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ENGINEERING EDUCATION: STUDENTS´ VOICES ON THEIR PROFESSIONAL TRAINNING

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Abstract

The reported study focuses on the academic practices of freshman and senior engineering students while gaining the required experience to become engineers. The theoretical framework derives from a sociocultural perspective, where the appropriation of disciplinary tools and artifacts, and the ways in which students participate in the disciplines, are crucial. The participants were 47 engineering students from a Mexican state university, who participated in six focus groups. The data obtained was analyzed using techniques of content analysis. In general, the students' comments show different levels of appropriation of the disciplinary tools, and different ways of perceiving their professional training in terms of the challenges that it presents for them, and they mentioned which aspects of these differences they considered to be significant. Dissimilarities between the majors, in particular those regarding the professional internships, are also discussed. To conclude, the paper provides suggestions for improving engineer training right from the beginning of their university studies, and has implications for other state universities working with similar programs.

Key words: higher education, engineering education, qualitative research, university students.

1. Introduction

In all countries, training in the sciences and engineering is at the center of the debate on educational systems. In Mexico, the course of study in engineering schools and faculties have seen substantial changes in the last decades following the formation, on June 6, 2002, of the Council for the Accreditation of Engineering Studies (Consejo de Acreditación para la Enseñanza de la Ingeniería – CACEI). The CACEI is the agent responsible for reviewing these programs and granting them certification (recognition of their quality).

The campus of the state-wide public university being studied offers the following majors, inaugurated on the dates indicated in parenthesis: Civil engineering (1983), Electronic engineering (1989), Computer engineering (1994) and Industrial engineering (2002). Recent reforms to the course of studies

address first and foremost the concern for the academic quality of engineer training in an increasingly high-tech world. Currently, academic programs in universities seek to reflect the recognition of engineers' responsibility in taking into account social and environmental factors in their work. This task has been addressed by endorsing a work-integrated learning approach to the curriculum (Bosco & Ferns, 2014), through practical learning experiences within the universities and extracurricular activities within society at large (Inagaki, 2014), or other institutional practices to support and accompany students during their study years, such as introducing academic advisors (Khalil & Williamson, 2014), work-based learning and workplace mentors (Siebert & Costley, 2013) or supervisors (Peach, Ruinard & Webb, 2014), or international work placements (Gribble et al., 2014). The great challenge for Mexican universities is in offering courses that are linked to the future demands of society, and educating engineers with a humanistic component so that they are capable of resolving problems and working in new settings that are increasingly affected by developments in science and technology (Leyva-Ramos, 1988).

This study aims to gather the opinions of students in the training process regarding their participation and the levels of appropriation of the tools and artifacts of the discipline.

2. Theoretical Framework

From a sociocultural perspective, knowledge – lessons – can only be considered as such when it has been internalized or appropriated, becoming part of the personal wealth of students' knowledge that can be seen when put into practice. The acquisition of a discipline, engineering in this case, can be considered cultural acquisition in as much as all "disciplines represent groups of people who share norms and conventions for discourse and practice" (Moje, 2011, p. 54). Belonging to a group of people – future engineers in this case – "means the possibility of sharing implicit beliefs, that is, ways of categorizing reality that do not have to be explained, as they are taken for granted" (Lalueza et al., 2004, p. 18). It is understood that these people have already appropriated the tools and artifacts that are the foundation for the understanding of the group, the fundamental ones being reading and writing disciplinary texts, as well as the use of devices for operating in the profession. Therefore, the students should be familiarized with the disciplinary tools of their field of action in the contexts of specific activities so that they can appropriate them and move from considering themselves, "students of a discipline" to "professionals of a discipline" (Stevens et al., 2008).

