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Synthesis-Identity Essay 1: History and Philosophy of Engineering

In this essay I present a general vision of what are the epistemological and intellectual threads that several authors discussed around engineering. In particular, I will discuss about how epistemology may influence engineering in the institutional, scientific, and educational practices. Furthermore, by means of the framework of the components of Activity Theory I will present three cases, each of them portraying institutional, scientific, and educational epistemologies, respectively.

Epistemology is a branch of philosophy that focuses on the study of the nature, sources and limits of knowledge (Noddings 2006). The responses of what knowledge is reflect people's beliefs about how the mind acquires knowledge about the world. These beliefs are shaped by the historical background and culture, and influence many aspects ranging from scientific, professional, and educational practice. Consequently, epistemologies influence engineering activity systems as well, and as such, I find appropriate to use the six main components of Activity Theory as a framework for a cohesive way to present and describe three cases in which epistemologies have influenced and perhaps shaped what is known to be an engineer in the U.S. context. However although Activity Theory is a powerful tool to analyze an activity system, I would like to clarify that that is not my purpose. I will not use Activity Theory as a tool to discover contradictions between components of an activity system (Barab, Evans, and Baek 2004) nor as a tool for identifying boundaries (Gieryn 1999), but as a tool to aid the unification, organization, and synthesis of ideas presented by the authors.

Activity Theory is "a socio-historical approach for understanding human's thought, learning, and action within a whole activity system" (Park 2005). The six main components of Activity Theory are: subject, object, tools, rules, community, and the division of labor (see Figure 1.). Mappin (2000) described the six components of activity theory as follows: a) subject refers to the person or group engaged in the activity, b) an object is the goal held by the subject, c) the tools refer to the artifacts which help to achieve the outcomes of the activity, d) the community is formed by the people who share the same goal with the subject, e) rules regulate the actions and interactions of the system and f) the division of labor refers to the division of tasks as well as hierarchies among community members.

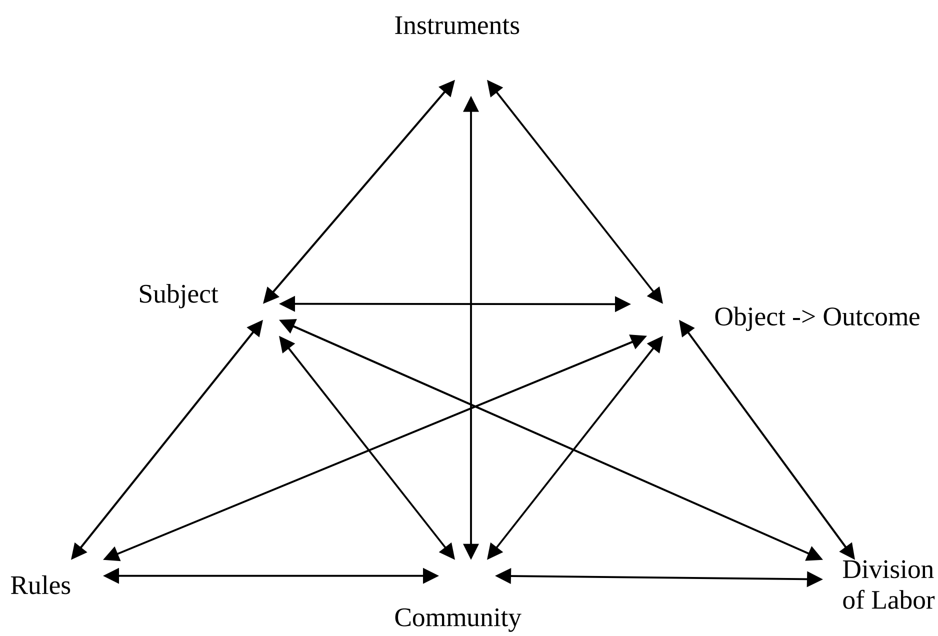

Figure 1: Activity Theory Triangle

To describe who an engineer is, what goal(s) engineers may want to accomplish, what tools an engineer needs in order to accomplish that goal, in which community the engineer operates, under which rules and constraints, which engineering activities the engineer performs, and how that activity is distributed within a community results in the intersection of all epistemologies that include institutional, professional, scientific and educational. A general engineering activity system would look as follows:

Subject— The engineer is the person who is involved in an activity. It may also include groups of engineers as well as organizations and institutions.

