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An Integrative Literature Review on Gender in Engineering Education

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공학교육에서의 성별에 관한 통합적 문헌 고찰

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ABSTRACT
This paper investigated how three representative domestic and international engineering education journals explored societal supports contributing to retention and persistence in engineering, especially among women. An integrative literature review of engineering education journals was carried out to identify the flow of research and practice of engineering education for females. The findings indicate that retention and persistence of women in engineering is closely relevant to issues of diversity management, collaboration competency, and self-leadership.

Keywords: women, engineering education, diversity management, collaboration competency, self-leadership

I. Introduction

When it comes to the employment in engineering field, gender inequality is a deep-rooted problem. Many people concerned about the possibility that formalized supports for female engineering students would aggravate visible discrimination or cause counter-discrimination. This sort of problem can be resolved by contemplating about fundamental grounds of the controversy. What does it mean to increase the number of female engineers working as regular and managerial employees? If gender-related biases are removed, can human resource development in engineering field upgrade its quantity and quality?

Without rethinking about the above backdrop of controversy, discussing the rationales of gender equity is of no use almost all the time. Therefore, it is necessary to make clear and concrete arguments about how establishing woman-friendly environment is connected to the progress of engineering field.

Previous research presents useful guidelines about this conundrum. While traditional engineering culture is likely to regard a genius as a geek sticking to problem-solving and being uninterested in social agenda, femininity can add humane and socially helpful dimension to the future engineering field (Du & Anette, 2009). In other words, strengthening femininity refers to not only supporting women but paying attention to social influences or implications of engineering. Unlike old common sense, society·culture·economy needs to be integrated with science and engineering in order to raise scientists or engineers to understand social needs and requirements based on convergence. For this reason, seemingly assistive activities such as customer support or marketing are becoming more important to engineers than before. Rather, in today's society, developing these areas usually represented as feminine activities can contribute to maximize the expertise of engineers by cultivating empathy and user-centered reasoning. For this reason, alleviating gender inequity and strengthening

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femininity could result in producing new type of knowledge as well as improving the status of women (Amelink & Meszaros, 2011). Particularly, some engineering fields such as computer, game, chemical, and bio-molecular engineering are urged to take woman-friendly policies due to the increasing number of female students (Gu & Kim, 2014).

Despite the importance of support for female engineering students as mentioned above, main statistical indicators on gender equity in engineering field (ex. employment stability, leadership) show that female status has not been significantly forwarded when compared to the past decade (Amelink & Creamer, 2011). Even though educational and institutional updates or corrections have been added to existing academic and workplace system, it is still less likely that female engineers are able to survive in engineering career as managerial leaders than male engineers do. If so, how can we work out this problem? Throughout literature review, this paper aims to make a roadmap to construct educational system designed for both male and female engineering students, which means searching for ways of peaceful coexistence of men and women in engineering field. At the same time, this paper was written for those who want to know the trend of three representative engineering education journals about gender and diversity during 2005-2016.

II. Purpose Statement

The purpose of this study is to investigate common issues and research gaps associated with women in engineering through integrative literature review. It is believed that "Integrative literature review is a distinctive form of research that generates new knowledge about the topic reviewed" (Torraco, 2005) By researching current knowledge and on the state of women engineering education, this study is designed to explore effective educational supports for female engineering students to boost diversity and equity in engineering education from HRD (Human Resource Development) perspective.

Since this study intends to reflect on the topic of women engineering from HRD perspective, "contextual support" suggested by Raelin et al. (Raelin et al., 2014) was reclassified according to HRD's main domains in which HRD scholars and practitioners traditionally categorized: organization development (OD), training & development (T&D), and career development (CD). The definition of HRD main domains are described below.

Table 1 Definition of HRD domains (Hamlin & Stewart, 2011)

HRD Domains	Definition
Organization Development	The process of implementing organizational change for the purpose of improving organizational effectiveness and performance
Training & Development	The process of developing knowledge, skills, and competencies to improve individual or group effectiveness and performance
Career Development	The process of enhancing human potential and personal growth to improve individual effectiveness and performance

In addition, instead of "demographic characteristics" of the version of Raelin et al. (Raelin et al., 2014), job prospects for female engineering students based on gender-balanced point of view were considered in the conceptual framework of this study because this study was designed to find effective ways to encourage female engineering students to successfully remain in engineering career.