But sociocultural studies show that this appropriation is not automatic, but instead it is carried out through slow and complex processes over a long period of time through the participation of people in the defining practices of the group. The concept of "histories of participation" shows the complexity of this appropriation (Moje & Lewis, 2007). Each person has a different history of participation, formed according to their prior experiences in school and outside of it, which provides them with a set of resources to face future experiences. In this way the paths to appropriation of tools and artifacts of a particular discipline – or culture – are extremely variable and diverse. From this perspective, learning is always a situational process and therefore the context in which it is generated is of great importance (Wenger, 2001). The command of a discipline, "involves not only 'learning about' the subject matter but also 'learning to be' a full participant in the field. This involves acquiring the practices and the norms of established practitioners in that field or acculturating into a community of practice" (Brown & Adler, 2008, p.13).

The full participation in a disciplinary field is not immediate; the work on communities of practice shows the ways in which the memberships in the community develop slowly through participation in the defining practices of that community (Wenger, 2001). At the beginning, when participants are novices, their participation is [almost] peripheral and to the extent that they become veterans/experts, learning, being recognized and gaining the trust of the group, their participation and responsibilities increase.

Participation is thus a central concept in the sociocultural theories on learning. "Although participation can be considered one of several learning objectives, participation itself is not 'acquired.' That is, we need to address ways in which the individual is affected by such participation and what resources he or she 'takes away' from these instructional experiences" (Moje, 2011, p. 50).

Researchers refer to this remnant as "residue of participation," to indicate the resources (knowledge, attitudes, emotions) to which, as a consequence of previous participation, the student will return to in future participations (Stevens et al., 2008). Always with Moje (2011), the students require a certain level of knowledge, identification with the domain and a clear objective, so that their participation in the disciplinary practices is significant. She states that, "[one cannot critique unless] one identifies with the discipline, and one cannot identify with the discipline without the tools of the discipline" (p. 55).

In our work, we propose that the identification with the domain can be seen, to some extent, in the students' level of commitment to the discipline (evidenced in the time and intensity dedicated to their studies). There are clear indications that learning to be an engineer, is about relating learning to purposes and goals; Lankshear (2011) illustrates this by citing Gee "Learning a new domain, whether physics or

furniture making, requires learners to see and value work and the world in new ways, in the ways in which physicists and furniture makers do" (p.14).

Besides, the academic goals of the students affect their performance in various ways since they determine the time and intensity that they will dedicate to their studies (Locke, 2001). For example, having a long term goal can allow them to direct their efforts towards specific objectives, working harder, and encouraging them to make a greater effort than if their goal was lower. Goals also influence persistence given that they allow the students to control and invest the necessary time in order to achieve difficult goals. Goals can also affect the action taken by permitting the students to use their prior skills and knowledge and apply them in practice.

Based on the theoretical considerations described above, the research question explored in this work is: from the students' point of view, do they consider that the ways in which they are introduced to the practice of their profession allows them to appropriate the tools and artifacts of the discipline?

3. METHODOLOGY

This work is based on a broader research project of the literacy practices of students and professors from two faculties at the university. The methodology utilized to gather the experiences of the students consisted in the application of a questionnaire and group interviews. In this work we report the results of the interviews with engineering students: freshman (two groups) and seniors (two groups from electronic engineering and two groups from civil engineering). All the interviews were transcribed and analyzed using content analysis techniques (Krippendorff, 2003). In order to maintain confidentiality and facilitate the analysis, the participants were numbered; their comments transcribed literally, demarcated by commas, indicate the student that made the comment [i.e., S28].

Of the six group interviews, four were carried out in the Vice-rector's offices and two in the corresponding laboratories. The average duration of the interviews was 45 minutes; the range of time varied from 18 to 75 minutes. The participants were 47 engineering students of which 38 (81 %) were men and 9 (19 %) women. Their age range, by academic level was the following: 14 freshman students between 17 and 19 years and one 30 year old; 14 senior civil engineering students between 21 and 25 years of age and one 32 year old; 17 senior electronic engineering students between 21 and 26 years of age, 10 of which were 22 years old (59%). Of the 47 students, 15 (32%) work and study, the majority of them part time. All of the students, with the exception of the two who are 30 years and older, were single. These participants were representative of the population of the faculty as a whole. Regarding gender, the proportion of participants,

81% men and 19% women, reflects the proportion of engineering students on the campus that counts with 1,247 students enrolled: 1,004 men (80.51%) and 243 women (19.49%). In terms of age, the expected age range for university students is 18 to 24 years, and the respondents, 43 (92%) falls into that range.

