受损的页面内容无法自然阅读，但根据页面的结构和上下文，可以推断出内容是关于技术与知识的同步性框架在异步环境中的应用。
TOWARD KNOWLEDGE TECHNOLOGY SYNCRONICITY FRAMEWORK FOR ASYCHRONOUS ENVIRONMENT

Simon Cleveland, City University of Seattle, Seattle, Washington, USA
Gregory Block, Brandeis University, Waltham, Massachusetts, USA

ABSTRACT

While distance learning education continues to grow, online instructors face certain asynchronous uncertainties when it comes to knowledge exchange with students. To counteract such uncertainties and minimize teaching deficiencies expected to occur in asynchronous learning environments, this study examines a set of knowledge building blocks that play a role in the online knowledge exchange process. Knowledge technology synchronicity framework for asynchronous environment is proposed that integrates knowledge seeking behavior, knowledge properties, knowledge domains, knowledge types, knowledge tools, and technology synchronicity. A real-life case is provided to integrate the framework in practice.

Keywords
Asynchronous education, virtual classroom, knowledge seeking, knowledge properties, knowledge dimensions, knowledge tools, knowledge types, synchronicity, framework

INTRODUCTION

A key component of distance learning platforms is an asynchronous learning environment, which promises to allow both students and their instructors to engage in learning at their own pace and schedule, without having to adhere to a fixed meeting time or location (Moller, 1998; Swan, 2001). Asynchronous learning can be effective for tasks where steps and outcomes are well-defined, such as an assignment to review academic literature to participate in a discussion forum (Loncar, Barrett & Liu, 2014; Nandi, Hamilton & Harland, 2012); however, in tasks where the steps are not well-defined or outcomes are not known in advance, a student may struggle when questions or uncertainties arise and there is no guidance on how to proceed (e.g. software engineering tasks)(Arkorful & Abaidoo, 2015; Dowling, Godfrey & Gyles, 2003).

Research has identified numerous techniques for addressing these deficiencies in asynchronous learning (Chen & Wang, 2004; Johnson & Altowairiki, 2016; Underdown & Martin, 2016); however, many of the approaches require some form of synchronous intervention (cognitive apprenticeships) (Jonaseen et al., 1995), or are limited to addressing finite problems that can be anticipated in advance (scaffolding)(Sims, Dobbs & Hand, 2002). These approaches do not improve a student's own problem solving skills for indeterminate problems without resorting to synchronous interactions, thus representing a challenge for online programs that offer ‘self-
paced’ competency-based degrees with minimum intervention by instructors. As a result, the research question for this study is: how can knowledge be organized to minimize teaching deficiencies expected to occur in asynchronous learning environments?

In this paper, the authors present an asynchronous knowledge technology synchronicity framework that integrates knowledge form, types, dimensions, and technology synchronicity required for completing knowledge exchange in a virtual classroom. An example is provided to illustrate a deficiency in knowledge transfer and to integrate the framework.

The rest of the paper is structured as follows. First, an examination of knowledge exchange in the virtual classroom is performed and a set of building blocks is analyzed in detail. Next, a framework to organize the knowledge exchange properties are proposed. The paper concludes with a summary and a call for further research.

**VIRTUAL KNOWLEDGE EXCHANGE**

In this study, the authors define asynchronous learning as the process of acquiring and converting knowledge within an online environment that is independent of space and time. The process, which was made possible by advancements in the technology for computer-mediated communication (CMC), has revolutionized the education industry. It has bridged the interaction between students and educators through virtual classrooms hosted within online learning systems (OLS).

The modern virtual classroom is a space where students interact with one another and with the instructor through forums, simulations, and collaborative assignments. Such interaction has been found effective in increasing the motivation to learn, mastery of course material, and greater quality of educational experience (Hiltz and Wellman, 1997). The interaction between instructor and students consists of complex processes that involve the seeking, acquisition, conversion, and integration of knowledge between parties. In the following section, we examine specific behaviors, knowledge properties, knowledge domains, and knowledge tools that will be used to formulate the proposed framework.

