2006-1312: FEATURES OF A CONSTRUCTIVIST MICROCLIMATE SITUATED IN A BEHAVIORIST LEARNING ENVIRONMENT AT A UNIVERSITY-BASED ENGINEERING RESEARCH CONSORTIUM

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Features of a constructivist microclimate situated in a behaviorist learning environment at a university-based engineering research consortium

I. Introduction

A pressing need to reinvigorate the mission of the university to provide effective learning experiences for the students while maintaining the scholarly vitality of the faculty is felt inside and outside the academia. This is readily evidenced by the various calls for reforms that have become the guiding principles for action among the leadership of national educational and research advocacy agencies[1-5]. Besides various other factors, this near uniform consensus has been due to various studies that have shown the limited effectiveness of the teaching processes in today's classrooms that are said to be implicitly objectivist or positivist in their epistemic basis[6]. In the process, the cognitive model for acquisition of knowledge held by educational psychologists has gradually evolved from a behaviorist towards a constructivist viewpoint[8]. Such a learning process, built upon constructivist epistemic assumptions, attributes a critical and enabling role to the situated variables in realizing cognition[9]. Learning is said to take place when it is situated in communities of practice, where the learners extend their proximal zone of skills through their interactions with experts[10]. Arguably, such a viewpoint places an enormous burden in developing and implementing reforms within the existing institutions of education. If one takes a literal view of authentic experiences leading to education, even the role of a school becomes unclear[11]. However, on examination of successful learning models that exist within the institutions of higher education, one finds examples of thriving communities of practice, exhibiting all the features of constructivist models, particularly in the context of graduate education.

The objective of this paper is to present the prototype features of a situated cognition space as prescribed by the learning environment theorists in a thriving learning community emergent in an engineering research consortium within a university. In this case, the emergence of the learning community has been spontaneous and the evolution of the learning environment has been natural, in that they are the result of action through conventional wisdom and not shaped by a formal application of instructional design theory. The 'microclimate' has thus evolved to provide a community of practice for students, while retaining the strong conventional behaviorist models normally ambient in the classrooms at large universities. In describing the features of the prototype, the goal for the paper is to make the case that constructivist learning climate can be fostered within more conventional behavioral learning environments, leading to highly effective and rewarding educational communities.

A brief overview of dominant paradigms of learning theory is presented in Section II. In Sections III and IV the primary prescriptions for instructional design based on the corresponding learning models are presented. The learning environmental features of the case example, namely the Wisconsin Electric Machines and Power Electronics Consortium are described in Section V, along with informal survey results. The concluding section discusses the implications of the paper as well as the model's extension towards an undergraduate educational program.

II. Dominant Learning Models

The ‘cone’ of learning shown in Fig. 1 has often been used to illustrate the educational effectiveness of various domains of learning experiences[12]. The activities at the bottom of the cone are said to provide learning opportunities with higher motivational and retention levels compared to those that are at the top, where the ‘top heavy’ classical teaching styles have a limited effectiveness. The identification of the bedrock that forms the pyramid, described by direct purposeful experiences has been a powerful and inspiring notion that has inspired the call for providing real world experiences in instructional design.

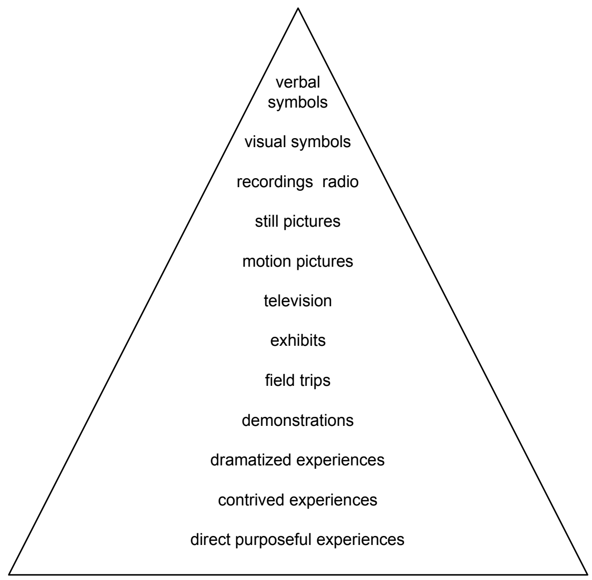

Fig. 1: The cone of experience, adapted from[12].

