International Journal of Engineering Education Vol. 28, No. 3, pp. 701–712, 2012
Printed in Great Britain

0949-149X/91 $3.00+0.00

Teaching Engineering with Wikis*

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In this paper we discuss the nature of five university professors' use of wikis in education and their personal epistemologies pertaining to wikis. A group of students collaboratively authoring a wiki article is an epistemologically different practice from students writing individual papers. A wiki-supported learning environment cultivates more student-centered pedagogies by distributing the power of knowing towards the students, which in turn may lead to a formation of a community of practice. How and why professors use wikis in teaching are critical to explore for the efforts to cultivate more student-centered teaching practices in higher education. Study data are collected through individual interviews. Analyses revealed that participants used wikis to improve student collaboration, to reach an optimal solution to a given problem, to form an asynchronous and egalitarian learning medium, to have students negotiate and construct knowledge, and to have students work collectively. According to our participants, wikis provided a medium for communities of practice to begin emerging. However the communities did not fully develop because of the limited time within the course of a semester. We recommend any future studies investigate the ways to cultivate more sustainable wiki-supported learning communities.

Keywords: wiki; student-centered; personal epistemologies; knowledge construction; communities of practice

1. Introduction

In today's post-secondary education, technology is widely used [e.g., 1–3]. Most undergraduate science and engineering courses have supplementary web-based learning environments [e.g., 3–8]. A unique opportunity that web-based learning environments offer to the traditional teaching-learning context is the online communication medium. Using a wiki-type environment as a learning tool, students in a typical class can easily access a page on the Internet and generate a collaboratively authored text. Nowadays, wikis are used in education for different purposes. Pedagogical uses of wikis include, but not limited to, peer-reviewing each others' projects [9], supporting classroom management [10], sharing reflections and thoughts [11], ice-breaking activities to enhance trust among students [12], and collaborative publishing for writing-to-learn experience and generating original ideas [13].

The nature of the collaboration of students engaging in creating a wiki site is quite different from the nature of individual students working on individual papers. The wiki entry process is similar to an ongoing peer-review process among the students. Writing a wiki-article as a learning activity or creating a wiki-site with peers has epistemological implications. The information generated and authored in a wiki entry is the outcome of multiple individuals. Epistemologically speaking, the information in a wiki entry is socially constructed. It is generated through a collectivist effort instead of an individualistic one. Moreover, as a learning activity, a wiki has the potential to cultivate more student-centered pedagogies in teaching and learning. Students reading and editing a wiki entry not only function as active learners but also as the sources of learning [14]. For the efforts to cultivate more student-centered pedagogies, how and why university professors use wikis in teaching and their personal epistemologies pertaining to wikis are insightful for the engineering education researchers. In this paper we report the findings of a collective case study that explored a group of university instructors' pedagogical and epistemological intentions to use wikis in their teaching of engineering and related subjects in higher education.

2. Wikis and student-centered pedagogies

Traditional teaching strategies focus on transmitting knowledge to the students and expect that students will be able to report the same knowledge. In a typical traditional-learning environment, the information students should learn (and be able to report back) is often known by the experts, the teachers, or the textbooks. Recent educational research and reform movements emphasize the essence of student-centered strategies over the traditional, teaching-centered pedagogies [e.g., 15–16]. Group work, collaborative activities, and peer review are the preferred teaching methods in student-centered pedagogies. Knowledge does not necessarily need to be transferred to the students; instead, it should be used by the students in analyzing the topic of interest in order to generate argu-

* Accepted 5 January 2012.

ments and solutions to the problems and concerns of the current time and location. It is important that students process the information and generate an artifact (a solution, an original paper, or an argument), preferably in collaboration with their peers. One student reporting the same information in summary or in brief documentation is, apparently, not a desired learning activity in student-centered pedagogies. Regardless of the research and agreement in the education literature, most undergraduate students are still being asked to write individual papers and complete tasks without an open access to information resources. Writing a wiki article with peers appears to be an ideal student-centered learning activity. However, using wikis in teaching is still a novel practice and not yet well explored in engineering education literature.

In education, researchers who studied the effects of wikis on student learning outcomes pointed out various learning theories and teaching strategies. The two overarching characteristics of them are that (a) students work communally but not individually and (b) the information is shared and enacted but not being transmitted or personalized.

For example, in teaching the digital media and communication design, Bruns and Humphreys asked their student participants to communally choose topics and work together to generate M/Cyclopedia (Media/Culture), a wiki-based encyclopedic collection of information on new media concepts and topics [17]. As a part of social constructivist pedagogies in tertiary education, participating students developed skills at writing creative entries, generating new arguments, critically evaluating the information they found, and working in collaboration with peers.