**Knowledge Seeking Behaviors**

First, an examination of the process of knowledge seeking is performed. A key factor in the process of knowledge exchange is knowledge seeking behaviors. Such behaviors are defined as scanning for data and information in order to satisfy certain information needs (Xu, Tan, & Yang, 2006). These activities are best explained by the information foraging theory that postulates that individuals would forage for information when they encounter vague problems requiring solutions (Pirolli & Card, 1999).

Studies show that such behaviors fall into various categories. For example, Vandenbosch and Huff (1997) proposed four such categories:
• Undirected—purposeless exposure to information;
• Conditioned—exposure that is not based on specific search for information;
• Informal—attempt to discover information that has no structure;
• Formal—directed attempt to discover precise information.

Furthermore, studies found that knowledge seeking behavior encompasses focused search which “occurs when organizational members or units actively search in a narrow segment of the organization's internal or external environment, often in response to actual or suspected problems or opportunities,'(Huber, 1991, p. 97).

Finally, according to Belkin (1980), knowledge seeking behaviors consist of:

• Seeker’s awareness of knowledge disparity;
• Quest for gathering relevant information;
• Awareness of reduced knowledge disparity.

Savolainen (2006) argued that specific triggers evoke knowledge seeking behaviors. Once the trigger occurs, a seeker considers potential sources of information, retrieves the knowledge, and evaluates its relevance. The outcome of this behavior consists of assessment of the acquired knowledge, whether it has fulfilled the information need, or further knowledge seeking is necessary.

The virtual classroom poses specific disadvantages to learning when it comes to knowledge seeking behaviors (Posey et al., 2010). For example, the asynchronous discussion forums have been found to limit problem solving learning in courses on physics and statistics (Hong et al., 2003; Kortemeyer, 2006). Furthermore, asynchronous discussions have been perceived as unreal and less meaningful (Merryfield, 2001), as well as contributing to the feelings of isolation and not being part of learning communities (Hrastinski, 2008).

In the software engineering discipline, a student may be directed to complete a task involving a programming language. Slight, undetectable missteps in a programming assignment may involve syntactical, lexical, or logical errors that cannot be easily anticipated at the time a course is designed. Successful engineering students rely on problem solving skills, which generally involve a series of heuristics that conclude when a solution has been identified; however, in the virtual classroom, students cannot easily distinguish between intrinsic errors (that is, unanticipated conditions that are inherent to the assignment) and hygienic errors (that is, unexpected errors that are inherent to the platform). Students are expected to reason through intrinsic errors, but can be expected to rely on their instructor to help them resolve hygienic errors. As a result, in the virtual asynchronous learning classroom, the instructor is not available to provide guidance to the student, so the student may consider all errors to be hygienic and request the instructor solve the problem the student should be equipped to solve.
Knowledge Properties

In order to understand the disadvantages of asynchronous learning, examination is performed of the properties of knowledge. Knowledge exchange involves the process of capturing, organizing, transferring, and reusing experiential knowledge (Lin, 2006). In this study, the authors adopt the view that knowledge in the virtual classroom resides in two forms: tacit (non-codifiable, rooted in the minds of experts, capable of transfer via shadowing and mentoring) and explicit (codifiable and capable of transfer using techniques, such as stories, metaphors, and models) (Polanyi, 1966, Nonaka, 1994). In the virtual classroom, instructors should be capable of using asynchronous technology to transfer the explicit form of knowledge by articulating key theoretical concepts and their application in practice. In contrast, the tacit knowledge form would be impossible to transfer via asynchronous mode due to the limitations of interactions and technology.

Extant literature suggests several categories of knowledge properties. For example, Miller and Jablin (1991) introduced three categories:

- Referent – associated with specific function;
- Appraisal – associated with selected performance;
- Relational – associated with acceptance of social behavior.

Other researchers have added technical type, which was related to information that is used for “defining a problem/task; learning techniques applicable to dealing with the problem/task; finding solutions; or identifying a piece of missing data,” (Madzar, 2001, p. 222). Cross and Sproull (2004) proposed five additional categories to include:

- Solutions;
- Meta-knowledge;
- Problem reformulation;
- Validation of plans or solutions; and
- Legitimation from contact with a respected person.