Although various solutions to the problem of instructional design informed by research and abstractions in education and social sciences have been presented in the form of descriptive and prescriptive concepts over the past century, only recently have these ideas been crystallized to develop an emerging body of knowledge defined to be the theoretical foundations of learning environments[9]. The major driving factor leading to this development has been the interest in the design of computer or more commonly termed ‘technology–based’ virtual learning environments for improving education in and outside the classroom, fueled by the ubiquitous proliferation of the personal computers and the Internet. Nevertheless, the core conceptualizations are certainly ‘technology-neutral’, and apply to the study of learning environments at large. In the literature on foundations of learning environments, two models form the dominant theme of the discussion, namely behaviorism and constructivism.

In its most extreme but perhaps simplistic interpretation, the behaviorist model views learning as a process of conditioning the learner to adopt a certain behavior based on experiences that lead to an appropriate response when subjected to a particular stimulus, conditioned either naturally or through reinforcements such as punishments and rewards. It focuses on statistically significant observations of objective physical phenomena in controlled experiments conducted on learners, with repeatable results leading to the development and acceptance of a coherent theoretical model.

In start, contrast to the behavioral model that focuses on external conditioning variables, the constructivist model posits learning to be an internal process negotiated by the students who construct a mental model that describes the world of reality by reflecting on their experiences[11]. Learning is viewed as the development of mental models with individuals to accommodate their worldly experiences through observations and reflections. In such a learning model, the role of the instructor is that of a catalyst in the clumsy and cumbersome process that enables students to negotiate and reflect on their experiences and construct relevant mental models. Instructional design that is aligned with the learning model is a much more complicated process. Instruction has to account for students' prior knowledge and develop customized curricula, emphasizing experiences, expeditions, and inquiry. Open-ended questions, problems, and dialogue among students are encouraged, while grades and testing are replaced with self and peer assessment allowing students to negotiate their own progress.

In addition to these two dominant models, various other models have also entered the discussion under different designations. These two dominant models may be considered to be the most polarizing in terms of their prescriptions for instructional design, while the proposed paper is aimed to illustrate a synthetic approach that combines aspects of both models. Therefore, the brief overview presented here, limited to behaviorist and constructivist models is considered to be sufficient for the purpose of placing the case under study in the broad picture.

III. Behaviorist Instruction Design

At the heart of designing instruction on the basis of behavioral learning models is the assumption that education is an applied science, guided by hypotheses, verified through empirical inquiry, which discovers processes that may be precisely employed in the classroom. In its most articulated and preferred vision, instruction is realized while students engage in doing tasks that lead to learning. The tasks are often broken down into sub-tasks, which progress in a linear fashion realizing instruction in a parts-to-whole sequence. Success in the sub-tasks and tasks provide a reinforcing and motivating factor for continued learning.

1) Objectives

During instruction, the tasks at hand are specified through clearly articulated learning objectives. Explicit formulation of objectives is necessary to associate the instructional goals with the evaluation and assessment process.

2) Outcomes

Objectives of the various tasks and subtasks lead to specific outcomes so that learning effectiveness and instructional effectiveness can be clearly evaluated and assessed to provide for continuing process improvement.

3) Taxonomies

The objectives and associated outcomes follow a detailed taxonomy of action verbs that are classified into categories such as comprehension, analysis, synthesis, etc, that place the corresponding instruction at different degrees of sophistication.

4) Instructional strategies

Based on the taxonomical classifications, appropriately prescribed best-practice instructional techniques based on proven results are employed. The goal is to provide a high degree of alignment between instructional objectives, instructional techniques, learning outcomes and assessment strategies to realize an overall effective process.

