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Millennial Students & Technology Use: Implications for Undergraduate Education

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ABSTRACT
This paper investigates the impact of ubiquitous computing on undergraduate educational delivery and student learning. It focuses on the analysis of interdisciplinary literature relating to how the newest generation of undergraduate students interacts with and learns using digital technologies. It also reports the results of a preliminary study that investigated the expectations, technology use preferences, and information-seeking strategies of today's "Millennial" undergraduate students, and of the professors who teach them. The two groups' ways of learning and interacting with digital media are compared and contrasted, and recommendations for better supporting today's students' learning behaviors and preferences are offered.

Author Keywords
Undergraduate education, ubiquitous computing, collaborative learning, educational technology.

ACM Classification Keywords
H.5.3 Group and Organization Interfaces.

INTRODUCTION: THE MILLENNIAL GENERATION

"Most students entering our colleges and universities today are younger than the microcomputer, are more comfortable working on a keyboard than writing in a spiral notebook, and are happier reading from a computer screen then from paper in hand. For them, constant connectivity—being in touch with friends and family at any time and from any place—is of utmost importance." [18, pg. 15]

How do today's undergraduates fit into the established framework of higher education? And how can educators harness current and emerging information technologies to better support student learning? The iPod is only the latest in a series of technologies that can be viewed as establishing a specific social structure in society. Williams [50] argues that the form and uses of television as a technology developed in the ways that they did because of a desire to consume technology within the domestic space. Television technologies were developed to connect users to the outside world in ways that ensured that they were not disturbed by it. Wherever people went, with wired or portable television devices, they could consume these resources within their individual sphere, free from the need to socialize. Williams termed this phenomenon "mobile privatization" [50]. Portable media players can now support a wide variety of rich media formats to display images, play audio and video files, and display textbook contents. Users can download content from various locations via WiFi access, or download via the internet for later viewing.

As a result, education outside the classroom has become relatively location-free. There are two major expectations that have historically driven the development of such technologies. The first is that multimedia content may be customized for individual uses and purposes by the user. Using RSS feed technology, users can configure a software application to automatically download only content in which they are interested. The second is that content is to be consumed within the private sphere, creating a "technological bubble" around the user [29]. If we accept the latter premise, it provides both a challenge and an opportunity for higher education. The challenge is that it may mitigate against the mechanisms by which instructors encourage the peer-learning and collaborative work that is part of personal development and preparation for the social workplace. The opportunity is that it may also facilitate a more active and ongoing interaction with learning materials by the individual, as they can participate in an increasing number of social spaces.

We need to ask if the premise is correct for all of our students. Born between 1979 and 1994, students who came of age in or around the Millennium comprise the bulk of today's undergraduates and will continue to do so for much of the next decade. A number of studies have examined the information and communication technology (ICT) use patterns and preferences of the members of this so-called Millennial generation (also called "Millennials," "the Net generation," "digital natives," "the Nintendo Generation" and "Generation Y"). In general, Millennials' relationships to technology are different from that of previous generations; technology, and ICT use particularly, plays a much larger role in their everyday lives [8, 20]. For these young people, "technology is assumed to be a natural part of the environment" [33, pg. 38], and consequently, "Today's students have a high comfort level with technology and technological change." [14]

This emerging body of work suggests that today's undergraduates are "digital natives," [39] whose learning preferences and information use behaviors differ from those of previous generations, particularly in regard to technology-mediated learning. They have a stronger preference for collaborative work; they are keen to experiment (as distinct from the risk-averse attitude of their predecessors); and they cannot understand why anyone would not be able to listen to music, carry on a conversation with friends, and do coursework at the same time [8, 20, 46]. The hypertext format of the Web has led to new non-linear information use patterns, including non-linear researching styles unlike those of most of the scholars who teach them [2, 6] and unlike the information preferences of previous generations of students as well. This generation also often shows distaste for information presented in traditional text-only formats, tending to favor texts images and multimedia components breaking up texts [2, 22, 32]. Due to these new information behaviors and preferences, Manuel [32] has found that "the lecture is an especially ineffective instructional technique for Gen Y students." Yet the lecture is still the most prevalent mode of educational delivery at the undergraduate level.