Boulos, Maramba, and Wheeler studied a wiki environment in medical and health education [18]. They maintained that the wiki engaged students in effective learning, since it served as a source for obtaining information and knowledge and as a virtual collaboration tool for sharing information among individuals. Wikis, as part of a virtual community of practice, enhanced individuals' learning experiences and increased engagement and collaboration in digital learning environments.

Höller and Reisinger designed a wiki-based project in theoretical physics to enhance student motivation and learning experiences [19]. They used MediaWiki, a specialized wiki software, to overcome some of the editorial and technical weaknesses WebCT Vista had at the university. MediaWiki users were able to more conveniently access and use the wiki pages for their discussions and for their content writing. MediaWiki supports LaTeX symbols and a syntax that are needed to write standard sophisticated formulas used in physics and in other theoretical sciences. Höller and Reisinger noted that the learning environment created through MediaWiki encouraged the students to post and ask questions more frequently. Increased interaction among the students led to more effective analysis and synthesis of the course content.

Elgort et al. studied students' and instructors' perceptions of using wikis in graduate-level courses [20]. They explored how wikis affected students' collaborative-learning experiences and attitudes towards working in teams. Their analyses revealed that students and instructors viewed wikis as a valuable tool for collaborative group activities, specifically in collecting and organizing information for a project. Wikis encouraged students to participate more frequently in the group's activities. Wikis also provided instructors with opportunities to manage and oversee the group's activities.

From social-constructivist perspectives, knowledge is socially constructed. Ontologically, this means scientific knowledge is not constructed by one individual (e.g., a scientist) with the use of human sense organs (e.g., with a simple empirical experiment); rather, it is a negotiation and communal agreement of multiple individuals providing the best explanation of a given phenomenon (that may include modeling, theorizing, predicting, etc.). This negotiation and communal agreement requires a group of people and a social environment. In scientific fields, practitioners form their own communities and negotiate on their knowledge claims that they construct within those communities (e.g., conferences, official peer review, journal publication, etc.). An epistemological explanation of a social constructivist perspective is that the construction of knowledge requires a collectivist context but not an individualist context. Social interaction and communal agreement underline the main differences between social constructivist perspective and other perspectives aimed at explaining *episteme* (e.g., logical positivism, post-positivism, simple, mild, naïve, and radical constructivism, etc.). The literature is blurred when one discusses 'constructivism' and attempts to explain its epistemological position. Pedagogically speaking, instead of presenting the information to the students as discovered bodies of knowledge, students working in collaboration and constructing their own knowledge (or its representation) is a preferred method in student-centered learning environments [15].

3. Wikis and communities of practice

The discourse of the community that wiki users' form as they collaborate in generating a wiki article can be discussed with the notions of 'legitimate

peripheral participation' [21] and 'communities of practice' [22]. A community of practice comprises any group of people engaged in a collective activity where they share their ideas with the group members over an extended period of time. Wenger identifies a community of practice involving three characteristics: (a) mutual engagement, (b) joint enterprise, and (c) shared repertoire. Mutual engagement refers to membership in a community where members establish norms as well as individual identities and build social relationships that keep the members of the community together. Wenger defines a joint enterprise as a dynamic process, not a static agreement. A joint enterprise is a result of a collective process of negotiation among the group members. A predefined goal or a project objective is not a joint enterprise. Finally, a shared repertoire is a set of resources a community produces through interaction and negotiation [22].

Wikis provide a social platform where the students and the instructor of a class can form a community of practice with the abovementioned three characteristics embedded. That is not to say that a wiki creates a community of practice per se; neither do discussion boards or blogs. However, people contributing to a wiki site form a community of practice over an extended period.

In a chapter Wenger co-authored with White, Smith, and Rowe, they discussed the roles of technologies (the contributions that they can make) in communities of practice [23]. They maintained that a technology used by a community should be designed for ease of use and learning, for evolution, for closeness at hand, and for users' perspective. Technology users should not have much difficulty using the technology or in learning how to use it. Wikis as technological tools are easy to use and anyone who is familiar with computers can easily learn how to use wikis. It is expected that the community's needs will evolve over time; that is a challenge for any technology provider. A community-building technology should be able to evolve as the community's needs change over time. Wikis, in their current form, are not evolving substantially. However, users can easily add or delete pages to an existing wiki site and change the structure and the content of the wiki site they are creating as their needs change over time. The technology's platform should be designed for closeness at hand, meaning that members of a community should be able to access the platform on a day-to-day basis, with minimum requirements or hassle. Wenger et al. noted that this is possibly one reason why e-mail is still a very successful community-building tool. Wikis require the user to open a web browser and connect to the wiki site. However, because of the minimum requirements (other than regular Web site access), wikis are less of a hassle than logging into a blackboard site or a secured school or office server.