5) Learning support

The role of the instructor, in addition to designing and articulating the appropriate objectives and outcomes, is to provide the necessary support to the students in executing the tasks on hand through consulting, instructional aids, just-in-time training, etc.

6) Feedback

A well-aligned objective→ engagement→ outcome→ assessment→ success cycle, leading to an effective learning process depends on appropriate reinforcement provided through timely feedback to the students regarding their degree of success to make corrective improvements.

7) Transfer

Although the capability to transfer the skills mastered during a particular focused learning cycle beyond the immediate tasks is implicit in the process, the assessment phase in the learning cycle is generally precluded. It is however assumed, much to the chagrin of the critics of the behavioral model, such transfer of skills even within the same taxonomical category and technical field required adequate practice.

Even if the articulation of objectives → outcomes learning cycle is not always explicitly articulated, it is clear that the dominant instructional approach utilized in engineering education today is based on the behavioral model. Furthermore, students entering the engineering educational institutions are almost always preconditioned through their immersion in the behavioral conditioning process during their K-12 years. It is also noteworthy that the epistemic assumptions of the prescriptive reforms of engineering education set in motion through ABET's Engineering Criteria 2000, emphasizing program objectives, outcomes, etc. are based on the behaviorist framework.

IV. Constructivist Instruction Design

Just as the constructivist model does not subscribe to a linear step-by-step progression of learning unlike the behaviorist model, it also defies a step-by-step description of an instructional design process based on its tenets. On the other hand, certain guiding principles to be specifically addressed in developing effective learning environments are put forth, as described:

1) Social aspect of learning

Learning is innately associated with being, since our lives constantly involve interactive negotiations with the reality of our immediate world. Our social interactions with peers, teachers, family and acquaintances all play a role in the construction of our mental model of the world, leading to our being. Therefore, successful learning environments bridge the students learning activities with the world at large through their social interactions.

2) Motivational context for learning

Since learning is defined as the construction of mental models to represent the external realities, providing a worldly context that associates the knowledge with the students' lives provides anchor-points for new construction. The context serves as a setting for applying the knowledge gained from learning, thereby providing a means for enjoying the 'fruits of learning' as a natural motivating factor.

3) Active engagement

At the outset, the acknowledgement of learning as an active process mirrors the image of 'task-engagement' prescribed in the behaviorist model. However, active learners are said to construct an image of the reality internally in their mind as opposed to accepting knowledge resulting from success of the external outcomes. Internal reflection in the mind during and after engaging in the hands-on experience is when the construction of knowledge in the mind is said to take place.

4) Language elements

Construction of knowledge within the mind while reflecting on the actions during and after the process is dependent on appropriate language structures specific to particular domains in addition to the inherent knowledge inventory elements specific to the domains.

5) Pre-requisite knowledge elements

While this aspect closely parallels the sequential break down of tasks into various subtasks in the behaviorist approach, the constructivist model focuses on the construction of new knowledge through pathways reaching to the existing knowledge state of the learner and not on having been engaged previously in appropriate subtasks.

6) Learning to learn

Since building knowledge structures within the mind that represent the external objective reality is at the core of acquiring and retaining knowledge, a great emphasis is placed on skills of learning how to represent and use knowledge within the mind, or simply put, learning to learn.

7) Time

Learning is considered to be on a continuum, where revisiting ideas, applying them, refining the internal representations, building upon them, etc. all require a significant amount of time. The partitioning of activity spaced neatly into consecutive cycles of sub-task and task engagement is considered too simplistic to represent the complexity of education.

Thus, the constructive learning experience represents a progressive movement in education that emphasizes various external social aspects of learning environments as affecting the internal process of education to occur. While it was noted in the previous section that the macroscopic structure of ABET Engineering Criteria 2000 reflect a behavioral point of view, to be sure, the microscopic details of the prescriptive reforms may be observed within them.