4. **Results and Discussion**

In spite of little existing research on the topic in Mexico, the lack of vocational orientation and alignment between the high school curriculum (especially the public high schools) and the higher education curriculum is a problem that can be observed in the high dropout rates during the first university semesters. The engineering students are aware of this from the beginning: "The first semester they give us an introduction and that is really when you realize if you are in the right major; there are many people that leave in the first or second semesters because in the core classes, the introduction that they give us in the university, you discover if you are really going to continue or they say, 'this really isn't my thing.'" [S12].

The students also say that they resent the change in the course expectations between the high school and university levels. They feel that courses are, "very different, in all aspects [S8]" especially in the mathematics classes: "In high school they made us do easy exercises, they explained them to us and here they give us hard ones [S8]." It is important to clarify that in spite of feeling that the mathematics exercises were "difficult," when questioned about their reasons for selecting engineering major, the majority say "I like mathematics [S8]." When asked about the classes that they took in high school that are most related to their major and that influenced them to make the decision they respond that they were: "mathematics [S9]," "physics [S10, 11]," and they feel that, in spite of the difficulties, they are advancing: "[we have seen progress] in mathematics…when I first came here I felt like I really couldn't keep up but my understanding of logics has improved, it is a lot of logic [S10]," "supposedly that is what they are trying to do with mathematics, develop our logic to be able to solve problems [S14]." Surprisingly, they say that the mathematics classes are: "where they give us the least homework [S7]."

One of the requirements for engineers in the 21st century is having developed oral and written communication skills, because writing practices are constitutive of each field of knowledge, and are subject to the conventions of each domain (Moje, 2011). However, in spite of its relevance, the students do not perceive a curricular strategy that develops these skills, nor do they perceive reading disciplinary texts as the introduction to disciplinary discourses and the groundwork on which they will base their knowledge. Freshman students indicate that the classes do not require much reading, except

> "In the introduction class, we read more than in Communication because in Communication we look at examples on the chalkboard, accents, maybe exams; but in Introduction, since we look at history, we have to read everything and do activities related to the reading. But there are few classes where we do reading." [S12]

When questioned about the academic nature of their written work, the students comment that they write essays and practice reports. The classes in which they have written the most essays are: Human Development (the essays must be submitted by hand), Introduction to Engineering and Oral and Written Communication. In regards to their difficulties in writing essays, they comment that the most common mistakes are in spelling and placing accents: "only the spelling mistakes, they count a lot [S3]." No one mentioned having problems in structuring their essays or expressing their ideas. In order to address the writing problems that arise in their homework, they explain that the professor of the Communication class corrects them and makes them do writing exercises in class: "she separates syllable by syllable; she puts stress where there are different accents [S8]," and they feel that the objective of the homework is "to improve spelling and understand the topic [S11], [understand and] *pass* what you are studying [S14]." The students are conscious of their written language problems: "we don't even know Spanish and they want us to learn English [laughs] [S8]."

In terms of their work load, the freshman students in general said that they felt it was adequate, "to me the classes are very accessible, mathematics is the most complicated, nothing more [S5]." When asked about the grades that they hope to obtain with the effort made in mathematics they say that they hope to have grades between 7, 8 and 9 [out of 10] because, "our best efforts don't even reach 9 [S7]." Paradoxically, when asked specifically about their level of commitment to their classes, the majority mentions that they are giving between 70% and 85% of their best effort; with the exception of two students that said they were giving 100%. They affirm that "in some classes we give more, like in Introduction to Engineering [S15]," "because the professor is more demanding [S10]," "in some [we give] more than in others because of the professor's attitude [S12]." From the point of view of sociocultural theories on learning, the group is seen as a community, where its members interact constantly and influence each other's behavior, thus the nature of the interactions with the professor is considered an important factor in determining the attitudes of the students towards the professor and the course activities.

