SEARCHING FOR SYMBIOSIS: OPPORTUNTIES AND OBSTACLES IN FORMULA SAE TEAM/SCHOOL ADMINISTRATION RELATIONSHIPS

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ABSTRACT

While engineering student project-based learning teams are primarily focused on their main goals, they also operate within the larger administrative context of their home school. In an ideal world, team and administration goals are symbiotic and furthered by mutually supportive policy and action. However, there are many potential points of contradiction between a team's goals and the concerns of the school's larger administration. Student team leaders often face the daunting task of managing their workflow while balancing administrative and legal priorities that may seem counterproductive or even hostile to team goals. Given the unequal power relations at play, ignoring administrative goals is often not an option - failure to comply to administrative rules and norms can lead to consequences that can threaten the team's very existence.

This paper highlights examples of team/administration cooperation and conflict from a particular PBL team context – Formula SAE (FSAE) automotive racing teams. Members of teams participating in the North American FSAE competitions from 2013-2015 shared specific stories of team/administration cooperation and conflict in written surveys and competition site interviews as part of a larger dissertation research project. Team experiences with administration vary from symbiotic, supportive relationships to ultimately detrimental to team success. While a positive relationship with administration doesn't guarantee an FSAE team will be successful, such a relationship does remove significant barriers to team success. This paper suggests CDIO standards provide a framework to help school administrations advocate for the resources that can best assist FSAE and similar student-managed project-based learning engineering teams.

KEYWORDS

Project-based learning, active learning environments, Formula SAE, student project teams, CDIO Standards 3, 5, 6, 7, 8, 9

INTRODUCTION

Student engineering project-based learning teams are intensive learning experiences where groups of students collaborate to achieve specific technical objectives that are often framed and evaluated by external agencies. Consistent with CDIO Standards 5 and 7, students in such teams not only develop applied knowledge of engineering concepts, but also develop critical professional skills such as systems engineering, collaborative work, team leadership, and effective oral and written communication (CDIO, 2018).

This paper suggests one critical management skill team leaders develop is negotiating a balance between team goals and those of their supporting school. Student engineering project-based learning teams require the support of their larger administration. A strong relationship with school administration removes many potential barriers to team success, whereas a problematic relationship with school administration can lead to considerable headaches and even jeopardize the team's existence, given the goals of administration are likely to trump a team's particular needs.

This paper examines findings from survey and interview research done in conjunction with the author's larger dissertation research on information management concerns in one particular project-based learning context, Formula SAE. The primary goal of Formula teams is to design, manufacture, test and race a small formula-style racecar. Student Formula teams have a long history and international reach, with over 500 student-managed teams competing in over 10 intercollegiate competitive events worldwide (FS World, 2018), the largest two of which are sponsored and structured by the Society for Automotive Engineers (SAE). As will be discussed below, Formula SAE teams have varied experiences in dealing with their home institutions that can range from mutually supportive to combative. This paper also argues that CDIO standards can help structure mutually beneficial symbiotic relationships between Formula SAE teams and their larger administration.

THE TEAM/ADMINISTRATION RELATIONSHIP IN THE FORMULA SAE CONTEXT: A CULTURAL-HISTORICAL ACTIVITY THEORY (CHAT) PERPSECTIVE

This research is founded on cultural historical activity theory (CHAT). CHAT is a meso-level theory grounded in human activity and the larger cultural and political forces that enable and constrain it (Engeström, 1987). Developing from roots in constructivist learning (Vygotsky, 1978), CHAT notes that a team's core activity is necessarily constrained by rules, community and division of labor, which pose the possibility for contradictions that need to be attended to in order for the core activity to be successful. As presented previously at CDIO, this theoretical model shows promise as a means of framing research questions across numerous specific case studies (Jones, 2015).

The below diagram represents the six core components of CHAT, visualizing "…the individual practitioner, the colleagues and co-workers of the workplace community, the conceptual and practical tools and the shared objects as a unified dynamic whole." (Engeström, 1991, p. 267).