For educators, the question becomes how we can stop using our own generation – with its focus on individual work, the private sphere, and a preference for single-tasking – as a model for instructional delivery and how we can understand the needs of the Millennial generation. Since Millennial students show a preference for working collaboratively, it seems that social computing, and ubiquitous computing technologies in particular, might be well-suited to the learning styles of most of today's undergraduate students.

SELECTION OF TECHNOLOGIES FOR EDUCATIONAL DELIVERY AND LEARNING

Research investigating the impact of various presentation and delivery technologies on educational outcomes has been inconclusive as it has ignored the relationship between uses of technology and instructional method [21]. An instructional method is "any way to shape information that activates, supplants or compensates for the cognitive processes necessary for achievement or motivation" [42]; cited by Clark [12]. The impacts of instructional technologies, which selectively present information and learning objectives in ways that draw on research into the cognitive and social processes of learning, are frequently confused with the impacts of delivery technologies, which provide effective access to those methods and environments [24]. Some authors argue that the use of specific technologies, media and instructional method are inseparable. New technologies and media permit new representations of and interactions with learning content, that result in deeper learning outcomes [25]. Other researchers argue that it is not the media per se that permit deep learning, but the instructional method [12, 19]. Joy and Garcia observe that most studies of media use are flawed, in that they do not distinguish between technologies used for content representation and technologies used for delivery of, or access to, instructional resources. Most researchers in technology mediation do not have a sufficient grasp of the differences between instructional paradigms and ignore these differences. Once instructional method is considered, the impact of specific media or technology has no significant effect on learning outcomes [21].

There is no dominant framework by which to define instructional methods and many terms are used inconsistently in the various literatures that consider educational approaches. For example, van Aalst and Hill argue that "the 'object' [of learning] consists of one or more problems of understanding in the area that the subject is investigating" [48]. This statement reflects a very learner-centered, constructivist paradigm, that is typical of the Computer-Supported Collaborative Learning (CSCL) community to which the authors belong. In comparison, the approach employed by Computer-Aided Instruction (CAI) advocates and researchers may be viewed as atomistic [30]. CAI applications – often used in disciplines where an experimental approach is the norm, such as engineering or cognitive psychology – support a sequence of activities that is obtained when specific learning goals are decomposed into their component tasks and evaluated as a measurable difference in displayed proficiency [24]. So we start our analysis of the literature by differentiating four dominant paradigms governing the use of instructional methods, synthesized from the educational literature [3, 7, 24, 36, 43, among others]. These are summarized in Table 1. There are many different

Theory of Learning	Theory of Pedagogy	Approach to Instruction and Learning	Typical Instructional Methods
Didactic instruction supporting atomistic learning [1, 30]	Instructor-centered. Instructor acts as subject-matter expert, providing ideas & experiences necessary for students to learn new subjects.	Instructor provides or directs students to specific resources and expects them to use specific analysis methods in their coursework. The approach combines the delivery of factual information with intellectual coaching and instructor-learner dialogue (often using the Socratic method).	Lectures Structured problem analysis Instructor-led deconstruction of readings and texts.
Constructivist learning [15, 37]	Learner-centered. Students construct an internal model of how the world works through learning-by-doing.	Instructor provides students with structured activities and resources that permit the learner to construct new knowledge from their experiences and to reflect on their experiences, internalizing knowledge.	Guided assignment completion Tutorial or class exercises Laboratory experiments Structured problem analysis
Problem-based learning [44, 47]	Learner-centered Students develop transferable skills by applying abstract knowledge to real situations.	Instructor facilitates students in allowing students to experiment with *formulating* and resolving problems in complex, real-world settings. Students may work alone or collaboratively, with progressively reduced instructor input.	Course projects (where students are free to select own focus and methods) Case study analysis Domain-specific simulations and games
Collaborative learning	Community or group centered. Focuses on the joint construction of knowledge across groups of learners.	May build on one or more of the other categories, but also incorporates *sustained interaction* between learners to maximize the opportunities for joint knowledge construction.	Group analysis and projects; Interactive, collective course discussions; WIKI page construction Online CHAT rooms.