Using the conceptual framework on undergraduate retention by Raelin, Bailey, Hamann, Pendleton, Reisberg, and Whitman (Raelin, Bailey, Hamann, Pendleton, Resiberg, & Whitman, 2014) as an initial guide, this integrative literature review deals with peer-reviewed research within engineering education to identify how scholars or practitioners address the issues faced by female engineering students and what kinds of gaps are found in existing research.

III. Conceptual Framework

As Raelin et al. (Raelin et al., 2014) suggested, this study also assumes that self-efficacy of female engineering students facilitates retention and career persistence of female engineering students. Generally, self-efficacy is an individual's perceived level of competence or the degree to which s/he is capable of completing a task. Bandura (Bandura, 1986) identified four sources of self-efficacy: performance accomplishments, vicarious experience, verbal persuasion,

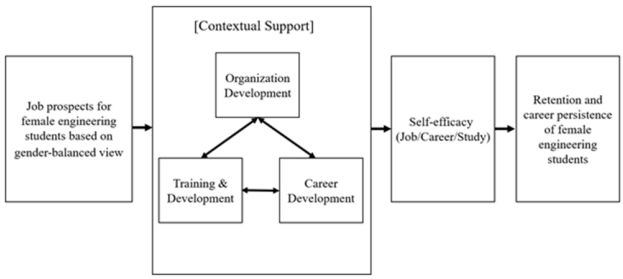

Fig. 1 Conceptual Framework on Gender and Diversity in Engineering Education

and physiological and affective states. Here, social cognitive career theory (SCCT) utilizing the concept of self-efficacy can give us useful explanations about how social cognition affects career decision-making and willingness to go on. Lent et al. (Lent, Brown, Talleyrand, McPartland, Davis, Chopra., & Chai, 2002) developed social cognitive career theory (SCCT) characterized as "a conceptual framework aimed at understanding the processes through which people develop educational/vocational interests, make career-relevant choices, and achieve performances of varying quality in their educational and occupational pursuits" (Lent et al., 2002). Throughout this integrative literature review starting from social cognitive career theory (SCCT), previous research will be analyzed according to the type of contextual support in order to identify future possibilities and barriers of nurturing female engineers.

IV. Research Method

Because this study originally targeted to analyze three academic journals on engineering education, which limited the literature review to studies published in European Journal of Engineering Education (EJEE), Journal of Engineering Education (JEE), and Journal of Engineering Education Research (JEER). The three journals were chosen in that this study was designed to investigate the academic trend of three continents such as North America, Europe, and Asia. European Journal of Engineering Education (EJEE) is an official academic journal of the European Society for Engineering Education. In addition, Journal of Engineering Education (JEE) has been published on behalf the American Society for Engineering Education. Likewise,

Table 2 Findings by Type of Publication

Publication	Initial Results	Final Results
European Journal of Engineering Education (EJEE)	42	6
Journal of Engineering Education (JEE)	23	6
Journal of Engineering Education Research (JEER)	21	5
Total	86	17

Journal of Engineering Education Research (JEER) is one of representative Asian journals published in Korea.

The search term "gender or woman/women or female or diversity" was combined with each of the following terms individually to search each journal: education, job, assistance program, and student. The literature search was limited necessarily by a time frame, 2005-2016. 86 articles were finally available for selection after removing irrelevant studies. Table 1 represents the number of available articles for the aforementioned descriptors in each of the three academic journals.

The second stage of this review consisted of a staged review (Turns, Sattler, Eliot, Kilgore, & Mobrand, 2012). Titles, keywords, and abstracts of 86 articles were reviewed. Studies that were not related to HRD practices, work, and higher education were excluded. This narrowed the number of relevant articles to 17. Table 2 gives an overview of the type of publications where the 17 selected articles were published.

The topics of finally selected papers are as follows: gendered effect of cooperative education, gender and achievement, collaborative educational policies for females, self-efficacy, problem and project-based learning, career satisfaction, and motivational factors.

V. Literature Review

The articles reviewed for this study were grouped into three main areas to influence retention and career persistence of female engineering students: organization development, training & development, and career development. This section will explain the findings of the research studies in each group in an attempt to identify and critique contextual supports that may contribute to self-efficacy

of female engineering students which affects their retention and career persistence.