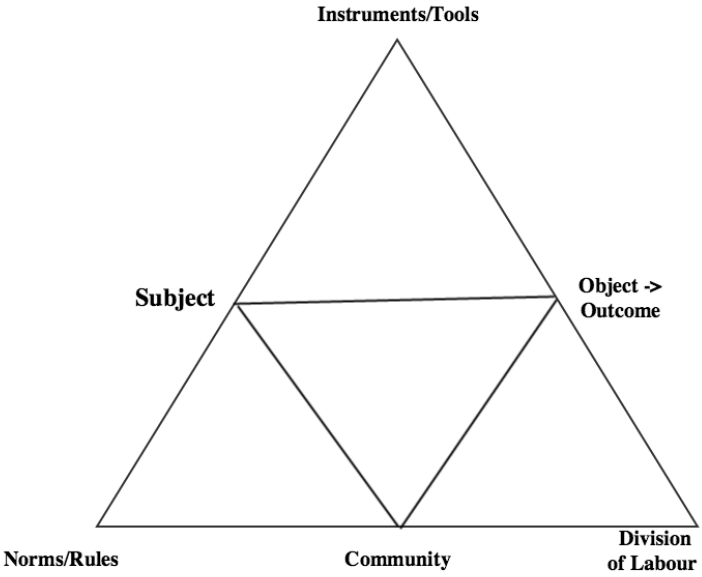

Figure 1: Engeström's representation of cultural-historical activity theory
(adapted from Engestrom, 1987; 1991)

In the top triangle, we see Vygotsky's (1978) construction of a core activity - a relationship between subjects and their intended objects/outcomes mediated by tools (also translated from original Russian to instruments or artefacts). The subject can be either an individual or collective, depending on the level of analysis. As varying instruments/tools may lead to objects of varying quality and value, subjects must reconcile varying results of creative engagement to arrive at objects that best related to intended outcomes.

Complicating matters are the lower components that ground activity in social and historical foundations. *Community* includes all others that may be affected by the subject's desired outcome. *Norms/Rules* (referred to as praxis in some translations) are both written rules and procedures and unwritten norms that govern interaction. These are necessary to mediate social order and help regulate larger questions of justice, ethics, and morality. *Division of labor* acknowledges that power relations are often unequal, leading to political negotiations to ensure the overall outcome of the activity can be attained.

Relations among these six core components can yield many different types of tension, which Engeström (2008) denotes as contradiction.

Contradiction	**Description**
Primary	Differences *within* a given node in an activity system (e.g., competing interpretations of goals by individual subjects)
Secondary	Differences *between* two given nodes in an activity system (e.g., interactions among subjects, instruments/tools and object)
Tertiary	Change in activities *over time* (e.g., evolution of an activity such that later versions significantly differ from previous)
Quaternary	Differences between *two competing activities* (e.g., two subjects attempting to achieve the same outcome)

Table 1: Engeström's outline of contradictions
(adapted from Engeström, 2008)

An understanding of CHAT and its contradictions helps frame potential research questions regarding FSAE team work and the team's relationship with its home school. While the team uses various instruments/tools to build and refine relevant objects, it does not do so in a vacuum. The team exists in a larger academic community that has its own norms, rules and responsibilities, creating potential secondary contradictions between the core activity and all three of the cultural/political dimensions of CHAT. Given school administrations have broader fiduciary, resources, and legal responsibilities, any serious quaternary contradiction between administration and team outcomes is likely to resolve in favor of administration priorities.

FSAE team leaders must negotiate this web of interrelated factors with caution else larger, more powerful forces beyond their control intervene to suspend team activity. Given that team leaders are often quite focused on their own core activity and might be less versed in the responsibilities and details of their surrounding bureaucracy, there are multiple points of contention and contradiction that may arise. Through survey responses and competition interviews done in 2013-2015 as part of larger dissertation research, team members were asked to reflect on their relationships with their school's administration. Specific reflections are shared here by reference number – an anonymized table of respondents can be found in the larger work (Jones, 2017).

DISCUSSION

While most FSAE team members surveyed or interviewed noted that team/administration relationships were positive, they were often eager to share events that complicated their progress towards the team's core activity. This paper suggests schools that live by the intent of the following CDIO standards (whether members of CDIO or not) are more likely to provide a more supportive environment for their FSAE teams. However, even in such environments, points of contradiction can occur.