Table 1. Paradigms Governing Selection of Instructional Methods.

"flavors" and combinations of the approaches given in Table 1, that have been categorized as instructional approaches in their own right. Our intention is to differentiate among philosophies of instruction: not to provide an exhaustive categorization, but to provide a framework by which an instructor's approach to course structuring and delivery may be analyzed. As such, we may assess the fit between the instructional approach employed and the learner's approach to engagement with course tasks, resources, and technology. After Koschmann [24], we distinguish between the implicit theory of learning upon which the paradigm is constructed and its accompanying theory of pedagogy, the model of instruction that underlies the paradigm.

Instructional technologies are developed as part of a system of instruction that focuses on a specific paradigm of learning that embeds a structure (or "scaffold") for specific elements of the learning experience. The design of learning environments needs to be "scaffolded" in ways that fit with a theory of instruction that achieves the desired outcomes, if courses are to result in deep student learning [41]. Scaffolding provides a "roadmap" and a process that guides learners in specific ways, structuring interactions with the instructor, other learners, information resources, and the technology used to deliver these processual and informational elements of the course. To employ course scaffolding effectively, we need to be concerned with:

1. The design and specification of tasks to engage and direct the learner in the process of knowledge acquisition and development of understanding;
2. The design and specification of (process) supports for the learner to structure the learning experience and to provide meaningful forms of feedback; and
3. The design and specification of the learning resources needed by the learner to successfully complete the set tasks and to facilitate the scaffolding and guidance [35, page 13].

We would argue that there are important elements missing from the scaffolding concept that are related to assumptions about the instructional methods, the fit between the paradigm of learning adopted by the instructor and that adopted by students, learners' information-seeking strategies, and the impact of technology on each of these elements. In Table 1, we differentiated among four paradigms of instruction that had very distinct expectations of how course interactions would be structured. The research indicates that the selection of technologies to support course delivery is

often mismatched with the paradigm of instruction underlying the course [12, 21]. But this is only part of the picture. As discussed below, student information-seeking strategies and technology preferences may undermine the intent of the course scaffolding and delivery strategy. We need to supplement the scaffolding concept with an explicit understanding of the pedagogical paradigm supported by the instructional methods employed and its fit with technology selection by instructors and students.

FIT OF TECHNOLOGIES WITH INFORMATION SEEKING STRATEGIES

Many educators argue that we need to incorporate the use of rich media informational resources, such as streaming video, online images, and text feeds, delivery via ubiquitous technology, and the use of social collaboration technology platforms into higher education design strategies, to meet the expectations of the emerging generation of undergraduates. Although information behavior work is a rapidly growing subset of library and information science research, most information behavior work has focused on adults or children, with relatively little research attention paid to teenagers' and young adults' information needs and uses [2, 45]. Most of the studies that do exist have focused on categorizing the types of information that teens and young adults need. For example, Fourie and Kruger divided adolescents' basic information needs into physiological, affective, and cognitive needs [17]. Latrobe and Havener identified six categories of information needs: course-related activities, current lifestyles, future plans, relationships with others, health, and general information [27]. Shenton and Dixon created a typology of 13 categories of information that children and teens needs, such as "advice" and "affective support" [45]. In a meta-analysis of information behavior research relating to this generation's use of the Internet resources, Large showed that Internet use is playing an increasing role in the lives of today's young people [26]. A number of large national surveys have also showed teen ICT use to be on the rise [28, 40].

But does widespread instructional use of ubiquitous and social technologies fit with student preferences or support their information-seeking strategies? A report by the Pew Foundation found that only 12% of US people online had ever downloaded a podcast, a streamed audio presentation, provided online and deliverable to targeted portable media devices. Males are more likely than females to have experimented with podcasts. Of those who had downloaded a podcast, only 14% were in the age range of 18-29, the typical undergraduate student range [31]. This low rate of use cannot be seen as a generational issue, but as a targeted use issue. Users will only download a podcast when it provides more information, in a more accessible, or entertaining form than its text equivalent. A major news organization observed that less than 2% of the audience for a recent news item downloaded the video podcast. The text-based webpage story was read thousands of times, while the podcast was only downloaded a few dozen times [5]. In many ways, podcasting appears an ideal technology to satisfy students' learning preferences. It supports their advanced ability to interpret visual information, their desire for social contact during instruction, and their ability to "move seamlessly between physical and virtual interactions" [34, p. 12]. But its impact on information seeking and social information sharing may be a poor fit with the intended educational outcomes and may not reflect the ways in which students prefer to share and locate information.