Wenger et al. noted that it is important to analyze the usefulness of any tool for its intended purposes on the basis of the features it includes. Wikis are often used in education for students to collaboratively work on their course projects; therefore, exploring the usefulness of the tool used in education provides insight into how effective it is. Wenger et al. maintained that a critical role of technology is to provide new sources for making togetherness more continuous, in spite of separation in time and space. Online tools, in general, provide a sense of togetherness, regardless of differences in time and space. A wiki can be used to develop the sense of togetherness for the class members [23].

Science and engineering professors in postsecondary institutions have already been using wikis in their teaching. However, there is not much literature on why university instructors use wikis in their classes and what characteristics educational wiki communities have. We do not know if professors are using the wikis in teaching because they want their students to form a community of practice or if they wish to convey a different epistemological stance than traditional teacher-centered instruction can do.

4. Wikis and epistemological beliefs

Epistemology is the study of beliefs about the nature of knowledge and its acquisition [24]. One's personal epistemology can be defined as his or her conceptualization of the nature of knowledge and its acquisition. We view a wiki platform as a collaborative environment where the information generated by the users evolves within the discourse of the wiki context. This is quite different from a traditional teacher-centered instructional medium, where students learn the information from a teacher or a textbook, but not necessarily from each other. The resources of information as knowledge and how knowledge is enacted and re-generated are fundamentally different in a traditional teacher-centered instruction and in a wiki environment. University professors who use wikis in their teaching may hold distinctively different epistemological beliefs than professors who use teacher-centered, knowledge-oriented strategies.

We have assumed that different individuals have different epistemological beliefs; thereby, their daily life practices, particularly how they guide their students to learn, are shaped by their personal epistemologies. Hence, exploring professors' personal epistemologies pertaining to wiki use in teaching is critical to understanding why and how professors use wikis in teaching. The findings of this study will

help explore and further enhance the characteristics of student-centered instructional strategies.

Not many studies focused on wikis' pedagogical potentials and epistemological nuances in education [25, 26]. Wikis are different from blogs, discussion posts, or any online learning environment tools. When we look to the knowledge representation at a learning environment in a typical class, students learn about the knowledge from an authority (e.g., a textbook, instructors' notes, or the instructor). Students present the knowledge they learn back to their instructors, often individually (e.g., an individually written paper or a project) and sometimes in groups of two or more but rarely as a whole class. Blogs and discussion posts enable students to communicate with one another and share the knowledge they learn and/or synthesize in their class work. Wikis, as opposed to blogs and discussion posts, enable students to create, learn from, and make changes to the knowledge they learn (or its representation) in an ongoing manner. The continuous nature of the knowledge construction (or its representation) and its communication among the class members make wikis epistemologically different from any other technological or educational tool.

Wikis' pedagogical potentials include more student-centered practices, because in a wiki, students create their entries according to what they know (or what they understood from the subject matter). As long as the text they write is their original writing and thoughts, they do write what they know, understand, or synthesize. Students' misconceptions can be found by looking at their wiki entries. Yet, these misconceptions are not necessarily individual misconceptions, since the wiki article is communally written. It is also likely that students contribute to a wiki entry according to what they are interested in and what they think is the right thing to include. Because of these characteristics, a wiki created by the students is a student-centered learning activity.

Ruth and Houghton noted that wikis in teaching can cultivate a different way of thinking, learning, and knowing that many practitioners are not familiar with [26]. Wikis can foster a collaborative and egalitarian learning experience, valuing group interaction over individual performance. By using wikis in a learning environment, students can play an active role in the formation of knowledge representation that is different from presentation of information in a typical class. What makes wikis different from blogs, discussion posts, or other learning technologies is wikis allow for participatory engagement. Participatory engagement focuses on construction of knowledge instead of presentation of information.

Ren, Baker, and Zhang investigated the effect of a wiki-based learning environment on pre-service teachers' epistemological beliefs [25]. They used an adapted Epistemological Belief Inventory to capture the students' beliefs on five epistemological dimensions, namely, simple knowledge, certain knowledge, omniscient authority, innate ability, and quick learning, as hypothesized by the other researchers [27–29]. One group of participating students (n = 80) wrote a Wikibook on their course content and used it as their instructional resource. Another group of students (n = 149) used traditional textbooks as the primary resources of their course content. Study findings revealed that students writing their own Wikibook tended to believe certain knowledge less than their traditional class counterparts did. That is to say, student-written Wikibooks affected students' personal epistemologies in that they viewed knowledge as being tentative and evolving over time instead of fixed and rigid.

