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FILE: A TAXONOMY OF FORMAL AND INFORMAL LEARNING ENVIRONMENTS

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1. INTRODUCTION

As educational research expands beyond formal learning environments, it is important to identify dimensions and attributes associated with informal learning environments. Approximately, 85% of a person's waking hours between the ages of 5-17, and 98% of a person's waking hours across the lifespan are spent outside of the classroom (LIFE Center, 2005). Therefore it is critical to understand issues of self-learning and collaborative learning that occur outside of the formal classroom environment.

The FILE (Formal and Informal Learning Environments) taxonomy presented in this paper is based on a synthesis of published research findings and theoretical discussions of learning. The FILE taxonomy provides common schema for considering the differences between informal and formal environments. This schema is particularly important as the boundaries between informal and formal learning environments are often blurred.

The FILE taxonomy consists of four different scales of learning evidenced in both formal and informal environments: self directed/collaborative, active/passive, learner/goal oriented, and mandatory/voluntary. Additionally, we discuss an additional scale of monoculture/diversity that should be considered when designing learning environments to be culturally accessible to all learners. The scales were chosen based on characteristics of informal and formal learning as evidenced in research, and several of the scales were collapsed from multiple characteristics. The scales are then mapped onto eight common learning environments:

- Curricular Learning (anything during normal school hours)
- Learning in Designed Settings (science centers, museums, zoos, aquariums)
- Extracurricular Learning (tutoring, afterschool programs, design competitions, etc.)
- Outreach Learning (developed through an outside source)
- Learning from Media (books, television, games, social network, internet)
- Service Learning (e.g. Engineers Without Borders, Engineering for a Sustainable World)
- Everyday Learning (play, family conversations)
- Professional Learning (workplace learning, professional societies, internships, co-ops)

The eight common learning environments allow for cross-comparison of the scales, helping to distinguish the boundaries between formal and informal learning in each of these environments. The following sections will go in depth on the definition of the scales and how the eight learning environments fit within the scale. The eight common learning environments are presented in order that they map on the scale.

2. SELF-DIRECTED TO COLLABORATIVE

The defining characteristic of self-directed learning is the totality of responsibility that rests with an individual in defining the parameters of the learning experience: determining objectives, defining the contents to be learned and the progression of learning, selecting methods and techniques to be used, monitoring this procedure, and evaluating what has been acquired (Holic & Council of Europe, 1981). The importance of self-directed learning is largely due to its far-reaching presence within the daily experience of people. Self-directed learning in an informal environment occurs whenever people learn by themselves through the observation of reality. Beyond independent observation, more structured yet still independent/autonomous learning environments are also widely available in the form of mass media – books, television programming, internet web sites, and computer software.

Collaborative learning is more than just the presence of multiple individuals learning together. For learning to be collaborative, a supportive environment must exist where individuals of a group work towards the same ends. The importance of collaborative learning is that it allows individuals to learn skills that could not have been learned alone (Mayberry, 1998).

2.1 Curricular learning

In traditional K-12 pedagogy, learning is neither self-directed nor collaborative. Instead, the learner is dependent on the teacher to 'direct what, when, how a subject is learned and to test that it has been learned' (M. K. Smith, 2002, p. 6). However, since the call to restructure science education in the late 1960s, the classroom culture of learning since the mid-1980s has shifted to rely on students to 'actively participate in a network of informal social relations and work in collaborative learning settings' (Maryberry, 1998, p. 445).

2.2 Learning in Designed Settings

Designed settings provide environments for learners that are free of the 'strong cultural pressures to participate or achieve a particular goal, as they may be pressured to do in schools, educational programs, or workplace settings' (National Research Council & Committee on Learning Science in Informal Environments, 2009, p. 128). Because learners are allowed to freely operate, the level of a learner's participation in designed spaces takes on a self-directed character that relies mainly on the learner's own motivations.

2.3 Learning from Media

Media provides learning opportunities that are both self-directed and collaborative. For instance, the act of watching a documentary about killer whales may seem very self-directed, but if the same documentary were shown in a biology class and later discussed in the class setting, the same documentary offers collaborative learning opportunities.