STUDY METHOD

This paper explores what is known about how to scaffold courses for Millennial generation students using rich media and ubiquitous technologies to derive a framework for instructional design. We report the findings from a small sample study of Millennial students' uses of technology for learning and information management. We conducted exploratory, in-depth interviews with 7 undergraduate students and 7 professors in the Drexel College of Information Science & Technology (Drexel IST) to understand how they were using various applications of technology, for what purpose, what information seeking strategy they used in learning or instruction, and why. While the sample size was small, we explored the issues in depth over time so that we could explore issues that arose from various work tasks and contingencies. In our findings, we compare the technology preferences of students with instructors' expectations to understand discordances in current approaches to undergraduate education. Drexel IST professors may be more likely to use technology than those in other fields, and the students interviewed were mostly very successful academically (six of seven described themselves as "high achieving"). So our findings may not be typical. But the students did appear to consider themselves typical and mentioned similar criteria for technology use applied by students in other programs, as well as by other Drexel IST students.

THE ROLE OF TECHNOLOGY IN MEETING LEARNING PROCESS EXPECTATIONS

What The Literature Says

A number of studies have concluded that the relationship of Millennial generation students to ICT's is different from that of previous generations. Technology plays a much larger role in their everyday lives than it did for previous generations [8, 20, 28, 34, 46]. Their learning preferences vary from other generations' with a stronger preference for collaborative work, experiential and inductive learning opportunities, and multi-tasking [33]. Their learning preferences also vary from other generations', with a stronger preference for collaborative

work, experiential and inductive learning opportunities, and multi-tasking [8, 33, 46]. Millennial students are more likely than previous generations to have strong family ties and long-term social network associations that they maintain through technology. They prefer to learn and work socially, establishing strong peer-networks through which they help each other. They expect learning environments to mirror their socially-connected lives [8, 20, 28, 34, 46]. For many educators effective educational delivery focuses on how emerging uses of technology can best support these learning preferences, while others view these preferences as a reflection of poorly-developed learning skills.

How Millennial Students Select Technologies For Learning Support

The emerging generation of undergraduate students appears to use very different criteria to select technologies and applications for tasks than the generation of students that preceded them. It will come as no surprise that students select an information delivery technology based on a balance of convenience and just-in-time preparation of coursework. But Millennial students appear to have an additional level of sophistication in what is considered just-in-time. In determining task priorities and preparation needs, students appear to consider the importance of the assigned work to their course grade, the degree to which course knowledge domain is relevant to their career goals, and the degree to which they consider themselves to be a high achiever academically. This contrasts with previous generations of students, who reportedly made task planning decisions on the basis of workload alone [7]. While previous students appeared to balance information quality and information search time, newer students appear to prioritize search time. These students do appear to have well-developed criteria by which to judge both credibility and information quality, as discussed in the next section. They are proud of their ability to discriminate high quality sources from low-quality ones. But search time overrides all other considerations.

The most distinct change in technology use for this generation appears to be the use of internet social-networking applications. Of the 7 students interviewed, only one – a non-traditional adult student – did not use either Facebook or Myspace. Most (5 out of 7) used a social networking application to keep in touch with distant friends, while 3 used it to contact new friends. Despite the high reported use, only one of the students identified social-networking sites as one of their primary modes of communication. The surprising finding was that students overwhelmingly reported selecting the communication medium based on the social prospects of the contact. If the contact was a fellow student, the individual would use Facebook or Myspace if they saw the contact as a potentially long-term friend. This allowed them to share information about activities, tastes (e.g. in music or books), and shared friends, which they viewed as helpful in building a relationship with the new contact. If the contact was someone from whom they just needed information in order to complete a work assignment, they would meet in person, pick up the phone, or email that person. Students did not appear to consider experimentation with various technologies as time wasted. All 7 students reported having multiple accounts on various social networking sites. When one account became "messy" (their word), students just opened a new account. "Messy" appeared to include a variety of issues: too many contacts to manage, old personal information that reflected badly on them, or simply having forgotten their password. When asked which communication methods they preferred, all 7 included face-to-face communication, 6 mentioned email, and 4 mentioned phone calls. For communication with instructors, students valued immediacy of communication and then formality. Most students preferred a face-to-face meeting, with email an alternative if a meeting were not possible.