5. Research questions

We posed two research questions in this study: (a) what are the university professors' pedagogical intentions to use wikis in teaching and (b) what are the professors' personal epistemologies, particularly their conceptualization of knowledge construction in wiki environments?

6. Methods

In the present study, we conducted a collective instrumental case study [30] with five undergraduate instructors as cases who have used wikis in their teaching. To recruit the study participants, we sent invitation e-mails to science and engineering professors e-mail list-servers. In the invitation e-mail, we summarized our study purpose and briefly described the data-collection procedure. Eleven university professors from different campuses at North America responded to our invitation e-mail. Among the eleven, we interviewed five of them. The other six were either not available for an interview or did not respond to our follow-up e-mails.

Our participants were selected based on their willingness to participate and convenience to the researchers [31]. Three participants have been teaching undergraduate courses and two were teaching graduate courses in different campuses across North America (including Canada and US). Two participants were teaching in engineering fields (one in civil engineering and one in aerospace engineering) and one participant was teaching at the school of system and enterprises. Among the remaining two partici-

Table 1. Study participants' demographics and the characteristics of the courses they used wikis in teaching

Participant (all pseudonyms)	Sex	Years used wikis	Teaching experience	Subject taught	Students' characteristics as captured in the interviews	Role of the wiki environment in the course
Tom	Male	One	Over 5	Systems engineering	Ten graduate students	Supplementary activity
Lisa	Female	Several years	Over 10	Engineering writing	Around 100 freshmen	Supplementary activity
Mike	Male	Couple years	Over 2	Aerospace engineering	Three undergraduates, two graduates and a large group of high school students	Primary activity
Johnson	Male	Several years	Over 10	Structural engineering	Around 50 sophomores	Supplementary activity
Cindy	Female	One	Over 2	STEM education	Ten graduate students	Supplementary activity course

pants, one was teaching a STEM education course and the other was an engineering writing course. Table 1 lists the participants' sex, years they used wikis, teaching experiences, subject taught the characteristics of the students taught and the role of wiki environment in the courses.

6.1 Study design

The present study was a multiple-case design [30] with five university instructors who used, or have been using, a wiki environment in their teaching. The case under investigation is the instructor and her epistemological and pedagogical ecology (views, beliefs, and opinions) pertaining to using wikis in teaching. Multiple case studies provide information from several intrinsic single cases (or individual cases) in order to make implications about the general population. This does not mean that our findings can be generalized across all instructors using wikis in their teaching, yet our findings provide insightful information about the characteristics of the general study population.

6.2 Data collection

We collected data through individual, one-on-one interviews. We designed a semi-structured interview protocol that guided the interview conversations. The interview questions are listed in the Appendix. The questions in the protocol were used to cover the main themes we originally planned to investigate, meaning that actual conversation might or might not include the exact wordings of the items listed. As needed, emerging questions were asked. In our conversations with the interviewees, we asked questions about the nature and characteristics of their wiki use in teaching and their personal epistemologies pertaining to wikis.

Before the interviews took place, participants were informed about their rights as participants. We asked each participant to review and sign the Institutional Review Board approved human consent form. All five participants agreed to participate and provided their consent before we recorded the interviews.

We conducted semi-structured phone interviews with four undergraduate-level instructors and one face-to-face interview with a graduate-level instructor. Each interview lasted around 45 minutes. All interviews were recorded and transcribed verbatim.

6.3 Analysis

We analyzed the transcriptions using the constant comparative method [32]. In our analysis, we performed open and axial coding followed by selective coding. In open coding, we generated codes in two ways: (a) either the exact words our participants used (in vivo codes) or (b) words that we used to represent the incidents participants portrayed in the interview (sociologically constructed codes). For example, non-'authoritarian' nature of wikis that is different from blogs is an in-vivo code that one of our interviewees used in her conversation. An example to a sociologically constructed code is the 'egalitarian medium' that researchers assigned to an incident the interviewee described during the conversation.

During the axial coding for the second and subsequent times we read the transcriptions, we clustered and re-organized the codes we generated in the open coding. After finalizing the axial coding, we performed selective coding, where we categorized the codes under some main titles. In selective coding, we also delimited the codes as needed. In other words, we deleted a few codes that did not fall into any meaningful category or did not appear as important to the present study.

7. Findings

In this section, we summarize our findings. Each sub-title represents a main category we generated at the selective-coding stage.

7.1 Wikis as improved collaboration

Our participants viewed wikis as a means of providing a collaboration tool free of time and location restrictions. Tom (a pseudonym), who taught a systems engineering course using a wiki environment, highlighted the collaborative nature of the wikis as their most beneficial characteristic. Tom said, 'Wikis are a really nice way of collecting individual contributions for collaborative outcomes or unified outcomes.'