1. Contextual Support: Organization Development

These days, worldwide universities are challenged to respond to complex global problems by developing effective strategies. Since innovations and creative solutions are needed in order to cope with global challenges, institutions of higher education need diverse people with different perspectives to come up with new sources of creativity and innovation. Under the circumstances, gender is seen as a part of diversity and diversity as a part of gender. As Leicht-Scholten, Weheliye, and Wolffram (Leicht-Scholten, Weheliye, & Wolffram, 2009) suggested, gender and diversity management could be a suitable political strategy to deal with tricky challenges within academic institutions. For this reason, Leicht-Scholten et al. (Leicht-Scholten, 2009) argued that gender and diversity management should be able to foster cultural change for a fair representation of women and other minority groups, which focuses on the integration of gender and diversity issues in research and teaching.

At this point, it is necessary to think about how gender and diversity management can be applied to higher education system both smoothly and effectively. Assuming that gender and diversity management always leads to encourage female engineering students to remain in engineering career is not appropriate because retention and career persistence is likely to be influenced by lots of predictable and unpredictable societal variables. For this reason, developing an open and non-discriminating atmosphere for gender and diversity management needs to be regarded as a prerequisite for higher education institutions to stay competitive and entrepreneurial in terms of knowledge production as well as to attract and retain diverse students including female engineering ones.

Designing and implementing cooperative education programs is one of examples of applying gender and diversity management to higher education institutions. Generally, cooperative education (co-op) programs during undergraduate years are believed to help students transition into full-time work more easily and help them overcome the 'reality shock' attributed to first-job experiences for uninitiated novices (Elfering, Semmer, Tschan, Kalin, & Bucher, 2007). Besides, as Blair, Millea, and Hammer (Blair, Millea, & Hammer, 2004) noted, those who completed more than three semesters of co-op are likely to have superior academic performance and to earn higher starting salaries. Existing empirical research on gendered effect of co-op program (Raelin et al., 2014) also confirmed that co-op program can improve the retention of women and men in their undergraduate studies.

As mentioned above, the quantitative research of Raelin et al. (2014) is a great resource to prove the gendered effect of cooperative education, contextual support, and self-efficacy on undergraduate retention. This research included the cases of Northeastern University, Rochester Institute of Technology, University of Wyoming, and Virginia Tech in which students participate in co-op programs.

Out of four institutions, it is well known that majority of Northeastern University engineering students participate in three six-month co-ops and Rochester Institute of Technology let all engineering students participate in four to six three-month co-ops.

Regarding the effect of co-op program, Bailey, Raelin, Hamann, Pendleton, Reisberg, and Whitman (Bailey, Raelin, Hamann, Pendleton, Reisberg, & Whitman, 2012) suggested that co-op experiences positively influence work self-efficacy. Bailey et al. (Bailey et al., 2012) asserted that work self-efficacy implies a range of practices such as exhibiting teamwork, expressing sensitivity, managing politics, and handling pressure. Because these qualities are crucial for the success at workplace, gender and diversity management strengthening work self-efficacy is important for both female and male students.

As can be shown above, co-op programs proved to be helpful to support student career. However, existing research are found to ignore the possibility that the 'reality shock' faced by female engineering students in co-op program works as both a barrier and a turning point for female engineering students. In other words, all co-op programs are not supportive for female engineering students. Rather, co-op programs might prevent them from pursuing engineering career in case that its culture and value is not favorable for diversity. While existing

research acclaimed the positive aspects of co-op program, its negative sides were not well identified or analyzed.

When it comes to the effectiveness of co-op program, setting up the ultimate purpose of co-op programs is critical. Of course, it is also important to align specific strategies managing the co-op program with its purpose. Only if the purpose should correspond to the basic philosophy of gender and diversity management based on equity, co-op program could function as a supportive intervention to promote the retention and career persistence of female engineering students. Therefore, it is necessary to further perform quantitative or qualitative research to determine the quality of co-op program related to its contribution to equity and diversity.