How Professors Select Technologies For Learning Support

As might be expected, the use of social networking applications was lower than for students. Four of seven instructors reported using social networking. Those who did use a social networking application appeared to select this on the basis of professional visibility (three had an account on LinkedIn), or information sharing (Digg and del.ico.ious were the favorites). As might be expected, professors were more reflective when they considered the use of various technology applications. They saw their time as a long-term investment and were less willing to start using a technology that had no apparent benefits. Two of the 3 professors who did not currently use social networking applications had tried these, but found them of little use. This appeared to deter them from trying other social networking applications. The top three preferred communication methods were the same as those for students: 5 out of 7 stated face-to-face, 7 mentioned email, and 6 preferred phone calls.

Comparison

The most significant difference was in the use of social networking applications. Students were more likely to use social networks that enabled them to build and maintain social (friendship) relationships, while professors were more likely to use social networks that enabled them to build and maintain professional relationships. Another difference was the contrast in users' willingness to invest time in adopting or learning a new technology. For Millennial students, willingness to adopt was based on the potential of the technology to provide social network support. The time spent in configuring or learning a new application was immaterial. But for professors, the time

spent was paramount. Their willingness to adopt depended on the tradeoff between configuration and learning time and the expected professional payoff in using the technology.

Implications for Selection of Educational Technologies

Based on these preliminary results, students appear to select a technology on the basis of its social utility. They are willing to spend significant "wasted" time configuring and learning to use technologies that enable them to manage and develop networks of social contacts and friends in specific ways. When the technology application mitigates against this (for example, it becomes "messy"), they will abandon it and spend time in configuring or learning a new technology application or another instance of an existing application. In contrast, professors appear to value their time more, needing to be convinced that a technology will provide a significant payoff before they will adopt it. If they assume this type of attitude on the part of their students, they may select technologies that students have no motivation to use, or be disappointed when students abandon the technology part-way through a course. When learning communities are viewed as transitory, this may mitigate against the constructivist and collaborative approaches to instruction (Table 1) as the student is more engaged with their long-term social network than the short-term social network provided by the learning community. If an instructor prefers the didactic instruction approach, Millennial students' technology preferences are likely to present a poor fit with this paradigm of instruction unless they are placed in a learning environment where they have little opportunity for social contact and a strong motivation to prioritize work over social network building.

STUDENT INFORMATION SEEKING STRATEGIES

What The Literature Says

Traditional models of information-seeking reflect a world where the research goals are clear and the domain to be searched is well understood. This is rarely the case. Bates [4] presents an alternative, likening information-seeking to berry-picking. Information-seekers range through the information space available to them, moving from resource to resource as they spot new patches of relevant information. They evolve their search parameters as they find new resources, varying their information-seeking strategy dynamically. The concept of berry-picking was extended to web searches by Pirolli and Card [38], who developed the notion of adaptive search in terms of "information foraging." This concept reflects the use of a variety of short-term strategies to locate information and how these strategies adapt to the information environment. Komito [23] develops the idea of foraging, comparing our expectations of information-seeking behavior in a normative society that is guided by agreed rules of behavior (such as those guiding the didactic instructional paradigm of Table 1), with a model that he terms a "foraging society," reflecting the behavior of individuals as they participate in groups *without a strong collective identity* in their use of Internet resources: "Their loyalties are not to the group in which they currently live, but to their extended kinship network which includes people in other groups in other locales" [23, pp. 104]. More recent information-seeking theories appear to match well with the social community building behavior that was identified in our findings above.