Object—The object is the goal held by the engineer(s) that motivates the activity giving it a specific direction (Nardi 1996). For example, the engineer(s) could have the goal of teaching students, publishing scholarly articles, developing a product, implementing a pedagogical approach, etc.

Tools—Tools, also called artifacts, mediate the activity in controlling people's behavior. These may take the form of instruments, machines, signs, language, etc. Artifacts may have embedded a particular culture and history (Kuutti 1991). For the case of engineering these tools may take the form of mathematical models, technology, heuristics, tacit knowledge, organizational and communication skills, etc.

Community— Community can be seen at two different levels. At the macro level we can consider the culture, and for this particular context, the history of the U.S. At the micro level we can think of communities such as professional organizations and educational institutions.

Rules— In the context or communities described above, rules that regulate interactions within the system may take the form of codes of ethics, professional organization membership requirements, scholarly peer review, and guidelines for tenuretrack promotion. Rules that regulate actions, for example, in a design activity may include mathematical models, natural laws, and science principles.

Division of Labor— Division of labor can be seen in two dimensions. In the horizontal line, the division of labor may include teamwork development, roles participants take in a design process, roles participants take in a peer review process, roles assigned to employees working on a lab, etc. On the vertical dimension, we can talk about the hierarchies in organizations as well as status. Examples of those could be organizational structures in academia and industry, and levels of memberships in professional organizations, respectively.

Epistemologies in Engineering: Institutional, Scientific, and Educational

Collective as well as personal positions about the nature of knowledge seem to influence almost every aspect of individuals' daily life (Driscoll 2000). In the following four cases, I present how institutional, scientific, and educational epistemologies influence aspects of engineering—i.e. an engineering activity system.

Institutional Epistemologies

In the institutional aspect, Layton (1971) presented us a case of a mixture between institutional and professional epistemologies. He discussed how professional associations were formed and how they set their standards of membership. In this context the *community* may be composed of the engineers who belong and do not belong to the professional societies, perhaps engineers in the U.S. The *subject* is the professional organization itself, and its engineering participants who can play roles such as scientists, professionals, businessmen, and students as well. The *object* in the system would be the purpose of a technical society; namely to increase knowledge. The *rules* may range from the standards of membership established to codes of ethics developed by those organizations. *Divisions of labor* are related to the roles the participants have, but also it can be described in terms of the hierarchies and levels of memberships—i.e. presidencies of societies, full memberships, restricted memberships, etc. Tools may include broad examples, but in particular, I will point out language as one of the most important since it is how the term engineer is defined and, therefore, is the basis for membership qualification. Through this case it is clear that institutions also hold conceptions of what counts as legitimate knowledge as well as how you know what you claim to know (Schon 1995).

Scientific Epistemologies

In the scientific realm Williams (2003) presented us a case in which she discusses decisions about hiring and promoting faculty members--i.e. the *object* or goal of the activity system. The community involved in this process is the academic *community*. The engineer candidate or faculty, Academic Council, and the Dean of Engineering among others are considered as the *subjects* of the activity system; each of them with specific tasks to accomplish or *division of labor*. *Tools* used in this review process may include classifications and heuristics developed over time within that community. For example, Williams discussed the types of engineering cases: the science case, the design case and the systems case. Williams also indicated *rules* as normal academic yardsticks fit. These include quality and quantity of publications, quality of academic peer reviews, comparisons with other scholars, list of inventions or innovations, managerial problems solved as the unit of accomplishment, etc.