For future research, it is necessary to note that quality of co-op program depends on supportive social influences to facilitate effective gender and diversity management. For example, financial aid to those in need; modeling and conversation; positive messages of parents, faculty, and role models; peers to share constructive feedback about their efficacy; career choice encouragements from influential significant others. Without appropriate social supports, it is impossible to guarantee the success of co-op program. Thus, research on measuring the quality of co-op program is deeply connected to judging the quality of social influences added to co-op program.

In addition to co-op program, there are institutional and structural supports within higher education institutions. As can be seen in Han, Park, and Kang (Han, Park, & Kang, 2010), Korean government has supported female engineering students through WIE (Women in Engineering) project since 2006. WIE project started from gender-sensitive perspective to encourage engineering education to embrace equity and diversity. Now that the specific programs of WIE project overarch both curriculum redesign and adjustment to workplace, female engineering students participating in the project can benefit from its supportive service based on gender and diversity management.

Accomplishments and obstacles of WIE project are well elaborated in Han et al. (Han et al., 2010). While redesigned curriculum based on WIE project has promoted gender-sensitive recognition to support female engineering students, it was criticized due to the concern of counter-discrimination toward male students (Han et al., 2010). Besides, because WIE project was believed to target nurturing elite female engineers, its fundamental purpose pursuing equity and diversity was easily distorted by opponents. Even though it is clear that WIE project has contributed to establishing a role model of female engineers, its programs also brought confusions to the understanding of original purpose of the project. On the other hand, regarding the adjustment to workplace, WIE project has helped female engineering students maintain engineering career (Han et al., 2010). While its programs have been trying to respond to the social needs related to female engineers, it seems that it did not make enough efforts on recognizing female engineering students' own needs. Thus, it is likely that female engineering students were not motivated by their voluntary plans but led by directions produced by faculty members or educational administrators. Since most WIE programs to support female engineering career were designed to meet social needs or requirements, diversity in career-decision making was ignored by its project management. For instance, those who want to cultivate their career in unknown or unpromising fields might be excluded from the benefits of programs. All in all, WIE project has ironically worked as both a promoter and a disrupter when it comes to invigorating diversity in engineering education. Throughout literature review, therefore, it is believed existing organizational interventions can be really helpful if its design and implementation needs to be critically reexamined by diversity framework.

2. Contextual Support: Training & Development

Because the finally selected articles focused on P2BL (Problem and project-based learning) as teaching and learning methods, this section was designed to investigate the implications of P2BL and to critique them. P2BL has been recently highlighted for engineering education with importance of student-centered learning. It is true that P2BL can provide students opportunities for application of engineering knowledge in practice. However, this kind of pedagogy often makes students and educators question

its real effectiveness in that simply putting students together does not guarantee knowledge construction or increased academic achievement (Barron, 2003). For this reason, researchers have devoted to discover the conditions promoting effective or non-effective collaboration.

Earlier research examining the influences of ability level and gender produced mixed results (Stump, Hilpert, Husman, Chung, & Kim, 2011), leaving researchers without an irrefutable list of factors that led to effective collaboration. Stump et al. (Stump et al., 2011) asserted that the most consistently identified elements of effective collaboration have not been related to quantifiable factors such as ability level, gender, or participant number. Rather, students' cognitive process seemed to be critical to the quality of collaboration (Stump et al., 2011). The cognitive process refers to questioning or elaborating on each other's ideas and coming up with related explanations or solutions. Observing and analyzing student engagement behaviors in team projects, therefore, is more needed for future research.

After the literature review, research on determining the quality of collaboration based on diversity framework has been scarcely found throughout three representative academic journals on engineering education although collaboration is an ABET accreditation required component of engineering curriculum. Despite the importance of collaborative learning, research on engineering education does not explicitly suggest how engineering training programs can facilitate peer interactions identifying gaps in knowledge, stimulating elaboration of knowledge, and thus contributing to individual cognitive gains. While the effects of frequency or quantity of interaction during training programs has been well analyzed (Kodate, Kodate, & Kodate, 2014), the reviewed engineering education journals does not seem to be enough to clarify how to improve the quality of interaction in order to make helpful guidelines for existing or emergent engineering classes.