CDIO Standard	Description
3	**Integrated Curriculum:** *A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills*
5	**Design-Implement Experiences:** *A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level*
6	**Engineering Workspaces:** *Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning*
7	**Integrated Learning Experiences***: Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills*
8	**Active Learning:** *Teaching and learning based on active experiential learning methods*
9	**Enhancement of Faculty Competence:** *Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills*

Table 2: Relevant CDIO Standards (CDIO, 2018)

Securing Resources

A central concern for all FSAE teams is securing adequate resources to sustain their activity. Key resource requirements include financial support, access to specialized space and tools, and integration of team activities in academic planning and programming. On all three team experiences vary, often considerably.

Financial support is a core requirement for team success. A team starving for resources will find it difficult to secure key materials needed to manufacture the car or have the resources to attend competition. This becomes especially relevant for teams distant from competition venues or those who wish to explore distant competition opportunities. As a result, well-established FSAE teams will dedicate specific team members dedicated to sponsorship, industry liaison and school funding matters. This role is often how non-engineering students become involved with the team's core activity.

While some teams were reluctant to share financial information, enough respondents did respond to paint a quite varied picture of the fiscal landscape. For example, respondent #9 noted an annual contribution of US$60,000 from their school, while #17 and #25 both shared an approximately USD$20,000 figure. Respondent #32 was lobbying the student association to install a student activity fee to raise approximately US$15,000 a year. Faculty advisor #37 said the student association provided US$25,000 in funding, on top of facility support to be noted later.

At the other end of the spectrum, student #43 suggested they were struggling with trying to leverage an initial CDN$5000 administration grant – and this team has since disbanded. While money doesn't necessarily buy success, it is not hard to see how #43's struggles are qualitatively different than #9 or #37's significant outlays. Schools willing to allocate funds for student team success create an environment where team leaders can focus on their core activity without needing to dedicate core resources to fundraising.

Perhaps more essential is access to the space and tools required to legally conduct the core activity of building a racecar. FSAE teams require specialized machinery that come with significant safety and physical plant requirements. It is not an academic activity you can accommodate with a generic classroom. Given space is a key point of conflict in academia, having institutional relationships to secure access to space becomes a point of concern.

CDIO Standard 6 encourages school administrations to provide such spaces. For some teams, access to space and tools happens due to a strong and supportive administrative commitment to project-based learning teams. Facutlty advisor #37 noted:

> "For space, the team has space within what is called the [X], a 24,000 ft^2 space dedicated to the support of our student engineering competition teams. Each team within this space (there are currently 7 hosted) has office space, dedicated build and storage space, and access to the common machine tools. X is open 24/7. It has machine tooling available 24/7, up through 3-axis CNC mill. The school staffs a ½ time machinist/staff support person dedicated to the infrastructure support of the X and its teams." [#37]

This is gold standard practice – and not surprisingly, #37's team is a perennial contender in FSAE competition. However, most teams surveyed or interviewed did not note having full buildings dedicated to project team activity. #43 not only struggled with limited financial

support, but a working space that doubles as a loading dock. More common would be the experience of respondent #27, who stated they have "about 800 sq. ft. of dedicated space, but down two alleys – it's actually kind of scary to get there." [#27]. While FSAE teams will make do with what space is allocated to them, a school that actively supports teams with ample and accessible space creates the conditions where team activity can happen with minimal interference.

Another way a school can support a team's activity is through curriculum integration. Some teams are "clubs"– an extracurricular activity not otherwise integrated into curriculum. While one might think club teams are not likely to be successful, this is not necessarily the case – respondent #3 noted his team is a club that does not receive course credit, but is nevertheless one of the perennial contenders in the Michigan competition.

Some schools have a capstone design project course in the final year of their academic program, and team design projects can usually qualify for inclusion. Three respondents (#16, 21, and 23) noted they were presently getting course credit through a capstone course. Outside of formal capstone courses, respondent #8 explained "we do offer an engineering elective for FSAE participation provided certain prerequisites are met (you must have been on the team for at least a year and are currently holding a prominent design role)." [#8]

It should be noted that even where course credit is granted, participation is largely extracurricular. Some team members note full-time job equivalent level workloads on FSAE team work, and others note work done greatly exceeds what is normally done for similar credit hours. However, schools that offer capstone design or elective credit are acknowledging that such project work has value and relevance to the curriculum. This can help defend the project within the context of the academic community, allowing faculty to see this as part of the educational experience versus a club distracting students from their day-to-day academic work. Offering course credit can help mitigate any contradictions between the core activity of the team and the larger academic community.