V. Case Example

Engineering research consortia are among various models used to provide a sustained funding means for supporting pre-competitive leveraged research and education in various fields ranging from metal welding through semiconductor microelectronics. Some research consortia such as the Electric Power Research Institute operate as separate entities that pool financial resources and support research conducted by primary agencies such as universities and businesses. On the other hand, a few engineering research consortia are based within a university bringing a cluster of faculty and students together to form a community of practice, exhibiting a healthy and thriving scholarly environment.

The authors are junior faculty members affiliated with the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC), located at the University of Wisconsin-Madison, which has an established reputation in developing effective solutions to short-term and long-range technical problems pertaining to industrial electrical energy efficiency and training students in the field[13]. It was in the wake of the national energy crisis perceived 25 years ago that WEMPEC was founded in the spirit of the Wisconsin Idea to serve the needs of local industrial constituents in training students and developing technical expertise.

Sponsoring businesses provide a nominal $10,000 per year membership fee to sustain the education and research program. The sponsorship includes industries ranging from small businesses through multinational corporations from across the world. The relatively small amount of annual sponsorship fee allows championship of the consortium by technical personnel at the businesses, thus effectively shielding the participation from being affected by short-term ups and downs in the business cycles. The broad membership portfolio includes aerospace businesses, automotive industries, industrial automation manufacturers, national laboratories, semiconductor manufacturers, motor manufacturers, consumer equipment manufacturers, renewable energy companies, etc., with participatory interest in the power electronics and electric machines technology. This broad membership portfolio further shields the consortium from being affected by short term business cycles that naturally occur in the economy.

Sponsorship amounts are used to support graduate student stipends exclusively, with nominal expenses for administration and maintenance of laboratory support. Faculty members do not draw any salary support from the sponsorship either during the academic year or during the summer term, and have established a strong reputation for success in their educational mission.

Faculty members of WEMPEC have their ‘tenure home’ in the Departments of Electrical and Computer Engineering or Mechanical Engineering. They have developed a set of courses that form a complementary suite of technical skills intimately coupled with practice in the field of electric drives and power electronics. A list of courses regularly offered by WEMPEC faculty is listed in Table I. The pedagogic approach in all the courses strongly follows a behaviorist model, in keeping with the nominal academic traditions within the university education. Clearly articulated course objectives, task-oriented homework assignments, term projects, and grading though examinations are the norm in the courses. However, in addition to the classroom studies, ‘WEMPEC’ students undertake an academic journey during their graduate program, through their participation in the community, emerging as prototypical engineering professionals and leaders. Various particular aspects of the community of practice in shaping the learning process are outlined below:

1) *Shared values, beliefs, and ways of doing things*

A central value that is inculcated within the WEMPEC membership is the *Wisconsin Idea* often stated as, "the idealistic and humane concern that knowledge could and should have practical impact on the needs, problems and aspirations of the people"[14]. Contextual application in the real world is placed as a central emphasis in and outside the classroom – through classroom assignments, examination problems, term projects and laboratory experiences.

2) *Learning context*

Learning context for the community is provided through extensive interaction outside the classroom with the industrial sponsors of the consortium who number to about fifty[15]. In addition to the membership fee, several of the companies provide funding towards specific targeted research projects led by a faculty-student team.

3) *Social learning*

Graduate students working with different members of the faculty share common space where their laboratory work-benches and their writing/computer desks are located, and form a social/knowledge network sharing lunches, coffee-breaks, late-night pizza snacks and technical conversations.

4) *Rituals and practice*

Among the central rituals is the weekly meeting in which a representative from an industrial sponsor gives a technical seminar. Most often, the speaker at the seminar is a member of the alumni who provides a narrative experience of the technical problems and challenges faced in the particular industry, associating the practice with the learning experience at WEMPEC. The seminar is followed by a 'symposium' at a local pub, where the conversations continue on an informal basis.

Table I: List of courses offered regularly by WEMPEC faculty.