For this reason, it is necessary to consider the importance of developing competency model(s) for effective or successful collaboration in engineering education, which means incorporating collaboration competency model(s) into the engineering curriculum of higher education. Frequently cited definitions of competencies are as follows: "Competencies are underlying characteristics of people and indicate ways of behaving or thinking, generalizing across situations, and enduring for a reasonably long period of time." (Guion, 1991); "Competencies can be motives, traits, self-concepts, attitudes or values, content knowledge, or cognitive or behavioral skills – any individual characteristics that can be measured or counted reliably and that can be shown to differentiate significantly between superior and average performers, or between effective and ineffective performers" (Spencer & Spencer, 2008).

As is shown above, establishing collaboration competency model(s) can provide engineering students and educators to measure their achievements related to collaboration as well as to create future education/training plans for effective collaboration. Here, collaboration competency model(s) needs to include major attributes such as cognitive skills (knowledge, critical thinking, and problem-solving strategies), interpersonal skills, affective attributes, and technical/psychomotor skills that are required for competent performance of successful collaboration.

As of now, due to the absence of collaboration competency model(s) based on diversity framework, the effectiveness of engineering training/education programs such as P2BL is not so specifically proved by empirical research throughout three academic journals. Above all, for the purpose of developing collaboration competency model(s), more behavioral examples related to collaborative learning needs to be investigated to identify both achievement standards and criterion groups.

Measuring the level of collaboration competency often confuses engineering educators and students because it is not easy to prove how effective collaboration contributes to the success of team projects (Marra, Rodgers, Shen, & Bogue, 2009). In other words, harmonious collaboration does not always connect to excellent team performance. Oftentimes, amicable collaboration might hinder the inevitable process of trial and error even though it is important not to degrade the value of trial and error for problem-solving in engineering education. Collaboration competency model(s), therefore, needs to start from

resolving conflicts not preventing or eradicating them.

On the other hand, while reviewed three academic journals have been likely to focus on nurturing collaboration skills of engineering students, research on evaluating its educational effect has been rarely found during 2005-2016. In fact, the logic of cost-benefit analysis often makes engineering educators and students hesitate to weigh collaboration skill training because it is tricky to financially measure the contribution of collaboration skill training to final outputs (Wolfe & Powell, 2009). Of course, it is clear that economic efficiency is one of important criteria for determining the quality of collaboration training. For this reason, it is necessary to rethink about how the value of collaboration skill training specifically can be transformed to monetary cost and benefit after setting collaboration competency model(s).

Ultimately, developing collaboration competency model(s) in P2BL aims to raise students' creative confidence represented by 'self-efficacy'. Here, upgrading 'self-efficacy' is not applied to only female students. Collaboration skill training should be designed for both male and female students in terms of diversity framework. Thus, encouraging the recognition that gender and diversity management is necessary for satisfactory communication as well as for innovation is a prerequisite for collaboration trainings.

3. Contextual Support: Career Development

Jones, Paretti, Hein, and Knott (Jones, Parettie, Hein, & Knott, 2010) differentiated between expectancy-related constructs (i.e., engineering self-efficacy and expectations to succeed in engineering) and value-related constructs (i.e. engineering identity and beliefs about the importance and usefulness of engineering). Jones et al. (Jones et al., 2010)concluded that expectancy-related constructs tended to predict achievement and that value-related constructs predicted career plans in engineering for both men and women. As mentioned, strengthening value-related constructs is helpful for engineering students' career development.

Facilitating students' career development is crucial for boosting the diversity of engineering education. Especially, observing and assisting engineering identity formation is an important element in career development. Engineering identity studies have encompassed how engineering campuses frame engineering identity productions (Tonso, 2007). Internships, co-op opportunities, and group work promoted a professional engineering identity (Eliot & Turns, 2011), as did durable productions such as portfolios (Turns, Sattler, Eliot, Kilgore, & Mobrand, 2012). Anderson, Courter, McGlamery, Nathans-Kelly, and Nicometo (Anderson, Courter, McGlamery, Nathans-Kelly, & Nicometo, 2010) asserted that engineering identity is a complex equation that factors in problem solving, teamwork, learning, and personal contributions. Communication, particularly during team meetings, emerged as central to engineering work, though engineers wished for less time in meetings and more time doing hands-on engineering. This sort of conflict is called a tension between business constraints and quality engineering (Anderson et al., 2010). Likewise, during the process of identity formation, engineering students are required to face new type of engineering competencies (i.e. communication, leadership) being different from traditional one.