Finally, researchers categorized the wanted knowledge as task information (related to technical skills, or feedback associated with performance) and social information (related to social feedback) (Xu, Kim & Kankanhalli, 2010).

Knowledge Domains

In addition to knowledge behaviors and knowledge properties, it is prudent to discuss the impact of knowledge domains in the exchange of knowledge in asynchronous mode. First, the authors examine the knowledge exchange that occurs between parties within a shared knowledge domain. Cleveland (2016) argued that experienced parties can use ICTs to easily share
knowledge with knowledge seekers who have prior mental model and experiential understanding of the exchanged knowledge. This occurs as a result of the previously formulated mental models in each participant with regards to the transferred knowledge. As a result, in scenarios where knowledge is exchanged in the same domain of understanding, ICTs in a virtual classroom will facilitate the transfer of knowledge.

In contrast, if the parties lack understanding of the domain of the exchanged knowledge, the sharing process will be impacted due to ambiguity. In such a situation, knowledge seekers will not be able to leverage “mental models through which to filter the new information and to make sense of it,” (Cleveland, 2016, p. 4).

As a result, the greater the disparities between the domains of knowledge between the instructor and students in the virtual classroom, the less knowledge exchange will take place.

**Knowledge Types**

To combat such disparities, the main focus is on the types of knowledge. In addition to properties and domains of knowledge, it is argued that knowledge in the virtual classroom should be categorized for easier transmission. For this purpose, in this study the authors adopt the three knowledge types proposed by Shulman (1986):

- Subject matter content knowledge (SMCK);
- Pedagogical content knowledge (PCK);
- Curricular knowledge (CK).

Instructors who possess SMCK knowledge will be able to demonstrate why and how key concepts relate to the topic of the course. For example, when it comes to software engineering, an instructor should be able to explain why specific software requires detailed testing and how the testing should be conducted, via a case-based example.

PCK involves the use of a variety of methods (e.g. stories, examples, analogies) by the instructor to demonstrate specific subject matter knowledge. An instructor with substantial PCK will successfully help students integrate the subject matter knowledge.

Finally, the CK includes the creative use of textbooks and materials to help students fully master a specific discipline. For example, an instructor can incorporate a specific software package, along with a best practices software handbook, to help students reflect, brainstorm, and combine the subject matter lessons.

**Knowledge Dimensions**
In addition to form and type, it is argued that knowledge in the virtual classroom consists of four dimensions (as proposed by De Jong and Ferguson-Hessler, 1996): 1) situational, 2) procedural, 3) strategic, and 4) conceptual. Each of these knowledge dimensions involves different properties and as a result, will require different mediums of exchange. This leads to the conclusion that both the situational and procedural knowledge dimensions are related. For example, the situational knowledge dimension is related to a specific scenario that may require sequential steps to be executed in order for knowledge to be transferred. Furthermore, the procedural knowledge dimension is associated with a set of requirements and rules related to a situation.

In the software engineering scenario described earlier, an instructor has provided a set of steps for students to install a specific software program on their computers. As a result of the instructions, a student is experiencing a software-related malfunction and reaches out for specific information on how to resolve the errors.

To help with the software error, the instructor uses a conceptual knowledge dimension to relay principles associated with the software engineering domain. The conceptual knowledge dimension consists of a set of symbols and models that allow the instructor to tap into the student’s mental model (in our case, understanding of programming modules and code) and explain the cause of the errors.

Lastly, the instructor will convey specific actions to tie theory together with the practical example, via the strategic knowledge dimension.

**Knowledge Tools**

In addition to the types of knowledge, an examination of the tools that instructors can leverage to facilitate the knowledge exchange is performed. In this study, the focus is on three such tools: stories, reflections, and lessons learned.

**Stories**

A story represent an account of an event that allows the storyteller to share an identity, help the audience make decisions, and share an identity (Cleveland, 2013). Extant literature demonstrates that stories have been proven to transfer knowledge used to solve specific problems through the application of the experiences acquired through the narratives (Jonassen & Hernandez-Serrano, 2002; Newell, 2004). Some researchers report that stories are some of the most frequent tools to exchange tacit knowledge (Goffin & Koners, 2011). For example, one study found that storytelling and sharing of metaphors occurred every 20 minutes among personnel during post-implementation review meetings. Furthermore, Whyte and Classen (2012) found that storytelling was widely used to distribute information related to best practices and ideas, while Cleveland (2013) argued that “stories are powerful mechanisms for joining, sorting, and recombining personal and shared knowledge. They can also be used as input into the collective and self-reflection processes of the learning cycle,” (p. 3).