The availability of interactive media further provides collaborative opportunities for learning. Video games create interactive environments for teams of players that teach scientific concepts to participants as they play. For instance, the video game *Portal* 2 is designed in such a way that players must collaborate with one another to complete levels within the game. Players must coordinate with one another to move through a level by properly harnessing their own inertial forces. Along the way, players learn about physical concepts like linear momentum.

2.4 Extracurricular Learning

Whether looking at extracurricular activities from a K-12 or an adult learning perspective, it is hard to not identify them as highly collaborative learning environments. Extracurricular activities use the commonality of shared knowledge interests between individuals as to create opportunities for collaboration. Activities such as band or athletics exemplify the use of shared knowledge interests to join individuals together to accomplish goals that would not have been performed separately.

2.5 Everyday Learning

Everyday learning environments are more self-directed, but still offer many collaborative opportunities. Everyday learning tends to be self-directed when it occurs spontaneously. Spontaneous everyday learning often lacks collaboration because collaborative learning usually takes planning to coordinate. For example, a researcher documented a boy during the course of fishing. After observing a fish dying after it was taken out of the water, the boy asked, "Why do fish die outside the water?" (National Research Council & Committee on Learning Science in Informal Environments, 2009, p. 94). Due to the situation's spontaneity, it is possible to turn the boy's question into a collaborative learning experience.

In more deliberate pursuits that have a direct goal of learning, both self-directed and collaborative learning opportunities are available. A model airplane hobbyist with a self-directed goal of building new types of aircraft may learn concepts about aerodynamics along the way (National Research Council & Committee on Learning Science in Informal Environments, 2009, p. 194). In contrast, a volunteer interested in restoring woodland habitats may learn a lot about forestry through collaboration with other volunteers planting trees.

2.6 Service Learning

Service learning environments share a similar trait with extracurricular environments in that participants often share similar interests. This allows for collaborative learning to be more easily facilitated and gives service learning its collaborative quality. Service learning environments can

span formal and informal environments. Some programs, like EPICS (Engineering Projects in Community Service) or SLICE (Service Learning Integrated throughout the College of Engineering) are structured as part of students' curricular experience—students attend some lectures while also meeting with their community partners. Students complete course deliverables and receive course credit, but also negotiate their own learning plans and develop their own strategies and agendas for accomplishing their design goals. However, other service learning experiences are primarily situated only in the extracurricular and informal spaces. Engineers without Borders and Engineers for a Sustainable World are examples of these and the focus of our discussion of service learning.

2.7 Professional Learning

Professional learning environments are often self-directed. The direction of learning engaged in by a participant can be self-motivated but also depends on the support of the partner or employing organization to provide the right resources and accommodations. Many engineering learning experiences in organizations however are group or mentored experiences where the collaboration with a working peer, trainer, supervisor, team leader, project manager or partner is the catalyst for the learning experience.

2.8 Outreach Learning

Outreach learning environments may rely more on the self-direction of a student to guide the learning experience than on collaboration. If joining an outreach program may not have always been the student's choice, what the student chooses to learn often is. In this way exposure to community programs can be opportunities for learning or at least exposure to other types of people and value systems.

3. ACTIVE TO PASSIVE

Active learning may be observed in environments in which students are "engaged in the learning process" (Bonwell & Sutherland, 1996) by "doing things and thinking about the things they are doing" (Bonwell & Eison, 1991, p. 2). Conversely, passive learning may be identified by activities in which "students generally are exposed to information, yet rarely given the opportunity to process it" (Shakarian, 1995).

3.1 Curricular Learning

Current "traditional" teaching practices involve teachers dispensing a series of facts to students who later reiterate them on an exam. Students often sit passively in class listening to the teacher speak, reading from a textbook, or completing worksheets. Rote learning is the norm in the modern day classroom but reform efforts aim to incorporate more hands-on learning in the classroom; however the extent to which active learning exists in the classroom is, largely, at the discretion of the teacher (Kohn, 2000; Shakarian, 1995). Some environments are hard to classify as active or passive because the level of involvement in certain environments (i.e everyday learning or extracurricular learning) is up to the individual.