CDIO Standards 3, 5, 7 and 8 could have relevance on this particular issue. The more integrated into curriculum an FSAE team member is, the more likely their core activity can be tied to core learning outcomes, and the more likely the program will appreciate and respect the efforts of FSAE members as they engage their core activity. Teams that are designed as "clubs" automatically operate at the disadvantage of being not "real" in the eyes of curriculum planners and administrators.

Navigating Rules and Procedure

A major point of contention can be integrating team activity into the larger bureaucracy of a school's administration. Student team leaders may not be immediately aware of or sympathetic towards the requirements of their overarching administrative structure. For example, respondent #11 was the point person for internal and external relations for their team, and noted that they spent a lot of time working with "the Foundation", the unit which handles charitable donations.

> The Foundation requires that we get all external communication approved by them before sending out. This includes newsletters, sponsorship packets, and thank yous. They also require that we report all charitable donations that our organization receives, both monetary and gift in kind donations. It's been a little difficult to get all

> team members to get on board with this and get the required forms turned in in a timely manner, however, we are slowly making progress." [#11]

Her reflection showed no shortage of frustration over such boundary negotiations, but it was equally clear that these negotiations were necessary to process and acknowledge alumni contributions appropriately.

School administrations have their own procedures to track spending and to ensure only authorized individuals can make large purchases. It is likely that students will find these procedures to be barriers to their core activity. Respondent #9 shared this experience:

> "Our biggest conflict with University regulations comes with purchasing. An easy example is when we needed to purchase a new engine: We wanted to buy a CBR500R engine and had $4,500 to do so. We were not allowed to buy an entire bike and pull it apart for the engine and relevant electronics (despite the fact that it fit within our budget) because the University was uncomfortable with our team owning a motorcycle. We ultimately paid $4,000 for the company to pull the engine and electronics for us, which means we over-paid. This year, when we wanted to buy a new engine, one of our team members purchased one out-of-pocket on Ebay and then went for reimbursement to avoid the hassle. The school didn't like it, but it's easier to beg forgiveness then ask permission in cases like this." [#9]

The above example shows a certain level of resourcefulness in dealing with the intricacies of university administration – but also a willingness to throw the laws of the institution in the garbage. While I suspect sympathetic bureaucrats might be impressed by the above case, there are challenges in disregarding rules and procedure. Consider #23s reflection:

> "We were bored one Friday night and decided to build a compressed air potato gun from some stuff around the lab – we launched a few potatoes at the wall of the lab, splat splat splat. Then launched a few at the football field trying to clear the bleachers. Was fun until the campus police dropped by on reports of explosions. They don't like us much." [#23]

When campus police don't like you much, you may have serious troubles that cause your team to be sanctioned. To avoid bias, not included in this sample was the team behind the author's first experiences with this domain. While a largely successful and respected team, recent iterations of the team managed to violate internal rules and regulations as to be put on hiatus during the course of this research. Even quality connections to power structures that be are not enough to fend off administrative authority, especially when key rules are broken.

The Mediating Role of Faculty Advisors and Technicians

It is hoped that in such situations is that a strong faculty advisor may intervene, if only to explain away the core activity of FSAE teams. He or she can play a strong mentorship role, help guide exploration in a complex problem space, and help avoid going down backwards paths in project-based learning (Mandin et al, 1997).

As per competition rules, every team must have a faculty advisor, and that advisor is the point person for any official communication regarding rule interpretations or results (FSAE Rules, 2016). However, it is clear from on-site observation that some teams do not have any active faculty support at competition. Respondent #28 could not even name their advisor,

but did not seem too concerned: “It’s more a club at our school, so we do our thing. The machining guys at the lab are more helpful – I believe there’s a professor who handles some admin things, but haven’t seen him around at all.” [#28].

While I suspect the team has fun “doing its thing”, an amateur approach to an increasingly competitive event is not likely to yield extraordinary results. In #28’s case, competition scores over the years have been mediocre at best. Without expert input to help students negotiate technical and administrative problems, it becomes that much more challenging to develop a competition-valid design.

That noted, the temptation for some advisors to overreach is real and problematic.