Designation	Course
ECE 355	Electro-Mechanical Energy Conversion
ECE 377	Electrical and Electro-Mechanical Power Conversion
ECE 411	Introduction to Electric Drive Systems
ECE 412	Power Electronic Circuits
ECE 511	Theory and Control of Synchronous Machines
ECE 711	Dynamics and Control of AC Drives
ECE 712	Solid State Power Conversion
ECE 713	Electromagnetic Design of AC Machinery
ECE 714	Utility Applications of Power Electronics
ME 746	Dynamics of Controlled Systems
ECE 504	Electric Machines and Drive Systems Lab
ECE 512	Power Electronics Laboratory
ME/ECE 577	Automatic Control Laboratory

An annual review meeting forms a capstone ritual when representative from all the industrial sponsors descend upon the laboratory for two days. The days are filled with student presentations, poster sessions, lab tours, shared lunches, and a reception. It serves the purpose of an informal reunion among the alumni, faculty, friends, and also a recruiting fair for summer internships and long-term employment.

5) Interactionism

In addition to the academic rituals of seminars and technical reviews, an annual fall picnic, a holiday party, a spring pot-luck, and summer lab lunch round out the organized interaction experiences. A large emphasis is placed on personal interaction among students, faculty, staff, and practicing engineers in developing students' learning experiences as well as their careers.

6) Tools and artifacts as cultural repositories

The main cultural repository of the students' work is represented by their publications in conferences and journals, which form a shared archive in the WEMPEC library and more recently on the website[15]. More informal repositories are the prototype hardware devices built by the students for their thesis projects retained in the laboratory for future use and/or salvaging.

7) Mediation of artifacts

Throughout the process of interactive activities in and outside the classroom students learn to develop and mediate artifact terms, tools and activities such as 'd-q models,' 'reference frame dynamics,' 'observers,' 'winding functions,' 'switching functions,' etc. to construct their knowledge in the field of electric drive systems.

8) History

The consortium is celebrating its 25th anniversary in 2006 with approximately 550 members forming the WEMPEC family consisting of students, faculty, staff, alumni, and visitors. Members of the family constantly celebrate the shared history through narrations during various interactions at various informal meeting places and professional conferences.

9) Sustenance and renewal of membership

With a humble beginning of two faculty members in 1980, the group presently has a thriving membership well beyond the critical mass to represent a true community. The numbers of faculty, students, and sponsors at the inception of the consortium are compared with those at present in Table II. Furthermore, many of the student alumni from WEMPEC are themselves faculty at various universities around the world and strive to recreate outposts at their own locations. Successful similar programs in the area of power electronics and electric machines include Seoul National University, South Korea, Aachen University of Technology, Germany and Indian Institute of Science, Bangalore[16-18].

Table II: Statistics of WEMPEC membership at founding and at present.

Item	**1981**	**2005**
Number of faculty	2	5 full-time + 2 emeriti
Number of students	2	37
Number of sponsors	3	52
Cumulative 'family members' (includes alumni, visiting faculty, scholars)	0	543

In summary, the WEMPEC experience enables the construction of identity and self, knowledge realized in action, which is integrated into the life and membership of the community, while being situated squarely within the university community. A formal detailed assessment of the educational process is under development and could not be completed at present but will be presented in a future publication. However, selected quotes that highlight the learning experience as provided by some alumni on the occasion of the 25th anniversary upon solicitation (emphasis in original) are reproduced in Box 1.

Box 1: A selection of WEMPEC student alumni comments on the occasion of 25th anniversary.

"WEMPEC provides a unique environment where students are able to interact professionally and personally with many of the top minds in the power electronics and machines area."

"My time as a WEMPEC student has provided me with not only an outstanding and world-class technical education, but lasting personal and professional friendships which span the globe."

"I feel very honored and lucky to be a fellow WEMPEC'er due to the large fraction of the world's leaders in the power electronics and machines area who are or have been associated with WEMPEC."