Examining newest accreditation standards such as ABET criteria is helpful to understand how acquiring engineering competencies can contribute to developing engineering identity. However, accreditation standards seem to encompass a presumption that expectancy-related constructs are always connected to value-related ones. Therefore, it is necessary for ABET criteria to provide more specific evaluation guidelines about measuring how to differentiate expectancy-related constructs from value-related ones and how to solidify their connection.

Regarding career development of female engineering students, existing research of three academic journals is likely to focus on mentoring or coaching to support females (Youn, Han, & Choi, 2014). While it is true that mentoring or coaching is one of effective ways of framing engineering identity, these approaches might isolate female engineering students from real world led by male-dominant engineering culture. In other words, by mentoring or coaching, female engineering students need to learn how to collaborate with males instead of blaming male-dominant culture. Thus, when it comes to evaluating the effectiveness of mentoring or coaching program, it is needed to give a weighting on evaluation indicators

related to collaboration with males when compared with other indicators.

Hence, maintaining effective collaboration is closely connected to education on self-leadership. Self-leadership has been defined as "a comprehensive self-influence perspective that concerns leading oneself toward performance of naturally motivating tasks as well as managing oneself to do work that must be done but is not naturally motivating" (Manz, 1986). Under current circumstances, participating in interdisciplinary or cross-cultural teams is so common that engineers also need to be ready for collaborative work beyond existing borders such as gender, race, and nationality. Of course, empirical research utilizing these variables is often found throughout three academic journals. However, fundamental question was not fully answered yet: how to motivate students and faculty to respect diversity despite down-to-earth constraints; what makes faculty and students happier through collaboration. Therefore, additional case studies are needed to specify behavioral examples dealing with realistic constraints and satisfactions of students and faculty members in engineering education, which can provide a critical base for enhancing self-leadership of engineering students.

When it comes to career path of female engineering students, career decision-making is strongly influenced by socio-economic environment. For instance, in Korea, women have been struggling with work-life balance after marriage and so female engineers do. Besides, career severance is a serious problem for married women including female engineers. Without working out these problems, guaranteeing career persistence of female engineers seems to be impossible.

However, universities can play a role in improving or revising common sense by educational enlightenment. For instance, giving tips or information on "network career path" would help decision-making of female engineering students. Unlike traditional or vertical career path, "network career path" focuses on horizontal rotation and flexible time management (Kolmos, Mejlgaard, Haase, & Golgaard, 2013). Therefore, if mentors or coaches are not used to "network career path", their advice might not be opt for work frame of current era. From this aspect, continuing trainings for mentors or coaches as well as students are necessary for effective support for female engineering students.

If vertical career is not the only option for female engineering students, they also need to make efforts for redesigning their work life. Of course, mentors and coaches can lead them to better strategies for career development. However, without students' voluntary willingness, it is hard to continuously develop their competency through supporting programs. Universities, therefore, have to explore various ways of encouraging students' autonomous participation before implementing programs on career development by internalizing self-leadership.

VI. Recommendations

Regarding self-efficacy, empirical studies (Post-Kammer & Smith, 1985; Wheeler, 1983) pointed out the inclination that college-age women's self-efficacy within male-dominated fields was significantly lower than their self-efficacy in traditionally female occupations. The one exception to this finding was female engineering students; their self-efficacy was equivalent to or was not significantly different from that of their male counterparts. In addition, Hutchinson, Follman, Sumpter, and Bodner (Hutchison, Follman, Sumpter, & Bodner, 2006) reported that academic and advisory support significantly could enhance female students' academic self-efficacy.

However, at this point, it is necessary to conceive the gap between academic and work self-efficacy. Supporting diversity in academia is of no use unless workplace can embrace diversity. In this respect, smooth transition between academia and workplace is a critical factor to develop self-efficacy of female engineering students. As suggested in previous section, co-op program might be a good assistive basis for women or minority groups if the workplace can regularly provide dialogue sessions and conflict management meetings with both students/employees and faculty members/employers in order to facilitate diversity. Generally, dialogue sessions or conflict management meetings are categorized into team/work group interventions

in HRD (Human Resource Development) (Ingram, Bruning, &Mikawoz, 2009).For making a harmony between students/employees and faculty members/employers, trainings to strengthen emotional intelligence are needed for both of them. Although engineering studies are believed not to be directly relevant to emotional intelligence, raising emotional intelligence is closely connected to balanced point of view on gender and diversity management.