3.2 Learning in Designed Spaces

Over the years designed spaces have become promoters of active learning, however the extent of active learning varies greatly between designed settings.

Museums and Science Centers. "The educational value of museum collections lies in the displays of objects and interactive exhibitry" (Ramey-Gassert, Walberg III, & Walberg, 1994, p. 349). The nature of these exhibits allows visitors to manipulate objects, observe scientific phenomena, or conduct investigations (NRC, 2009)

Zoos. Thompson and Diem (1994) describe how zoos incorporate a variety of means to educate visitors by implementing strategies that will entice kinesthetic, auditory, tactual, and visual learners. Zoo-keepers and other employees provide discussions and lectures via Meet-a-keeper talks, providing detailed signage about the animals, items visitors can touch (i.e. snake skin or animal hair), or partake in educational toys, games, or activities.

Aquariums. Of the designed spaces discussed, aquariums appear to be the most passive as they primarily provide a "visual experience and conveyance of information through visual methods" (Bruce & Walker). Aquariums do include some interactive exhibits, for instance: allowing visitors to touch or interact with animals, allow visitors to look through a lens and see as certain fish might, or lift doors to expose images (Kodi and Wandersee, 1996); however it is the nature of the interaction that determines if active learning is occurring.

3.3 Learning from Media

Classifying the forms of media as either active or passive learning is challenging. Media sources such as television, books, movies, and the internet are easier to classify as passive because people are primarily listening or reading (Rockman, Bass, & Borland, 2007). Games on the other hand can be more active; for instance Horton, Liu, & Olmanson (2011) use a PBL based game that allows players to conduct research, perform scientific investigations, and make decisions.

3.4 Extracurricular Learning

There area variety of after-school programs, each with dfferent goals, such daycare, tutoring/homework help, and academic enhancement programs. Programs such as the Homework Zone described in Weisburd (2005) give students a place to work on homework, study, or give/get assistance with schoolwork. These after-school programs are predominantly paossive although sometimes students work on problems together.

After-school programs that are more academic, such as the Robotics 4-H program discussed in Barker and Ansorage (2007) promote active learning. In this program students used robots to learn programming and other engineering, science, and technology concepts. These robots provided a real-world context and allow students to see various science, engineering, and technology related principles in action and offer students time for reflection.

4. LEARNER CENTERED TO GOAL-ORIENTED TEACHING

Learning-centered education is a framework in which the focus is on learning without a specified outcome in mind. In this setting, the emphasis is on the process of learning rather than the content to be learned. The learner holds the primary responsibility for what is learned, in what manner or context. The knowledge gained in learning-centered education is sought out for its own sake, without an external motivation (Houle, 1961).

Goal-oriented education is designed with a specific goal, objective or outcome is intended (Houle, 1961). While learning occurs in many situations independent of a particular goal, goal-oriented education involves instruction "where there is a deliberate attempt to promote learning of specified knowledge or skill (Oswald & Reigeluth, 2002)." In a goal-oriented environment, students are placed in an situation where they have to achieve some goal, objective or outcome. The designation of a situation as goal-oriented does not limit the instructional methods employed, it simply implies that instruction towards a specified goal is occurring.
While both goal-oriented education and learning-centered education can be found in formal and informal environments, one can generalize that goal-oriented education occurs more often in formal environments and learning-centered education occurs more often in informal environments. However, increased pressure to assess outcomes has led to a tension in informal education regarding goal-oriented influences:

> "The challenge of developing clear and reasonable goals for learning science in informal environments is compounded by the real or perceived encroachment of a school agenda on such settings. This has led some to eschew formalized outcomes altogether and to embrace learner-defined outcomes instead. The committee's view is that it is unproductive to blindly adopt either purely academic goals or purely subjective learning goals. Instead, the committee prefers a third course that combines a variety of specialized science learning goals used in research and practice (National Research Council & Committee on Learning Science in Informal Environments, 2009, p. 3)."