> “It’s kind of an open secret that [Prof. X] does a lot of the core design work at [team A]. Students do a lot of the grunt work, but most of the main design parameters are set in advance at the top. I’d hate to work in that environment – and some of their team members off the record say so, at least that’s what they tell us when he’s not around. I almost went to [school] too – glad I didn’t, I know from meeting X a couple of times we wouldn’t get along.” [#22]

Given scores in the design competition for the team in question, centralizing power does not work well. The advisor in question is indeed well known to try to interfere with design judging, which is explicitly supposed to be a conversation between students and design judges. His over-enthusiasm has jeopardized his team’s ability to faithfully represent their design, to the team’s detriment, and to the point other teams have noticed. As the team in question wasn’t part of the research sample, I cannot confirm from this record – but from informal discussions with previous team leaders of the team in question, #22 is not alone in their observation.

Golding (1999) suggested that the the best role an advisor can play is a mediating role – not interfering with developing subject expertise, but also being aware enough to understand when intervention is necessary. Teams with sufficiently active – but not overly involved – advisors end up receiving the best of both worlds. As noted in CDIO Standard 9, this may require some attention to faculty competencies, as being a “guide on the side” (King, 1993) can be a complex role for experts to fall into.

A potential substitute for the role of advisor is technical staff, noted by eight teams as a valuable resource. Technical staff are often on hand to ensure safe operation of manufacturing tools, and are usually eager to share their specialized knowledge with students eager to learn. #34 was particularly enthused about their school’s lab manager:

> “[X] at our machine shop is a god. I’ve learned so much about machining and how to design for manufacturability from him – stuff I wouldn’t get out of regular courses. Spending weekends and early mornings in the lab with him you pick up so many things, and he really cares about people – he kept the lab open extra hours in our manufacturing push totally volunteering his time and we really wouldn’t have the car we have without that. He’s also funny as hell – I sometimes just drop by to hang out, and I’ve gone to grab a beer with him after shift a couple of times. He even came to competition last year with his family. Just an awesome supporter of us. We’d be pretty screwed if he left.” [#34]

Unfortunately, such staff are not always seen as necessary in the grand design of a department. Shortly after sharing this story, #34 noted, with significant pain, that the manager

in question was being let go, as his speciality was determined to be no longer relevant. #34s reaction made it clear how essential front-line technical staff can be when looking at an overall support approach.

Effective institutional support is often a multipronged affair. Technical and administrative staff are often direct contacts and resources for student project teams, and often more accessible than faculty. Standards 6 and 9 vaguely touch on administrative commitment to CDIO activity support, but having a strong supporting cast of support staff is probably the best manner of supporting student project teams. Alas, in many institutions, these jobs are can be tenuous and easy victims to larger budget priorities- but at the direct and negative effect to student project teams.

For many FSAE teams – most of which whom are already operating on tight budget - such hiring and firing decisions are seen as penny wise and pound foolish. High-level administrative decisions rarely take the needs of project-based learning student teams into account while making such choices, but given stories like #34, perhaps they should.

CONCLUSION

This paper looks at specific examples of how FSAE team members perceive their relationship with their administration. Given the context of interviews or surveys in this case, it's arguable that contextual factors may have skewed results to a generally positive report of the team/administration relationship. But even with that assumed bias, team members were happy to report specific problems with school administration.

Ideally, all parts of the institution can work collaboratively towards supporting FSAE and similar engineering student project teams. FSAE teams require financial support, space academic support, and the support of technical and administrative staff. Such an infrastructure immediately removes many challenges FSAE team leaders face. Given many team leaders are just learning how to run such a complex project, the less bother they immediately have to handle, the better.

This paper concludes by suggesting administrations pay special attention to CDIO Standards 3, 5,6, 7, 8 and 9 in developing plans to support FSAE and similar teams. This paper also fully admits that doing so will not guarantee FSAE or other project team success - but it cannot hurt.

To end on a personal example: at the 2004 Michigan competition, my team struggled to install a Walmart tarp to protect the car in the rain. Our paddock neighbors laughed and wondered why they had a school-branded trailer with roll-down canopy and we did not. For a long while, so did we. But one of the above teams won the competition, the other finished 87th. Having a high end trailer with various accoutrements does not substitute for a well-engineered car.

That said, the more FSAE teams can focus on their core activity and not cursing the wind in a Detroit parking lot, the more likely they are to be successful.

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