Instead of working individually on a given task, students can communally contribute to a wiki article. For an engineering problem that is ill defined, Tom maintained that wikis provided a medium to reach an optimal solution among the students. Tom said:

> 'I used the wiki so that they [students] could arrive at a collective solution to a problem using the wiki. Everybody individually contributed to that solution, so then all together at the end; we reached to an optimal solution from everybody's individual contributions.'

Mike (a pseudonym), who taught an aerospace engineering course, used the wiki environment in a similar way to how Tom used it. Mike said:

> 'We all used the wikis as central sources of information, so we each worked independently and put information on wikis so that everyone else could see the progress. Anytime we had an issue that needed input from other members of group . . . The group of students edited each other's work and made comments and, in some cases, left comments in the discussion page so somebody can go back in, view comments, fix something in their writing, and then answer in the discussion.'

Cindy (a pseudonym), who taught a STEM education graduate course, maintained that wikis easily connect the individuals and provide a medium for collaboration. Cindy said: '[A] wiki can be a good way for collaboration. It is a way of making the class work as whole.'

7.2 Wikis as an egalitarian and flexible medium

Our participants reported that wikis provide a flexible and an egalitarian medium to its user through its asynchronous and time- and space-restriction-free characteristics. Students are free to work at their own pace in a wiki. Wikis are classified as non-authoritarian, as compared to blogs, discussion posts, and other web-based educational tools.

> 'Wikis are to create freedom, where people are more allowed to do a lot of things at their own time and at their own pace.' [Mike]

> 'I view just web pages where there is a single author, but it is a bit more authoritarian nature than wiki. It is because other people cannot come in as easily to collaborate and to make changes and negotiate that information.' [Cindy]

Mike believed that a social medium like a wiki really helps to work asynchronously and saves time, since wiki collaboration reduces the number of meetings that the users may want to have face to face. Mike said, 'We [would otherwise] have to schedule meetings every few weeks. Instead, we were able to meet once every two weeks and review issues.'

Our participants agreed that the asynchronous aspect of wikis encourages the instructors to use it in their teaching because the user community saves time.

Mike said, '[A] wiki is asynchronous so that we don't necessarily need all students to be at the same place and at the same time. They can log in from whatever lab they are working on at the university.'

Cindy's attitude towards using wikis revealed consistency with Mike and Tom's positions in that wikis are asynchronous communication means that promote the users, who don't prefer face-to-face interaction, to be online and more effectively share information.

Participants agreed that wikis convey the essence of collaboration, negotiation, and social construction of knowledge. The collectivist perspective of wikis distinguishes it from other media, such as discussion threads and bulletin boards. Cindy highlighted this by saying, 'The strength of wikis is the social negotiation that occurs. It is a social construction and negotiation of information . . . those changed and altered by a group as a whole.'

7.3 Wikis as selective tools

Wikis are not flawless educational tools for all students. Tom, who taught a systems engineering course, reported that the wiki environment he used in his class did not work 'perfectly well for all of his students.' Some students in Tom's class participated more than the others did. The students who participated more gained more out of the wiki assignment than the students who participated less. Age was reported as one of the possible indicators for the degree of involvement in a wiki assignment. Considering that technology literacy is often correlated with age, Tom's point is worthy of sharing:

> 'What makes wikis difficult is that the concept of wikis is not readily acceptable by all. So you want individual diverse contributions. People who are actually engaged in maybe selected simply by their acceptance of the technology or the application itself. So I found when I implemented it in my classes, for example, that students who tend to be older and not as, sort of technology

embraces tend to sort of saying, well this wiki thing it's okay . . .it is difficult [to learn and use]'

7.4 Making interdisciplinary connections visible

An interesting theme that emerged in our analysis is that wikis make the connections between the different fields more visible. The hyperlinks and the linked pages created in a wiki entry by the students can make the connections easily explicit, not only to themselves, but also to the course instructor. Cindy mentioned this as:

'It [teaching with or using a wiki] enables me to see connections to other subject areas that I might not follow. It is [a] really fun journey and I learned types of connections between areas I did not imagine existed before. It normally happens when I use wikis.'

7.5 Wikis as communities of practice

Wikis were considered as a medium to build a community and encourage students to work in collaboration. Johnson, who was teaching a structural engineering course, reported that all of his students, with the exception of one, worked in groups in the wiki environment. According to Johnson, wikis provide a venue for groups to get together. Likewise, in Mike's class, groups of students worked on different projects and communicated through wikis. Student groups with different fields of expertise communicated and negotiated with each other and shared information. Mike noted:

'If there is a group of people that are working on a project together and each group member has different expertise and different focus—so in our case that would be electrical power group, software group, high school students group, other units like that—then they can collaborate through [a] wiki, share information as it pertains to other groups.'