**Reflection**
When it comes to reflection, studies report that this technique assists in the exchange of valuable lessons learned, support learning, and channel innovation (Knipfer, Kump, Wessel & Cress, 2012). Instructors can facilitate knowledge sharing through reflection by requiring students to use personal journals. Such journals, also known as reflective guides, leverage precise questions that allow students to document practices and identify relevant knowledge sources.

For example, extant literature reports that the use of reflective journals in organizations leads to the exchange of knowledge, conflict management, strengthening of interpersonal communication, and fortification of leadership skills (Loo, 2002). Moreover, studies on the use of reflective guides among students showed that the use of such guides significantly improved the processes of documenting lessons, and the capturing of valuable explicit knowledge (Matturro & Silva, 2010).

Lessons Learned

Finally, the authors introduce lessons learned documentation, a technique used in the project management field during post-project review meetings for knowledge creation. According to Williams (2008), 86% of the 522 participants in his study reported an increase in competency levels as a result of the application of this technique. The participants reported that lessons learned documentation helped them build their soft skills. Among the surveyed, 75% stated that learning diaries can be the tool to document lessons, while over 80% believed that such lessons can be captured and shared via stories. This study was supported by Tukel, Rom and Kremic (2008), who found that lessons learned documents prevented the loss of knowledge. Their key recommendation was for the wide application of such “methodical documentation” to facilitate learning practices.

Technology Synchronicity

Finally, it is argued that knowledge exchange in the virtual classroom demands either low or high synchronicity as proposed by the media synchronicity theory (MST) (Dennis et al., 2008).

The theory suggests that individuals leverage a set of communication patterns to exchange information in order to either minimize knowledge ambiguity within a specific domain, or validate pre-existing knowledge (Cleveland et. al, 2015). Each of the patterns is characterized by a specific process. First, the conveyance process occurs when individuals share brand new knowledge, which necessitates the creation or revision of a mental model, in order for the knowledge seeker to absorb such knowledge. The second process is convergence. During this process, the knowledge that is exchanged, has been encountered in the past, and is used to validate a pre-existing mental model in the knowledge seeker.

The theory also stipulates that the facilitation of the conveyance demands one-way broadcasting of knowledge in the direction of the knowledge seeker for the purposes of mental model formulation. On the other hand, the convergence process involves rapid and reoccurring transfer
of small knowledge amounts in order to validate the knowledge seeker’s pre-existing mental model (Cleveland et al., 2015).

Due to the differences in the amount and frequency of information transfer required to fulfill each processes’ demands, the theory explains that “the conveyance process will require technology channels to facilitate rich information flow, thus leading to low synchronicity between the participants (e.g. instant messaging, screen sharing, and file sharing), while convergence requires technology mediums that facilitate high synchronicity (video and audio conferencing).” (Cleveland et al., 2015, p. 7).

As a result, it is argued that in asynchronous environments, students who lack conceptual mental models in order to understand specific lessons, will require a highly synchronous communication medium of interaction with the instructor to formulate new mental models and absorb new knowledge (e.g. real-time video and audio sessions) (Cleveland 2016). Therefore, asynchronous virtual classrooms without rich medium capabilities (e.g. live conferencing, synchronous instant messaging) would be ill-equipped to allow the exchange of knowledge with conceptual and strategic knowledge dimensions.

**PROPOSED KNOWLEDGE TECHNOLOGY SYNCHRONICITY FRAMEWORK FOR ASYNCHRONOUS ENVIRONMENT**

Based on the analysis in this study, in Table 1 the authors propose a knowledge technology synchronicity framework (KTSF) for asynchronous environment that integrates the various building blocks of knowledge exchange, mainly: knowledge seeking behaviors, knowledge properties, knowledge domains, knowledge types, knowledge dimensions, knowledge tools, and technology synchronicity.