How Millennial Students Approach Information-Seeking

Millennial students appeared to use technology-mediated information seeking as their first recourse: all 7 students interviewed agreed that there are answers to most questions somewhere on the Internet. But technology is certainly not their sole source of information, nor is it considered infallible. Four students told us that they used technology for "everything," but then responded that they would to ask a person for information when they had a poorly-formed information need. When asked, "How do you find something out when you don't know what question to ask?" 5 of the 7 students responded that they would try an online search (Google) using what terms they knew in order to become familiar with the subject so that they could formulate a more specific query. The other students would locate an expert in the area to help flesh out a question instead of using electronic searches. But they appeared to expect to do this electronically. So technology appears to lie at the center of students' information-seeking strategies.

When describing their overall research process, most students started with Google to obtain a general understanding of the topic at hand and to refine their terminology. Based on this knowledge, they tended to move on to more academic sources to obtain specific, in-depth information about the topic. Their search completeness criteria combined an assessment of whether they had fulfilled the instructor's requirements with an abstract feeling of satisfaction with an answer. So how was this feeling of satisfaction achieved? Students did not seem to believe that they had a different search process when seeking academic information versus non-academic information; they just used different sources. Only one student mentioned critical evaluation of sources as a difference in the information-seeking process. Yet, when asked what factors influenced their selection of electronic resources, the most common response was credibility, followed by the usability of the interface, which was extremely important to them. Most students discussed the usability of various electronic source interfaces, with an emphasis on the time it took to obtain information. Interface usability appeared to constitute a major factor in their selection of electronic resources.

How Professors Approach Information-Seeking

Professors tended to use technology-mediated information seeking when they needed hard facts or discrete information. They contacted a human being, normally a colleague or a domain expert, when they needed more specialist or in-depth information. They prioritized source credibility, comprehensiveness, and accessibility when selecting electronic resources. Professors tended to research a question by determining key terminology, performing a general search, and structuring the problem. Their process seemed to be similar to students', except a few expressed a stronger degree of structure when tackling academic research. This is probably due to professors' academic background as well as personal habits; there were professors who confessed to having a very unstructured process, usually because they consider themselves practitioners rather than academics. They finish researching when a deadline is reached, interest or motivation decreases, or they feel they have obtained sufficient information. When professors are seeking academic information, they tend to use more scholarly sources than students, but do not differentiate between academic and non-academic information search strategies.

Comparison

Students and professors both use technology frequently when seeking information, but students tend to describe themselves as using it for "everything" while professors appear to be more selective in their use of electronic vs. human sources of information. However, students also expected to use technology to communicate with domain experts, which may explain why they think that they use technology for everything. Students expressed frustration at the inability of email to communicate complex information and the unwillingness of professors to communicate complex information via email.

A major difference was apparent in how the two groups identified subject experts. Students mentioned anyone in their social network who might know something about the area as "experts," while professors identified experts as people who specialized in the study of specific domains. Students would attempt to derive search terms by performing a Google search, then refine their terms as they proceeded. When information needs were ill-defined, their first recourse was to ask the professor, followed by fellow students and friends, until they understood what was required sufficiently to define search terms. Professors would define search terms first, then refine these through electronic searches.

The widely-held assumption that Millennial generation students do not have an information-seeking strategy or process appears unfounded. They may be less familiar with suitable search terms than their professors, but they clearly plan a set of search processes that results in a fulfilled information need. They also appear familiar with how to derive criteria by which to evaluate information quality and search completeness.

While insufficient information was gathered to understand the processes, or the reasons behind it, several professors suggested it was due to an ability to find information easily at any time about virtually any subject. Students today do not have the same need for a structured information-seeking process. Of course, even an unstructured search processes requires time, and many of the students mentioned their tendency to complete assignments the night before their due date. But procrastination is not unique to Millennial students.

Implications For Design Of Educational Technologies

Undergraduate students have a more sophisticated strategy in locating "high-quality" information than the short-term foraging strategy suggested by the literature. They appear to develop a strategy based on bricolage [11]. Students assemble parts in the same way that they would assemble parts of a jigsaw puzzle, piecing together assumed views of the sky, the end of a roof, some corner pieces, and a head-and-shoulders subassembly and placing these in relation to their understanding of the big picture. They associate a range of sources, people, and resources into partial collections of information that fit with an overall concept of what they think they need to understand. This is done contingently and emergently, as information, people, and resources become available.