It is questionable, though, whether or not the wikis our participants used enabled their students to form communities of practice. Because the course of a semester is relatively short, students' participation in a wiki environment does not necessarily form a community of practice. Cindy reported that the wiki environment she used did not reflect the communities of practice in her teaching, although she believed that the notion is embedded in wiki environments and she encouraged her students to form a community by asking them to post frequently on the wiki site throughout the semester. Cindy said:

'I can't define what we are doing as communities of practice, necessarily; I'd like to develop a community of practice, but one of the characteristics of a community of practice is that it develops spontaneously over time between individuals. It takes time to develop. It is not spontaneous in this environment. I refer to it as initiating a community of practice because there is not enough time for a community necessarily to develop, even though it is starting to develop.'

7.6 Instructors' personal epistemologies pertaining to Wikis

In the interviews, we did not ask our participants direct questions about epistemology. Our questions were about the construction of knowledge (and its representation) pertaining to wikis in teaching and learning. The findings below represent our interpretation of the participants' personal epistemologies as derived from their answers to the questions about the knowledge construction aspect of a wiki environment.

Johnson used Wikipedia in his teaching. He wanted his students to see that things are likely to change in Wikipedia in a shorter period and this reflects the tentative characteristics of knowledge that one can generalize to overall knowledge claims. Our interpretation is that Johnson viewed knowledge as changeable over time and not fixed and rigid.

Tom believed that optimal solutions are achieved by multiple contributions. Tom said, 'If you get enough diverse contributions, you reach an optimal solution, and the right solution.' Tom's personal epistemology was more aligned with the collectivist nature of knowledge construction. Tom believed that to reach an optimal solution, which one can also consider as the 'right' solution, multiple contributions are critical. Wikis provided a venue to convey this characteristic to the students.

Lisa, who taught an engineering writing course, viewed wiki-like environments, and in particular Wikipedia, as a dynamic venue. Lisa asked her students to reflect on what they did through the wiki site. Lisa provided her students an article written by Marshall Poe that discussed 'cathedral' versus 'bazaar' modes of knowledge generation. Although Lisa's students' wiki use was limited, she believed that using a wiki contributed to her students' knowledge-generation activities and to their personal epistemologies. Lisa said:

'My students [in the beginning] said engineering is very conservative in many ways, but I would say half of them moved away thinking differently about knowledge. They began to think that they can contribute to generating knowledge . . . I think they were convinced that wikis can facilitate a very responsible way of knowledge generation.'

Lisa's personal epistemology pertaining to wiki use in teaching corresponds to both Johnson and Tom's personal epistemologies pertaining to wiki use in regard to the collectivist facet of a wiki's use. Although Lisa's students worked and designed their wiki pages individually, she facilitated group work in that her students read and reviewed each other's wiki pages. This mirrors the collectivist nature of her wiki use in teaching.

Wikis can distribute the ability to know across its

users. In a traditional learning environment, it is assumed that the teacher is the main resource of information and she is the authority. Individual students are expected to receive the information from their teacher or from textbooks. However, wikis enable the user community to share and negotiate knowledge with each other. Cindy and Mike believed that wikis are non-authoritarian venues. Their personal epistemologies are more aligned with the notion that people interpret and create reality through interaction and negotiation. Wikis' distributed 'power of knowing' characteristics might have encouraged both instructors to use wikis in their classes.

7.7 Instructors' personal pedagogies pertaining to wikis

Johnson used Wikipedia in two different ways: (a) for his students to generate their theses or original ideas about structural engineering and (b) for spreading the knowledge on the Internet and sharing it with others.

Tom reported that not all students readily accept the wikis. Tom did not see wikis as improving all students' engagement. Tom said older students tend to question the user friendliness of the wiki environment as well as the validity of the wiki articles and not fully embrace them as younger students did. Tom said:

> 'The concept of wikis is not readily accepted by all. People who are actually engaged in maybe selected simply by their acceptance of technology, or the application itself.'

Mike reported that his students at the university level generated knowledge about the engineering projects and published them. Wikis helped them spread the knowledge more effectively than the papers because a wider audience, including high school students, was able to reach the content of their publications through the wiki.

Lisa used a wiki site as an alternative to the Blackboard course management system. She told us that she used the wiki (a) to see if her students could address their project; (b) to examine and compare different media, like wikis, as classroom platforms; and (c) as an alternative to printed documents. The blackboard was not effective for multiple users to work on one document in a short period. Lisa used a wiki to see if her class could overcome the limitation that a blackboard caused, as well as to understand if the dynamic aspect of a wiki could help in her teaching.