4.1 Curricular Learning

The typical curricular structure in which students are led through educational experiences with learning outcomes designed with a specific goal, standard, or criteria in mind can be understood in this context as goal-oriented education. A framework for curriculum development and instruction using ABET engineering criteria as a goal is provided by Felder and Brent. The authors provide guidance on how to convert ABET criteria into course specific objectives, instructional techniques to meet those objectives, and appropriate assessments. Within this structure, instructors determine the objectives of courses and curriculum by meshing the instructor's goals with overall program outcomes. Instruction is then provided through a variety of methods that provide the setting for students to meet the predetermined goals. A variety of assessment methods may be used to determine if students are meeting the desired goals (Felder & Brent, 2003).

However, there is some interest in facilitating learning-centered education within higher education. Huba and Freed's Learning-Centered Paradigm provides a structure for how learning-centered education may be understood in the college setting. Within this framework, students construct knowledge through gathering and synthesizing information and integrating it with the general skills of inquiry, communication, critical thinking and problem solving. There is an emphasis on generating questions regarding enduring and emerging issues and problems in real-life contexts, in an approach compatible with interdisciplinary investigation. Instead of instructors setting predetermined learning goals, professors and students learn together and evaluate learning together in a collaborative and support climate. In this environment, assessment is used to promote and diagnose learning, with the acknowledgement of learning from errors (Huba & Freed, 2000).

4.2 Learning in Designed Settings

Learning in designed settings is most likely to operate within learning-centered education, despite increased pressure to assess outcomes. Designed settings provide the environment for discovery in which a learner constructs knowledge by interacting with the world or representations of the world (National Research Council & Committee on Learning Science in Informal Environments, 2009). "Learning is at its peak when individuals can exercise choice over what and when they learn and feel that they control their own learning. Because museums are quintessential free-choice learning settings, they more often than not afford visitors abundant opportunity for both choice and control. When museums try too hard to mimic compulsory education or force specific learning agendas on the public, they undermine their own success and value as learning institutions (Falk & Dierking, 2000, p. 138).

4.3 Extracurricular Learning

A common form of extracurricular learning dealing with the discipline of engineering is robotics competitions. Robotics and other design competitions usual include a predetermined goal that can be met in a plurality of student designs. While much of the research in the area deals with robotics competitions as a method to increase participation in STEM fields, researchers are also seeking to understand how robotics and other design competitions can be used to meet desired outcomes or goals (Barker & Ansorge, 2007). In this manner, we may understand extracurricular learning as situated within goal-oriented education. As demonstrated by Barker and Ansorge, assessment techniques may be used to measure students' achievement of specified goals. Overall, extracurricular learning may be leveraged to assist curricular learning in meeting specific goals, objectives, standards or outcomes.

4.4 Learning from Media

While examples of learning from media can be found that demonstrate both learning-centered education and goal-centered education, the primary focus of research in this area is concerned with how to harness learning from media to meet goals or outcomes (National Research Council & Committee on Learning Science in Informal Environments, 2009).

4.5 Everyday Learning

Everyday learning by nature is independent of any explicit goal (National Research Council & Committee on Learning Science in Informal Environments, 2009). With this in mind, we may classify everyday learning as learning-centered.

5. MANDATORY VS VOLUNTARY

The mandatory or voluntary status of a given learning environment is determined by the degree of influence of larger institutions, organizations or individuals in a local learning environment. For instance external forces like law (Weber 1978), institutions like a school or university (Smith 1999), or roles like teacher or parent (Lukes 1986; Hagel & Powers 1992) compel a learner to be situated and active in a local learning environment by having sanctions for noncompliance. Sanctions are penalties that are enforced by some larger institution, person in a particular role, etc. For instance grade schools often have limits on how many absences a student can have. After reaching that threshold the students may be given detentions, have their parents notified, have their grades affected and so on. The point of these penalties is to compel a learner to be situated and active in a certain learning environment. Depending on the relative presence or absence of sanctions, the learning environment is more or less mandatory/voluntary.

