states that researchers must be concerned with preventing participants from being harmed, securing informed consent, protecting their privacy and anonymity, and being honest with them.

In consideration of these ethical issues, Smith (2012), stated that the identity of all individuals and the identity of the school or university who participated in the research would be protected, and this was

[1] Science, Technology, Engineering and Mathematics

achieved by using pseudonyms. Mc Laughlin (2005) also guaranteed anonymity of the institutions who participated in the research, by not disclosing their identities. The identity of the participants was also protected in Mc Laughlins' study. Hornback et. al. (2012) did not give any consideration to ethical issues.

Contribution of qualitative research in relation to the undergraduate female engineering experience

The research conducted by Smith (2012) provides insight into the reasons as to why women enter and decide to persist in engineering academia. This information can and should be used by colleges and universities to promote engineering as a career for women. In particular, the notion that parents and teachers play a significant role in determining the path which females take, suggests that colleges and universities must be proactive in engaging with parents and teachers. Based on the authors own experience of parental and educational influences, one was being "socialised" to enter the nursing profession as it was deemed more appropriate for a female and this was primarily due to the lack of information on engineering. Open days and information evenings are a viable method for engaging with parents and teachers and providing information on engineering as a potential career.

Smith (2012) also states that maths and science play a significant role into the reasons as to why women decide to enter the engineering profession. This suggests that greater emphasis should be placed on these subjects, particularly at secondary level education. Maths is a core subject and the Irish Government is proactive in emphasising its importance with the introduction of project maths and the bonus points system (Lubienski, 2011). The use of the bonus points system whereby students are rewarded extra points for undertaking higher level mathematics encourages students and further emphasizes its importance. The Irish Government also established Discover Science & Engineering (DSE) programme to promote a positive attitude towards science and encourages students to study science. It is through positive initiatives like project maths and DSE programmes that can emphasize the importance of mathematics and science. Colleges and universities should engage in such initiatives to promote engineering, this can easily be achieved by engaging in school visits with demonstrations to promote career awareness and can be used to educate students as to the role of the engineer in industry.

Team work and peer support are also reported by Smith (2012) as instrumental in the retention of women in engineering academia. Teamwork is based on the social constructivism principle which contends that knowledge is constructed through social interactions and is a form of collaborative learning. According to Frank et al. (2003), social constructivism permits learners to grasp important concepts 'through their interaction with others and with their world, and through interpretations of that world by actively constructing meaning' (p 274). Incorporating more team based learning activities into the undergraduate engineering curriculum can have a positive impact on engagement and retention particularly for female students. Peer support is important in ensuring the dynamics of team work are successful as well as providing an important support structure for female undergraduates.

Spotlighting articulated by McLoughlin (2005), states that to deliberately target female undergraduates, even if it is done with the best of intentions can have detrimental side effects. Processes which are put in place try and eradicate differences between males and females, tend to exacerbate the problem further. This can be regarded as counterproductive, further reinforcing discrimination, and leads to suggestions that women are in need of help. This can lead to feelings of self doubt which in turn can lead to resentment amongst male students. Colleges and universities have a responsibility to all students and should adopt a no-nonsense policy when it comes to spotlighting and provide programs which are all inclusive and do not seek to highlight any particular group.

Qualitative research has provided valuable information in relation to retention of female engineering students (Hornback et. al. 2012). In relation to career awareness in particular, it was reported that very often students enter engineering academia with very little knowledge as to the role of the engineer, project based learning and the use of guest speakers can have a positive impact in emphasizing the role that the engineer plays in industry. Project based learning is based on constructivism, and supports the idea that learners construct meanings through experience (Frank et. al. 2003) and it can be an extremely effective method for engaging students (Crosling et. al. 2009). Project based learning requires students to work individually and collaboratively on projects and therefore also supports team based learning. Enthusiastic lecturers were also

reported to have a positive impact on female students. Incorporating project based learning and ensuring that enthusiastic lectures are involved particularly in first year undergraduate curriculum can have huge benefits in relation to engagement and retention of females.

Conclusion

The purpose of this research was to critically evaluate three articles discussing the major issues affecting female undergraduate engineering students and to determine the contribution of qualitative research to our understanding of the female undergraduate engineering experience. The three articles outlined in this investigation were ideal for qualitative research as the aim was to elicit rich narrative descriptions from all participants involved. Qualitative methods in each of the three cases were much more appropriate for capturing the voices of the women, and provided a sense of empowerment for the women involved.

The use of qualitative research adopted by both Smith (2012) and Hornback et. al. (2012) allows for a much greater understanding of the major issues regarding the reasons as to why females choose engineering and the retention of females in engineering academia. This information would not have resulted from a quantitative investigation. The results produced by both of these investigations can be used to improve the undergraduate experience for female engineers, provided it is used in the correct manner. The results produced by Smith (2012) were consistent across all four institutions which suggests that these results have some reliability.

The research approach adopted by McLaughlin (2005) allowed for the emergence of a new phenomenon, in this instance Type III spotlighting. This particular phenomenon could is unlikely to have resulted from a quantitative investigation, since a quantitative investigation requires the phenomenon of interest to be specified prior to any form of data collection such that the correct instruments are chosen for the data collection process. Only through examination of the words of the participants and the interpretation of these words through qualitative methods was McLaughlin able to identify type III spotlighting. The results produced by this research provide opportunities for future studies to examine type III spotlighting further.

It must be emphasized that each of the articles analyzed have contributed towards our overall understanding of the major issues affecting female undergraduate engineering students. The use of qualitative research in each of these articles provides important insight into the major issues affecting female engineering students that would not be otherwise identifiable with quantitative research methods. This is one of the major benefits of qualitative research, it allows for a much greater understanding of the phenomenon under investigation and as demonstrated by McLaughlin (2005) can result in the identification of new phenomenon.

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