Wikis can be very effective in exploring students' backgrounds and interests, as well as encouraging them to take ownership of a study topic that they put on wiki pages. Cindy used wikis for such purposes because she wanted her students to explore certain topics that are of interest to them. Wikis have allowed her intent to happen. The information students put in the wiki helped Cindy know what her students were personally interested in and what they already know about the topic. She portrayed this process as 'scaffolding,' since she was able to see how her students were thinking, how they were benefiting from other students or the teacher, and how they were interacting with one another. Cindy said:

> 'If somebody is shy or they don't know as much about the topic and they don't share or they come from a different background, other children scaffold another student's learning experience.'

8. Discussion

8.1 Personal epistemologies and wikis

Wikis were appropriate teaching tools for our participants to convey that knowledge is tentative and evolves over time. Wikis provide a platform for sharing knowledge. The dynamic facet of wikis highlights that knowledge is socially created and it is subject to change.

Wikis shed light on the collectivist characteristics of epistemology through the process of knowledge sharing. The collaborative context in wikis facilitates multiple contributions to reach a socially generated body of knowledge. As our participants maintained, student collaboration in creating a wiki site was a communal activity. In other words, it was a collectivist endeavor, rather than an individualistic endeavor [33, 34]. This collectivist versus individualistic dichotomy has been studied in the nature of science research areas (i.e., what is science and how one can define scientific enterprise). In a similar way to how several scientists and practitioners work together and generate the knowledge they build within their communities through peer review and social interaction, students work together to write an article or generate a solution to a given engineering problem in a wiki platform. If one believes that science is an individualistic activity (for example, one scientist conducting experiments and generating the knowledge only from her experiences and experimental findings with no further social interaction with other scientists), then a good teaching practice would be to ask an individual student to investigate a topic and write a synthesis of it or generate a solution to a problem. However, if one believes that science is not an individualistic practice, that it is, instead, it is a collectivist practice that requires social interaction, then one student investigating a topic and writing a synthesis of it, or generating a solution to a problem, appears as a misleading pedagogical activity.

Our participants pointed out that one main reason they used wikis in their teaching was wikis are very convenient and effective tools for student group work in writing articles or generating solutions to engineering problems. We explain our participants' views on the effective characteristics of wikis as their desire to have their students work collectively, but not individually.

The collaborative and collectivist tenets of the wikis weaken the authority of the expert. By doing so, wiki contributors feel more empowered because they act as experts who are creating or re-representing the knowledge they work on. The knowledge sharing and the negotiation aspects of wikis (mostly in the form of editing the text as the users wish) encourage the user community to work collaboratively and co-create the knowledge. This characteristic of wikis highlights the co-creation of knowledge rather than re-presenting it.

The epistemological nuances in wikis can be summarized as:

- Knowledge is socially constructed and/or represented. Knowledge is shared and negotiated and changes over time.
- Collaboration and group work are essential. Individuals work together to co-create the knowledge or generate an optimal solution.
- Collectivist rather than individualistic. Only multiple users can complete the activity.
- Expert authority is weakened. The power of knowing is distributed over the wiki contributors.

8.2 Pedagogical potentials of wikis

Wikis require very low technology skills, yet some students who are not technology literate may need to spend some time learning how to login, edit, and post on a wiki site. In that regard, wikis become a venue to teach some basic Internet-based posting. In the long term, wikis support not only teaching about the content but also encourages students' development as life-long technology users [35]. Anecdotal evidence suggests that students who complete a course project on a wiki site have increased self-efficacy and are more confident in using online technologies. When students use a wiki site in a class, they learn how to use a wiki effectively and will be likely to use wikis in the future with more confidence.

Wikis bring insightful approaches to teaching at higher education levels. The collaborative and collectivist characteristics of wikis contribute to professors' teaching in a way that learners' activities become more student-centered, since students can generate original ideas or represent their own understanding, rather than summarizing or re-presenting already-known ideas. Thus, wikis provide an innovation to teaching and learning in that students take the ownership of the information they represent in their learning activity. This aspect also undermines the authority of the textbooks and the course instructor. The ability to know is equally distributed to the contributors of the wiki site. In turn, this enhances student commitment and mutual engagement.

Wikis provide a social platform that enhances student engagement in sharing knowledge, although asynchronous communication occurs. The non-authoritarian environment of a wiki contributes to building collaborative relationships; in turn, a solution to the problem emerges. This perspective strengthens the use of wikis in teaching at post-secondary institutions.

Pedagogical potentials of wikis in education entail the following dimensions:

- Promotes technological literacy and lifelong learning skills.
- Increases mutual engagement.
- Enhances the user commitment and promotes ownership.
- Provides an egalitarian environment.
- Develops a community.