5.1 Curricular learning

Particularly at K-12, where at least in the United States children are legally required to attend school (a federal level law) there is considerable social structure compelling students to attend and sanctions from both the school and the government for not attending. This effect is not as strong for college, as college is not mandated at a federal level, so sanctions or negative outcomes, like failing a class, are mostly given by the institution making both K12 and college mandatory learning environments.

5.2 Professional learning

Learning that happens in this environment is connected to place of work which in some cases is tied back to a school as well. Students may be required to enter internships or coops as part of their degree in some cases or may be able to opt into such programs, allowing for some voluntary action. However, once in an internship or coop there are sanctions for not coming to it, such as losing pay if it was a paying position, being asked to leave or having it affect the school program the student is in. Most learning however in a professional learning environment is voluntary not mandatory.

5.3 Service Learning + Extracurricular Learning

Looking at the mandatory/voluntary dimension, it is hard to distinguish between these two environments. Both allow for voluntary entry, but once a student has entered there are sanctions for not meeting expectations (like failing to show up to practice or not contributing to a design project) that can result in being removed from a team or not be able to participate as fully as

others. Sanctions in these environments, however, are potentially less varied than those in professional learning as students will not normally receive pay and service learning and extracurricular learning may not as be linked as strongly with curricular learning or a particular degree. And in one sense, possible sanctions from the community a group is designing for in service learning (disappointment, dissatisfaction with how something is designed) could be much stronger than those received from athletics or band, putting some space between service and extracurricular learning.

5.4 Outreach Learning

Outreach learning are typically more ephemeral in nature and often have more open boundaries (Song 2009)--that is people can choose to attend or not to attend--than service and extracurricular learning above, where there is some expectation for regular attendance. An institutuion such as a university invite an outside speaker, but that outside speaker will not likely have the same ability to penalize students for nonattendance, for example. Unlike designed settings below, outreach learning usually has a more focused set of learning outcomes (Wiggins & McTighe 1998) as part of the outreach mission.

5.5 Learning in Designed Settings

While sometimes a school may require students to go to a museum or zoo, many visits to these places involve no direct institutional action (e.g. a school busing students there), contrary to the environments above (NRC 2009). Parents may take their children to a zoo or aquarium but the external influence in these environments is familial role, such as a parents obligations to a child, not a larger institution like a school or business. Unlike tutoring or a design team that must address certain topics, in a museum the person has more freedom to attend and not attend to what he or she is interested in. Thus in designed settings less compulsion to cover particular topics or in cover them in a particular order, allowing for more voluntary action.

5.6 Media Learning

Media learning is distinguished from other learning environments because it can be deployed in many of the learning environments above (NRC 2009). Within one of the environments above media learning takes on the same mandatory/voluntary rating of the environment it is being used in. For example, in the classroom if students are required to participate in an online community, then that 'learning' is rather mandatory as long as it is compelled with the same sanctions as other actions in curricular learning. Removed from any of the above environments, media learning is leans more toward voluntary, again there may be an interpersonal relationship that exposes them to media, but there is more discretion to view/participate in these media forms (and a much wider selection of media to select from than a designed setting) and there are less appreciable sanctions for the learner (NRC 2009).

5.7 Everyday learning

This one ranks as the most voluntary of all the environments. While again there may be interpersonal relationships that compel someone to be situated in an everyday learning

environment, a lot of these learning environments are just chanced upon or sought with little compulsion from larger institutions like a university or business (Jarvis 2006).

6. MONOCULTURE AND DIVERSITY

A valued imbued within formal and informal learning environments is the accessibility of learning to all individuals, regardless of gender, race, ethnicity, ability, and socio-economic status (NRC, 2009, p. 209). All learning environments should represent a safe and inviting space for all to learn. However, considering learning engineering in informal environments, one might observe a tension between the approachable realm of the "informal environment" and the well-recognized, historic underrepresentation of women, minorities, and people with disabilities win the realm of learning or practicing "engineering" (NSF, 2011).