<table>
<thead>
<tr>
<th>Building Blocks</th>
<th>Concepts</th>
<th>Sources</th>
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<tbody>
<tr>
<td>Knowledge Seeking Behaviors</td>
<td>Categories include undirected, conditioned, informal, and formal; Information foraging theory; Awareness of disparity, quest for information gathering;</td>
<td>Xu, Tan, &amp; Yang, 2006; Pirolli &amp; Card, 1999; Vandenbosch &amp; Huff, 1997; Huber, 1991; Belkin (1980), Savolainen, 2006;</td>
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<td>Knowledge Domains</td>
<td>Within and Outside of Shared Knowledge Domains</td>
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<td>Knowledge Types</td>
<td>Subject matter content knowledge, Pedagogical content knowledge, Curricular knowledge</td>
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<td>Technology Synchronicity</td>
<td>High and Low</td>
<td>Dennis et al., 2008; Cleveland 2016, Cleveland et al., 2015</td>
</tr>
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</table>

*Table 1. Asynchronous Knowledge Technology Synchronicity Framework*
DISCUSSION

To illustrate the use of KTSF in transferring knowledge in the virtual classroom, the authors provide a specific case experienced in a graduate software engineering course taught in an asynchronous learning environment at a university in the northeastern area of the United States. The class took full advantage of discussion forums for students to prepare and discuss concepts related to predictive analytics. In addition, students were asked to complete exercises related to data preparation and analysis tasks in the programming language R. Finally, assessments were given to measure the students’ grasp of terms and concepts presented throughout the course. Class sizes usually ranged from 5-10 students. The majority of students were adult learners with professional careers, with an even mix of male and female students.

Discussion questions related to the material taught in each weekly lesson (explicit knowledge form with subject matter, pedagogical and curricular knowledge types), and students could refer to background information using the course textbook. Students had little difficulty submitting posts on time, with the requisite word and reference count. Discussions were generally one or two levels deep.

Five exercises were assigned in the course. The first exercise involved downloading and installing R Studio, a programming environment for writing and executing R scripts (procedural knowledge dimension). The instructions specified a web address where the student could choose the download package appropriate to their desktop device and instructions for installing the software. In subsequent exercises the students would create text files that contained R statements to manipulate data sources, transform data frames, and plot the results. Students who were familiar with the R Studio environment, including the process of downloading and installing software, but encountered installation errors, needed assistance (situational knowledge dimension) via asynchronous discussions (low synchronicity medium).

Students with very little or no knowledge of the R language, who had considerable challenge understanding the complexity of constructing R statements (conceptual knowledge dimension), encountered error messages that resulted from malformed commands. A common reaction to these unforeseen circumstances was for the student to reach out to the instructor to “intervene”; that is, to identify the source of the problem and instruct the student with what steps were required to remediate the problem. However, due to the asynchronous nature of the exchange, the communications were frequently cryptic (“You need to enclose the string variable in matching quotes”; “What is a string variable?”) and increasingly more frustrating to the participants. In such instances, the limitation of the asynchronous environment imposed considerable challenges to the ability to exchange knowledge via high synchronicity.

CONCLUSION

In this study, the authors provided arguments for the deficiencies of the asynchronous virtual classroom. Knowledge technology synchronicity framework for asynchronous environment was
proposed to characterize and categorize the building block form knowledge exchange in asynchronous classrooms. The research question for this study was: How can knowledge be organized to minimize teaching deficiencies expected to occur in asynchronous learning environments? To answer this question, seven distinct building blocks for knowledge exchange in asynchronous environments were examined. The authors assessed what drives knowledge exchange (knowledge seeking behaviors) and the properties, domains, types and dimensions of exchanged knowledge. Moreover, a set of knowledge tools and technology mediums were analyzed that can help facilitate the knowledge exchange in asynchronous classrooms.

Finally, the authors provided a specific case to illustrate the application of the framework in a virtual classroom. It is prudent to note that a limitation of this study is the single case used to support the framework. As a result, future research will focus on the application of the framework in hybrid learning environments and the examination of specific strategies that can help build student problem solving skills for open-ended problems in an asynchronous environment.

REFERENCES