8.3 Communities of practice

Our participants' personal epistemologies and their pedagogical practices about wikis reflected the notion of communities of practice. Participants explained their understandings about the term 'communities of practice' using the wiki context. Communities of practice involve mutual engagement, a joint enterprise, and a shared repertoire [31]. Our participants emphasized the collaborative and collectivist perspective of wikis in their teaching and highlighted that they wanted their students to work and produce a solution collaboratively.

Sharing knowledge, group collaboration, and social negotiation employed in a wiki platform reflect a community in which its members have common goals to accomplish. Depending upon the context, the collaboration can generate original ideas and theses or an optimal solution to a given problem.

Professors' perceptions about communities of practice in using wikis at teaching theoretically fit through well. However, that notion does not work practically in all wiki contexts because of students' insufficient perceptions about wikis. In the cases where students view their wiki activities as only summarizing concepts or defining terminology, the characteristics of the communities of practice a wiki environment can provide are hindered and a community does not emerge in a wiki environment. For future studies, students and instructors' perspectives about the use of wikis in teaching can be

explored concurrently to see if students' perceptions of wikis have a major impact on the nature of wiki use in teaching. In addition, students' personal epistemologies might be an interesting study to explore the extent to which students' personal epistemologies shape the nature of the wiki context in their learning.

Our participants did not agree that their wiki environments successfully cultivated student communities of practices. This is not a surprising finding, considering that a typical wiki environment (e.g., Wikipedia) does not include some major characteristics of a community of practice. Persistent identities and user history are two major characteristics that a typical wiki environment does not involve. Because a wiki article that is collaboratively generated is the final and the only product a wiki reader sees on the screen, the authors' personal identities, user histories, and other characteristics are completely hidden. When someone reads a Wikipedia article, for example, she doesn't necessarily know the authors' characteristics. Wikipedia lacks the context for a user identity to develop. Articles are the only products formed in a Wikipedia-type environment. Individuals' identities do not explicitly form in Wikipedia. The user community norms do not necessarily emerge, either. For example, risk doesn't exist in Wikipedia. Users' reputations as authors are not considered, either. This is because a wiki reader does not know the author's preceding posts to the site or the characteristics of her early contributions [36].

It is recommended that for a successful online learning environment to emerge and self-sustain, contributors' persistent identities, their user history, a relative risk of dismissal from the group, and a community norm should evolve within the environment [36, 37]. For personal and persistent identities to evolve in a community, the contributors should have their own voice and identity represented in their posts. In a typical wiki environment, though, this persistent identity is irrelevant. This doesn't mean that in every wiki the personal identities are ignored. Indeed, in professor-designed wikis, student users are often not anonymous and students and the instructor can track each other's posts and be able to know who is posting what. This awareness can foster a user identity and a user history over time, which, in turn, may help develop a relative risk of dismissal from the group and emergence of the community's own norms. We recommend that the future studies investigating student-generated wikis focus on the emergences of persistent identities, user history, risk of dismissal from the group, and a community's own norms, all of which are critical characteristics for a sustainable community of practice.

9. Conclusion

In this paper, we explored the nature of wiki use at the higher-education level with an engineering content focus and five professor's personal epistemologies pertaining to wikis in teaching. The study conclusion is that our participants' personal epistemologies were associated with their reasons for using wikis in teaching, as well as the context of the wikis they created for their teaching. Our participants agreed that wikis can be a venue for the communities of practice to emerge among the students; however the constraints of a semester long university course limit the community to mature and self-sustain.

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Appendix- Interview Protocol

Research Question: What are the professors' personal epistemologies and pedagogical intentions pertaining to wikis in teaching?

Note: The questions below were asked as appropriate. Some emerging questions were posed during the conversation and some of the below questions were omitted.

1. What leads you to use wiki? (Depending upon the conversation one or more of the followings were posed)
   - For what purposes do you use wiki?
   - What are the uses of wiki in science or engineering, in your opinion?
   - How do you engage your students in a wiki writing project?
   - How does a wiki help your instruction?
   - How do you think wikis affect your teaching?
   - What are the outcomes of using wikis in your course?
   - What challenges have you encountered in using wikis in your teaching?
2. What do you think the role of wikis in knowledge generation?
3. What is your general opinion about a wiki? What it is used for? (Possible key words interviewee may use are: wiki is a social tool, a mediating tool, a collaborative tool, a communication tool, a peer review tool, or a textual tool)
4. How can you explain the use of wikis within the context of a community of practices? (Alternatively: What was the group dynamic look like that your students formed in writing the wiki articles?)

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