While we did not explore this underrepresentation in depth here, we do note that such underrepresentation might indicate that the culture of these underrepresented groups might not be congruent with the "culture" of engineering. Though a concept worthy of much discussion, we define culture in a broad sense her here as "includ[ing] symbols, stories, rituals, tools, shared values, and norms of participations that people use to act, consider, communicate, assess, and understand both their daily lives and their images of the future" (NRC, 2009, p. 210). Though engineering has been traditionally viewed as purely within a technical/scientific culture and socially neutral (Bucciarelli, 2003, p. 40), several have argued that the culture of engineering, in fact, is what limits access to the profession by some of the underrepresented groups mentioned earlier (Foor, Walden, and Trytten, 2007; Faulkner, 2009).

We describe two approaches that are used by formal and informal learning environments to ameliorate cultural disparities with engineering experienced by some who engage this profession.

6.1 Diversity

The first approach is designing the learning environment (formal or informal) to ensure that it solicits and encourages diversity. Though the report is addressed to teachers of formal learning environments, the NRC (2000) report *How People Learn: Brain, Mind, Experience, and School* propose that teachers create environments that are focused on the learner, "recogniz[ing] the importance of building on the conceptual and cultural knowledge that students bring with them to the classroom" (NRC, 2000, p. 134). This spirit captures the essence of intentional programs that foster diversity. One example of many intentional efforts to ensure diversity in a learning environment is Olin College's intentional selectivity of students with consideration of gender balance and multiracial presence (Olin College: Admission, 2011)

6.2 Monoculture

The opposite approach to engendering accessibility to learning engineering is designing the learning environment to be a monoculture, that is, consisting of a group of individuals with a common, typically underrepresented, culture. Examples of such learning environments include the primarily African-American women Computer and Robotics Education (CARE) Camp at

Spelman College (Spelman C.A.R.E., n.d.) as well as the learning environment experienced by participation in the Society of Women Engineers (SWE, 2011). Such programs as these typically do not restrict other social groups from participation, but they are specifically intended to provide a safe place for individuals to learn engineering with a support group from a single, shared culture.

6.3 Classification Learning Environments

Though diversity and monoculture are seemingly opposite terms, we note that they are *both* paradigms sought after in order to avoid hegemony (that is, in this context, fostering the message that engineering is a white male profession). Examples of programs that incorporate diversity in their ethos would include any learning environment that considers multiple cultural voices. For example, designing a museum to include free nights makes the learning environment more accessible to those with a lower socio-economic status. When we examine the eight common learning environments identified earlier, we could find some examples that incorporate intentional diversity in the program as well as some examples that foster a monoculture environment.

For this reason, we suggest that placement on the monoculture vs. diversity spectrum relates more to an individual program's objectives than it does to the eight generalized learning environments that we describe earlier. The general learning environments, however, seem to typically not take a highly intentional approach to combat hegemony, as can be inferred from the continued existence of underrepresented groups in engineering (Foor et. al, 2007; Faulkner, 2009; NSF, 2011). However, we presented this section to encourage those designing learning environments to intentionally consider methods of providing accessibility to a broad range of learners.

7. DISCUSSION

In order to generate a visual representation, each of the authors individually mapped the eight common learning environments based upon the strength of association with the characteristic of the scale. This allowed cross comparison of the placement to account for personal bias. The authors then met to resolve any issues with the combined diagram (Figure 1).

By mapping the environments onto the scales for both informal and formal learning, certain trends appeared. Curricular and were firmly rooted in formal learning environments, whereas everyday learning, design settings, and service learning were in classified as informal. Media, outreach, extracurricular learning, and professional learning transverses both formal and informal learning, hinting at a synergy between these environments in learning. For example, a lesson plan could be developed around a popular children's book to encourage discussion about a standardized topic.