This example is well tied with Robson's (2002) discussion of how the approaches to social research affect our conceptions of what "to be scientific" means. As we can see from the example just discussed, this in turn, shapes our research methods as well as the results of it. In the same way, Schon (1995) discussed three new forms of scholarships that are closely tied to questions of epistemology. These "new forms of scholarships" are: a) the scholarship of integration giving meaning to isolated facts, b) the scholarship of application seeking to solve practical problems, and c) the scholarship of teaching focusing on transforming and extending knowledge.

Educational Epistemologies

Svarovsky and Shaffer (2006) presented us with an example of educational epistemological beliefs influence the activity of teaching in a design course. The authors' belief was that metacognitive level strategies such as reflection and coaching will enable students to apply particular design strategies to novel contexts. The authors presented the sophomores of a Biomedical Engineering course as the *subjects* whose *object* or goal is to perform engineering design and the design instructor whose goal is to facilitate design learning activities. The main author's idea is that by means of weekly design meeting and student design notebooks used as *tools* will develop students' practical and reflective thinking. The *community* viewed at the micro level is compounded by the design teams while the community described at the macro level is the Biomedical Engineering course. Through the authors' descriptions we can also identify some roles as well as *division of* *labor* among participants. For example, Mark is the design advisor while Erik, Ken, Nicholas, and Jack are the design team who may have specific roles within the team too. Interestingly, the authors also discussed students' epistemic frames consisting of skills, knowledge and values, and related those to the epistemology of engineering.

Through the above described example we can see how the educational epistemological beliefs affect the extent in which students get involved in learning activities. These beliefs also affect the way in which professors use several instructional strategies. For example, an instructor may have the belief that the knowledge is constructed and relative to individuals. Probably she will select strategies such as discussion, collaborative activities rather than a more Socratic approach. Another example discussed by Schon (1995) of how institutional as well as educational epistemologies influence engineering education, is the way in which knowledge is contained in a curriculum and how it is organized in the instructors' minds and is communicated to students. This organization of knowledge is instructors' minds and how it is communicated to students is well described by Palmer (1998) and referred to as "the paradox in teaching and learning" (p. 61). Palmer discussed that the teaching and learning practice is undermined by a culture of disconnection in which thinking in polarities is embedded in the Western culture. Therefore, what Palmer suggests is that instructors adopt a holistic view in which head and heart, facts and feelings, theory and practice, teaching and learning, join to leverage teaching and learning.

Conclusions

I would like to conclude this essay by relating some issues discussed in the readings to my personal identity as an engineer. I am an information systems engineer graduated from Instituto Tecnologico y de Estudios Superiores de Monterrey (ITESM) at Mexico City. Considering Layton's (1971) balance between business and professionalism I represent one of those *subjects* called management-oriented engineers in which the line between engineering, management, and technology is hard to discern (Williams). The *object* of an information systems engineer is the influence, analysis, design, development, application, and integration of information technologies. As an Information Systems Engineer the most relevant technical *tools* I used were software engineering principles, modeling tools, heuristics of interface design, and programming languages among others. Managerial *tools* included marketing, economics, finance, organizational, and communication skills. *Rules* involved in the activities related to software engineering included the business models, modeling methodologies, principles of interface design, syntax and semantics of programming languages to name just a few. In a software development team the most common roles and *division of labor* were mapped to the software development life cycle. As business analyst I was in charge of identifying business requirements, as designer I was in charge of transforming those requirements to general representation programmers would understand, as programmer I was in charge to code and implement those system functions, and as tester I was required to identify and fix failures in the system. Other managerial roles played in a software development team were the project leader and projects coordinator who were in charge of keeping track of the project in terms of time and budget. Finally, the *community* I used to be part of was at the micro level, my software development team, and at the macro level the industry of software engineering and a variety of some others when I was assigned a project with a client. From the arguments described above, I can say that my ideology lies between the ideology of engineering and the ideology of business (Williams 2003) My degree was created as an expanding engineering degree in which "there is no longer a clear boundary between autonomous non-human nature and human-generated processes" (Williams, p.31).

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