In terms of their opinion about the university's infrastructure and equipment, the students say that it is adequate, "good [S13]," "they are good, we don't have to fight with them [S10]." The interest that the students show in their future areas of specialization in engineering when they speak of their hobbies and

entertainment activities is noteworthy. They say that they watch related television programs: "like Discovery; for example, in my case with civil engineering, I watch Super Structures and that type of program [S6]," and they download computer programs from the internet for the pleasure of learning and experimenting with them.

In regards to how they visualize themselves as future engineers, they all imagine being, "fulfilled [S8]," "important [S7]," "successful [S2, S6]," though their jokes indicate that they still see their graduation as distant (for example, one student imagined himself "with a bigger belly [S10]"). Some have more clear expectations: "I see myself working for companies [S11]," "I would like to work outside of the country [S10]," "I don't see myself as an engineer here in this city since there isn't much work here; it doesn't matter if it is in other parts of the state, where there is more work than in this area [S14]." The senior students expressed their opinions more clearly about their education and future, as reported below.

Something that stands out in the interviews with seniors from both engineering careers is their perception of the relevance of the curriculum subjects for their professional education. This perception influences the time and effort that they dedicate to them starting from their entrance in the university. Our results indicate that this perceived relevance of the subject matter is even more significant and independent of the interest that the topic might incite in the students: "There are important courses that are harder than others; in these, in general, the majority dedicates more time than to others, which are mostly theory… those that use a structure or logic are the ones we dedicate more time to" [S25].

Another important factor that determines the time and effort that they invest in their homework is the professor's expectation level: "what we dedicate to reading and to completing work and homework depends on how much they expect of us [S30]."

The senior students in civil engineering say they would be willing to take other courses to enhance their professional training: "Sometimes in the major they demanded a lot in the courses and yes, we were overwhelmed trying to stay afloat, but from what I have seen in other universities the load is heavier, I think that we would be capable of carrying heavier workloads" [S16].

With regards to the activities that involve reading and writing, it is noted that civil engineering students say that, in comparison with other majors, they barely read, but they don't see that as detrimental nor are they aware of their advanced reading of mathematical language. The following statement, made by various students, illustrates this point: "we don't read much…[S19] Instead of reading we think…[S17] because we have to analyze something, for example, a problem... [S16] But we don't read all the time, in comparison to other majors…[S20]"

The value of professional internships underlines the importance in including them in the curriculum with the objective of promoting the development of professional competencies from the initial training as an engineer (Johnson & McGregor, 2005). They indicate that the emphasis on technical competencies within the major, developed in a decontextualized way is a thing of the past and the current curriculums in engineering emphasize the contextual aspects. In the case at hand, in general, the students perceive the professional internships as a central part of their training as engineers. However, we found differences between the civil engineering and electronic engineering students.

The majority of the civil engineering students said that they felt that they have appropriated the tools and artifacts of their field. They say that they feel confident in developing their engineering plans and good technical reports. They said that after the fourth semester they could manage many projects and in all the classes they carry out exercises. All the students showed a high level of identification with one of the specialties (surfaces, structures, highways, hydraulics) and various had plans to study a masters' degree [S16, S18, S19, S20, S21, S22, S28]. It is worth noting that when talking about their future they imagine it as "prosperous [S28, S30]," explaining their plans with short and medium term goals.

Finally, three of the respondents participated in the student exchange program [S24, S26, S27], taking a semester in universities in Spain, the United States and Canada respectively. This program has become a very important incentive for other students, since it allows them, in their last semesters, to enhance their professional training in other learning environments.

The electronic engineering students on the other hand said that they read a great deal, "it is more reading than writing, there is a lot to research [S45]" and they define texts that they read as "scientific texts [S42]". They say that their knowledge "gets stronger semester by semester [S46]" and they have perceived an incremental level in the difficulty of the classes; however, the students also said that they perceived discordance between theory and practice. They consider their professional practices insufficient (and deficient because of obsolete equipment).