On the other hand, establishing collaboration competency model(s) is necessary for both students and faculty members. Throughout reviewed academic journals, the importance of collaboration was frequently researched via empirical or theoretical methods even though research on how academic trainings or advisory support can help students or faculty members systematically develop collaboration competency was rarely found. In other words, collaboration competency should be regarded as a nurtured quality not as a natural trait, which means that trainings or advisory supports should be able to strengthen collaboration competency through step-by-step approach.

Under P2BL environments, understanding and practicing collaboration competency is needed for both students and faculty members. When considering that engineering faculty members were not familiar with collaborative learning in their undergraduate days, managing diversified teams represented by increasing number of women might be challenging for them. In this respect, continuing education related to collaboration competency should be regularly provided for engineering faculty members as well as students. Only if collaboration competency trainings are given to faculty members, it is possible for them to consistently update and revise specific guidelines for effective collaborative learning when they teach engineering students. Because traditional engineering curriculum was not likely to pay attention to collaboration competency, assistive trainings of faculty members are as important as that of student services. For example, engineering faculty members need to be familiar with interdisciplinary or multidisciplinary team teaching to strengthen cooperative learning and to gradually address project management competencies. As Rios-Carmenado, Lopez, and Garcia (2015) pointed out the importance of "pre-work experience" to link teaching activity to the business and industrial environment, engineering faculty members are currently required to be used to promoting professional project management skills in their teaching.

On the other hand, self-efficacy for female engineering students also can be bolstered via well-designed trainings or programs. Here, good trainings or programs refer to various opportunities encouraging female students to develop growth mindset. Of course, more important thing is to construct effective educational infrastructure to assist female engineering students beyond individual endeavors. While it is true that growth mindset approach may boost female students' confidence in engineering (Choi & Park, 2009), it is not appropriate that improving individual propensity is a panacea for resolving complex conundrums on equity and diversity. For this reason, cost-benefit analysis about equity and diversity management should be carefully applied to supporting projects for women or minority groups. Although taking a long-term view is critical for designing and implementing trainings or programs on social justice, political dynamics often does not allow enough time for academia or workplace to accumulate small achievements. Decision-making on economic efficiency based on capitalism might not work, particularly for disadvantageous people.

Regarding career development for female engineering students, it seemed that reviewed academic journals were inclined to focus on improving the effectiveness of advisory supports such as mentoring or coaching (Heo, Weon, & Lee, 2007). It is true that mentoring or coaching is still a useful option for decision-making on career development. However, it is necessary to consider that designing career paths of students is trickier than before because of difficulties in predicting long-term retention human resources. Up-to-dated technologies such as robots are predicted to alternate humans in many fields, which lead to confusions of defining human competency. In other words, traditional career paths might not work for students or employees in the future. Under the circumstances, women or other minority groups are likely to be key victims of restructuring

human resources.

If it is hard to redesign career paths due to the uncertainty of future workplace, rethinking about the ultimate purpose of mentoring or coaching is needed for effective assistance. As previously suggested in this study, education on self-leadership can be considered as the focus of coaching or mentoring when it comes to designing career paths. Of course, training students or employees for the adjustment of future tasks is still important for both academia and workplace. On the other hand, it is also recommended that giving more weights on unchangeable things such as enhancing self-leadership be necessary because it is hard to conceive a precise roadmap of highly changeable future career paths under current circumstances.

VII. Conclusion

During the past decades, endeavors to challenge existing socio-economic system were going on despite lots of barriers against diversity and equity. No one can be sure about whether it is possible to construct a society to perfectly guarantee equity and diversity by the efforts. However, throughout literature review, it was found that scholars and practitioners have been struggling with this topic to find out better solutions, which encourages us to redefine the problem and to implement more effective trainings or programs. The findings also indicate that retention and persistence of women in engineering is closely relevant to issues of diversity management, collaboration competency, and self-leadership. In addition to previous studies, research gaps and agendas suggested in this study below are expected to contribute to the development of the reviewed engineering education journals published in the future through empirical or theoretical research.

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