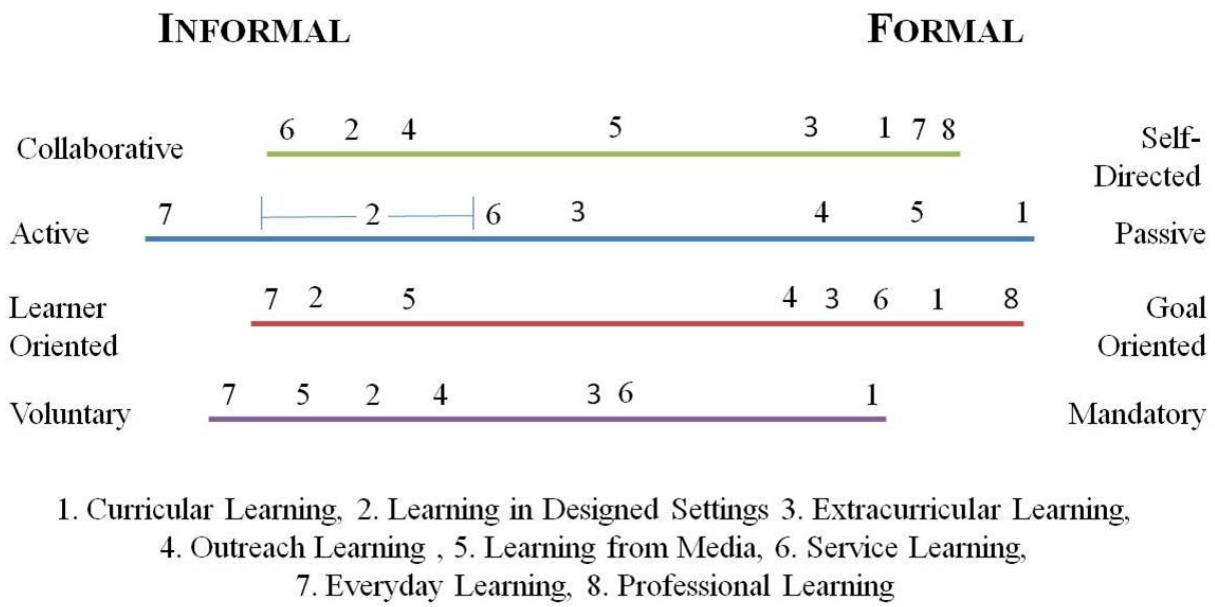

Figure 1. Tornado diagram of environments to scales of formal and informal learning.

The presence of informal learning environments does not override the use of formal learning environments. Nevertheless there are times when formal learning environments present constraints (e.g. time) that inhibit what can be learned or in other cases formal learning, represented here as curriculum learning, may not be the best environment for a particular topic. We now briefly explore how the FILE taxonomy can be used to assist a teacher in considering informal learning alternates when formal learning is insufficient for one of the reasons above or others.

Imagine an all too common scenario where there simply is not enough time to address all the content in a course. Suppose some of the content provides additional depth, but is not critical to a basic understanding of the core of the class. What would be some options for informal learning environments that could be leveraged in absence of time to address it in class? The dimensions of the FILE taxonomy can be used to provide guidance for questions like these. Immediately, looking at the mandatory-voluntary scale, we can mark off many of the more mandatory environments like professional learning or extracurricular and service learning. These require substantial commitment likely exceeding the import of supplemental material. Likewise designed settings are probably not the ideal choice as they are learner-centered, and with supplemental material there is a specific goal of learning that material. Everyday learning, media learning and outreach learning remain as possible options.

Everyday learning is the most difficult to leverage for a teacher, but media learning and outreach learning are two avenues that hold potential. The active-passive dimension of FILE indicates that some media learning is more active than others, for instance games instead of videos or text—the availability or ease of generation of these also depend on the educator and their resources. It may also be possible to find an outside speaker or workshop that students could be

encouraged to attend that covers the supplemental topics. Both of these environments can be self-directed or collaborative environments, depending on their structure. Examining the educational problem faced by an educator through the FILE taxonomy allows them to weigh and compare the utility of different informal environments. While other considerations may arise when applying FILE, this example attempts to illustrate how an educator might go about using it to assist to curricular limitations.

8. CONCLUSION

This taxonomy provides a conceptual tool useful for both educators and researchers in the design of learning environments. Educators may benefit from the opportunity to consider a variety of aspects of learning, and how formal environments might incorporate some of the beneficial aspects of informal learning experiences as well as make connections between learners' formal and informal environments. Researchers may benefit from this conceptual tool as it provides a schema for considering future research opportunities designing engineering learning across a range of learning environments.

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