"It had been a privilege to have a change being a member of WEMPEC. It is an ideal place for doing world class researches and making friends from all over the world."

"I believe that being part of the WEMPEC family is a distinction that not a lot of people are fortunate to have. This distinction comes with a fine education, great professionalism, and a lot of very good friends."

<u>"WEMPEC did really changed my life.</u> I am very grateful for what WEMPEC did in my career. I am very happy to belong to WEMPEC Family.

"WEMPEC faculty is just about completely responsible for helping me develop an interest, and get excited on just about every field of science and engineering, though what we worked on was power! Having faculty who were equally or more excited about our projects certainly helped, but <u>what I enjoyed most about being in WEMPEC is the opportunity of interacting with fellow students from around the world</u>. Finally, the experience would not have been complete without the able and a-lot-of-fun-to-work-with staff!"

"It was really inspiring to be a part of such a top-notch technical environment. There are <u>so many ways to learn at WEMPEC from other students, the seminars, the short courses, and industry people</u>. On top of that, the many friendships I developed there made it really enjoyable to be a part of the WEMPEC family."

<u>"WEMPEC rocks!"</u>

VI. Conclusions

Success of the engineering research consortium program established through its long-standing history of 25 years indicates the possibility of not merely a peaceful cohabitation of arguably extreme points of view represented by the behaviorist and constructivist models within the environment, but a thriving collaboration where the features of the best of both models are brought out to be effective in realizing rich scholarship. Remarkably, the faculty members of WEMPEC have internalized this feature as a natural consequence of their personal educational beliefs, without particular pre-mediation through theoretical studies on learning environments.

The educational features of WEMPEC described herein are by no means unique, and are found in various mutations among various graduate research and education program at various departments, colleges, and campuses. However, a cooperative tradition among the faculty in developing and committing to a shared vision while they negotiate their diverse professional and personal goals is rather exceptional. It is this feature that provides the scale that has enabled the learning community to become emergent.

This leads to a question whether the approach can be extended to develop such communities of undergraduate students on a broader basis. This is a complicated question whose answer depends on several factors, ultimately related to managing higher education resources. Firstly, the features of such communities situated within various settings will need to by studied using detailed ethnographic techniques. On the basis of the studies, enabling features may be identified and mechanisms for extensions may be developed on a pilot basis. The success of such attempts would depend on various factors that may be a separate topic of deliberation in itself.

However, in the absence of such extensive data, a preliminary provocative extrapolation is attempted here. Thus, acknowledging the risk of generalizing and overextending specific and parochial data, an examination of student enrolment numbers was conducted within the Electrical and Computer Engineering (ECE) Department and the College of Engineering (COE) at University of Wisconsin-Madison, and summarized in Table III[19]. It may be noted that the total number of undergraduate students in the ECE department is on par with the total number of graduate students. Similarly, within COE, the total number of declared undergraduate majors is even less than the total number of graduate students.

Table III: Statistics of Student Enrollment at UW-Madison in 2004-2005.

Total number of students	**Electrical and Computer Engineering**	**College of Engineering**
Undergraduate (with declared majors)	473	1089
Masters	145	522
Doctoral	315	1148
Total Graduate	460	1670

From the results summarized from Table III, and assuming that resources depend on the number of students, development and sustenance of learning communities at the undergraduate level would conceivably require resources that are commensurate with those required for highly effective graduate education in WEMPEC. Noticing that the majority of funds generated through sponsorship from the consortium are used to graduate student stipends and tuition remission, the marginal costs involved in maintaining the community of practice in addition to the preexisting instructional resources are nominal. Thus, if the classical-model undergraduate education prescribed to be reformed along the lines of affiliating students within various cluster-communities of practice, additional resources required may be safely estimated to be less than a factor of two. Nevertheless, resources required for reform represent a significant appropriation. Furthermore, even if such resources become in fact committed, it would be a challenge to develop organizational models that can coexist or supplant the existing administrative arrangements based on departmental partitions.

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