The students cited that the lack of equipment and materials to carry out their exercises was an institutional limitation (locally, since they said that in another campus the conditions and equipment are better): "there is a lack of laboratory equipment […] to be able to carry out exercises; there is not sufficient equipment or rather they don't exist…[S34]" "not even materials, in the eighth and ninth [semesters] we studied fiber optics and we never knew it in person [laughs]; we didn't have the opportunity to work with it [S36]" . They say that they can manage the most basic artifacts of their field, "we never worked with fiber

optics […] since it is different and expensive equipment [S35],” “in the exercises we used [obsolete] microcontrollers that companies donate and not what they are currently using in the market [S38].”

The electronic engineering major offers two areas of specialization to be taken in the last three semesters, “…you take the six classes in telecommunications or the six in mechatronics, but you are also at liberty to mix them, if you want you can learn everything a little bit [S35].” The students, especially those that opted for telecommunications, detected deficiencies in their training and think that they need other classes “like mobile communications, that they have in [the other campus] but not here [S31].”

Finally, the electronic engineering students were concerned not only by the propaedeutic professional practices in the university, but also by their internships outside the university: “Our class schedule is in the morning shift, but all other engineering majors in our faculty have the afternoon shift, so that somehow the students are able to do their practices in the mornings [S35].” “Most companies that take interns want them in the morning shift. I went to a company and they said ‘yes, of course’, but the [academic] schedule is in the morning ... [and I could not do my internship there] [S36].” This has caused the students to delay graduation and they have to spend an extra semester for their internship, which is a prerequisite for graduation.

To sum up, we can say that, in general, students are aware of their own level of appropriation of the disciplinary tools and artifacts provided by the institution throughout their professional education. Their appropriation levels differ due to their own histories of participation, but most of them are proud to have successfully met the academic challenges.

5. Conclusions

In general, the students’ comments show different levels of appropriation of the disciplinary tools and different perceptions of the professional training in terms of the challenges it presents them.

The results of the research show some problems with the curriculum and the institution. Among the first, is the conception of writing by the students as limited to spelling and grammar matters, a problem that derives from earlier academic cycles and is even supported by some of the activities assigned by the university professors. Writing is not considered as a constituent part of their disciplinary training, but as secondary, geared only to proper error-free presentation of their texts. Perhaps because of this, the students are not aware of the role of languages – textual, mathematics, iconic – as mediating resources in the appropriation of disciplinary knowledge.

In second place, the importance of the role of the professor in facilitating the appropriation of disciplinary tools and artifacts stands out. From the beginning of the program the students mention how much

the level of professor expectation influences the time and effort that they dedicate to their classes, which shows the need to define rigorous criteria for, among other things, the development of written texts at the university level.

Lastly, in regards to the institutional problems, the difference between students in the two engineering programs demonstrates the central role of the institution in providing spaces for internships for the students. For the identification with a discipline, it is necessary to have realized exercises in it, preferably in diverse contexts. This is especially important in the engineering majors which are continuously affected by scientific and technological advances.

Regarding the institutional programs, their strengths include the student exchange program, initiated in 2004, which encourages students to take a semester, a year in some cases, at other national and international universities. To participate in the program, students must have a good GPA and a reasonable handling of the language of the host country; this has increased the motivation to study and setting higher goals among the students.

On the other hand, given the institutional constraints, the university should continuously monitor the implementation of its programs, beyond obtaining accreditation from the CECAI. For example, the electronic engineering program shows gaps in the provision of space, equipment and materials suitable for laboratory and field exercises on campus, and in the coordination of internships in the local businesses and industries.

The institutional duty is to optimize the study time of their students. Considering the central importance of professional practices and internships in this field, the institution should find ways to work more closely with local companies, starting with having more flexible class schedules. Establishing an effective relationship with local business and industries will lead to better satisfaction of their needs while benefiting not only the students but the local community.

From the numerous aspects that merit further study, and taking into consideration the students' voices, our future work will be focused on reviewing the institutional programs and freshman courses in order to incorporate as many projects and hands-on activities as possible; this includes developing ways to monitor, report and evaluate the practical components, and in due course, their contribution to the development of the desired skills. Regarding senior students, the issues to be addressed comprise the analysis of propaedeutic professional practices within the university as well as by interns, if possible by including feedback from their hosts in local businesses and industries.

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