Of particular interest to HCI researchers were differences in definitions of information accessibility. Most professors did not consider accessibility a problem. Two professors discussed accessibility in terms of immediate availability as opposed to ease of use of the source itself. Students discussed the physical nature of information: its organization, the interface design, and the complexity of the language in which the information was presented.

FIT OF INSTRUCTIONAL METHODS WITH STUDENT TECHNOLOGY-USE *AND* INFORMATION-SEEKING

In the final part of our paper, we will demonstrate the application of a framework by which to analyze the fit between instructional methods and student technology use and information-seeking strategies. Drawing on developmental theory in psychology, activity theory is based on the concept that the connection between stimulus and response in human activity is transcended by 'a complex, mediated act' [49]. Activity theory has been employed in both HCI and CSCW research to account for the cultural-historical situatedness of human activity, in combination with the mediated relationship between the subject, who performs the activity, and the object of that activity [13, 16]. Figure 1 shows two interacting activity systems that interact to demonstrate the mechanisms and contradictions of systems of human activity [16]. The outcomes resulting from the two systems of activity

interact to produce a third outcome, that is consequent on the interactions between the two systems of activity.

In Figure 1, the left-hand side of the model analyzes a system of instruction from the perspective of the instructor, who has scaffolded their course to achieve a collaborative analysis of complex problems. This is mediated by their expectation that students will use two forms of technology-mediated communication, asynchronous discussion board postings and written assignment reports (an inherent contradiction, as these forms of technology mediation do not favor collaborative outcomes as communication is asynchronous – this is indicated by the lightning-flash, after Cole and Engeström [13]) The instructor's collaborative rules of behavior, the constructivist expectation of a community of learning, and the expected division of labor (none – work is collaborative), contrast with the student perspective shown on the right-hand-side of the model. The student lives in a different social world than the instructor: a "small world" [10], in which the student's long-term social network acts as a community into which current course members are admitted only if they display long-term social potential. Members of the student's social network determine the types of information that are important for its membership and which information sources they should trust. So the student object is mediated by a different set of information resources and technology, that draw on the student's social network to complete the report in minimum time. Examples of assignments from the student's fraternity, Facebook contacts, and information gleaned from online essays and readings on the assignment topic dominate the student's information search strategy. The student interprets instruction as didactic (the most common student experience) and so draws on rules of behavior based on *coordination* of work, rather than *collaboration*. Students divide the analysis problem into sub-problems and enable a division of labor that requires little collaboration to produce the assignment report. Emails to other group members and asynchronous discussion board postings (one of the main scaffolding mechanisms provided by the instructor) come very low on the list and are only resorted to when other sources of information prove insufficient. The instructor's model of constructivist learning is undermined by a set of interlocking student expectations and community norms that relate to the student's social network rather than the course community.

DISCUSSION

This example was derived from our preliminary study of undergraduate student learning behavior. Our analysis contains more detail than that summarized here -- this summary has been presented to communicate the value of this type of analysis concisely. It is with this understanding that we would recommend to instructors that they investigate technologies that support collaborative process, such as shared collaboration spaces or rich media artifact production, where students would view the object of their work as requiring collaboration. It would likely require 2-3 cycles of experimentation in the scaffolding design before the student perspective matched with the instructional intent. Or perhaps course scaffolding might be achieved through defining a different set of rules for course behavior, requiring collaborative reporting. In turn, this would need a different use of technology to support the changed system of activity. It is our intent to follow instructors, students, and courses in different disciplines over a period of time (as far as this is consistent with the anonymity of human subjects in our reported research) and to understand how course scaffolding designs develop with the lessons learned in exploiting new technologies.

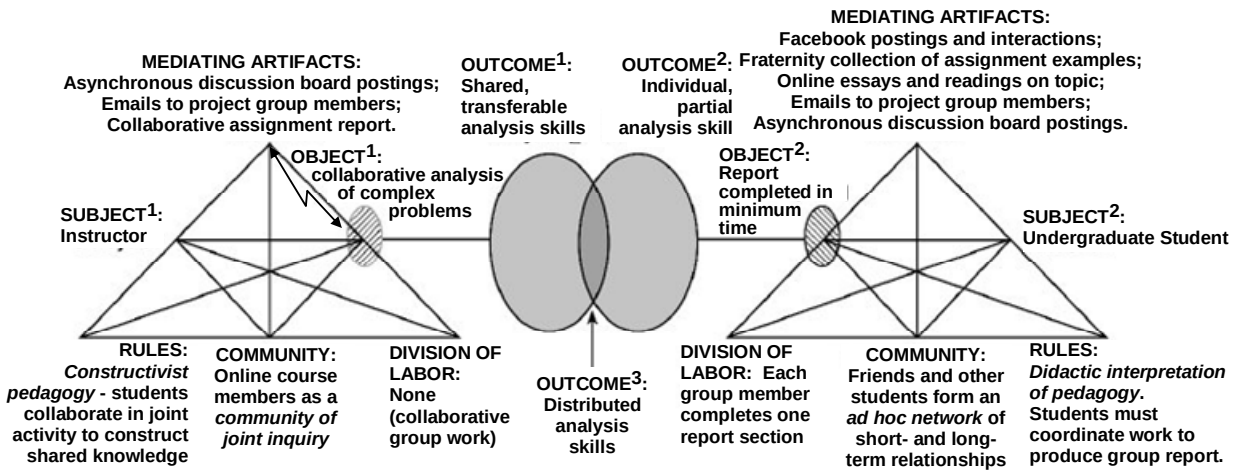

Figure 1. Using An Activity Theory Framework To Relate Instructor Course Scaffolding To Students' Information-Seeking Strategies

CONCLUSIONS

Carroll [9] calls for the assimilation of community and civic sector computing uses and knowledge into HCI, arguing that this would fundamentally enrich HCI concepts and approaches. Among other actions, he calls for a clarification of "the notion of community, used so widely, and yet so lightly, in contemporary HCI discourse," an emphasis on social engagement and human development, and an expansion of the concept of usability "to include larger-scope and longer-term social impacts" [9, pp. 307-308]. To meet this challenge, we studied the expectations, technology-use preferences, and information-seeking strategies of "Millennial" undergraduate students. We compared these to the pedagogical expectations that drive professors' ICT selection and use. We found that information seekers inhabit a "small world" [10] – their extended social network – in which members of their long-term social community determine the types of information that are important to its membership and which information sources they should trust. Social network membership is not based upon course community or proximity. Rather, students appear to develop a long-term social network that is mediated across home, work, and learning contexts by the use of technology. It is this community they call upon to provide subject "experts" and to support them in the processes of learning.

A preference for social uses of technology does not predicate an unsophisticated information-seeking strategy. In an information-rich world, the challenges that face us in designing and selecting technology applications for education of the new generation of students are not only how to facilitate finding and collecting information, but how to optimize the student's time. Poorly-designed user interfaces are of particular concern to them, possibly because they spend so much time configuring and learning new applications, or creating replacement accounts on existing applications. They appear to employ a bricolage strategy in assembling information for learning, and so they need rapid, easy access to a variety of information resources, as these suggest themselves.

In scaffolding courses, we need to consider (i) the design tasks to engage and direct the learner; (ii) the design and specification of (process) supports for the learner to structure the learning experience; and (iii) the provision or location of informational learning resources [35]. We have addressed element (i) by considering the key differences between instructional methods in Table 1. We addressed (ii) by exploring differences in Millennial students' expectations of learning processes and the role of technology in mediating these vs. the expectations of their professors. Although much has been written about the kinds of information technologies that exist for use in today's educational settings, relatively little work has been done into how students learn with technology and how educators can support these learning behaviors [11]. We therefore presented a framework for analysis, based on activity theory, to determine the degree of fit. This approach could be used more widely for this purpose.

This paper is not just about the use and impacts of technology. It is about understanding what motivates learners and instructors to use or to prefer specific types of technology for specific types of learning tasks. It is also about developing lessons learned that permit us to design and exploit technology-supported learning environments to ensure that pedagogical objectives are fulfilled and that undergraduates are *engaged* in learning.

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