Training people to master complex technologies through e-Learning: Case of UML technology training in a global organization

Completed Research Paper

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Abstract

E-Learning tools facilitate asynchronous (e.g., wiki) and synchronous (e.g., video-conferencing) learning. They may provide a cost effective way to train large numbers of people in global settings to leverage complex technologies such as Unified Modeling Language (UML) tools. Few industrial experiences from the use of e-Learning tools to train complex technologies have been reported. It is unclear whether e-Learning tools can be deployed to learn three types of knowledge: application, business context, and collaborative task knowledge. This paper draws upon a case study in a global corporation to evaluate the applicability of several classes of e-Learning tools for supporting the learning of application, business context, and collaborative task knowledge required to deploy a UML modeling tool globally. Intranet, e-mail, and a Virtual Meeting Tool (VMT) proved most beneficial for learning the three types of knowledge. Other organizations may benefit from using these classes of e-Learning tools to train people to use similar complex technologies in global organizations.

Keywords

E-Learning, training, global software development, UML, UML tool

Introduction

User training is critical for successful deployment of information systems (IS) (e.g., Attewell, 1992; Boström et al., 1990; Compeau et al., 1995; Nelson et al., 1995). Collaborative IS applications improve organizational coordination and collaboration among users to complete business processes and have extensive built-in control enforcing standard and shared work practices (Kang and Santhanam, 2003). They are increasing in complexity and need to be deeply engrained in organizational coordination, collaboration, and business practices. Users need to learn application, business context, and collaborative task knowledge to use collaborative IS applications effectively (Kang and Santhanam, 2003). Meeting these requirements is nontrivial and potentially expensive. Organizations are looking for new ways to accelerate learning and to cut IS training costs.

Using E-Learning tools is a way to meet the requirements. Organizations often routinely deploy tools to support asynchronous (e.g., wiki, discussion forums) and synchronous (e.g., video-conferencing, chat) meeting and collaboration practices. If they can use the same tools for training and learning complex technologies, little, if any, additional deployment investments for e-Learning tools are typically needed. However, few industrial experiences from the use of these tools to train complex technologies have been reported. Some prior research results indicate that e-Learning may be ineffective when the topics are complex. According to Piccoli et al. (2001) learners were less satisfied with e-Learning, when learning unfamiliar and complex topics, and more satisfied when learning familiar and non-complex topics like word processing. Hrastinski (2008) found that e-Learning is suitable for discussing and reflecting even complex topics but may need to be complemented with face-to-face meetings. It is unclear whether e-Learning can be successfully used as the only means to support the training of complex technologies in a
way that learners are satisfied with the training and learn application, business context, and collaborative
task knowledge.

This paper answers the following research question: which classes of e-Learning tools are the most
applicable ones for organizing and delivering technology training scalably so that large numbers of
learners learn application, business context, and collaborative task knowledge in order to master
collaborative IS applications and other similar complex technologies? This research draws upon a case
study in a global high-tech corporation, deploying complex technologies corporate-wide, to provide
insights into effective industrial practices for applying e-Learning in the training of complex technologies.
We expect the practices to be generalizable to other organizations leveraging complex technologies.

Literature review

This section introduces the concepts of e-Learning and UML technology and analyzes the limitations of
the current UML technology training research in industrial settings.

UML technology

Unified Modeling Language™ (UML) is an international standard for object-oriented systems modeling
modeling tools offer graphical editors for modeling systems. Tools generate software from UML models
and create UML models from the software, have a built-in knowledge of UML rules, and support
collaborative software development. Therefore, they are collaborative IS applications. UML and the
modeling tools constitute an important technology (hereafter “UML technology”) for supporting global
R&D. The extant literature provides few lessons for using e-Learning tools in UML technology training in

We consider UML technology a complex technology due to the following reasons. First, there is a high
number of diagrams and symbols that learners need to get familiar with. Second, modeling requires both
the understanding of UML and the ability to use the modeling tools. Third, using UML requires long-term
training and learning investments (Dori, 2002; Kobryn, 2002).

E-Learning

E-Learning comprises all forms of information and communication technology (ICT) mediated learning
(Tavangarian et al., 2004). It can be used alone or to complement other training modes. E-Learning tools
serve as a media to implement the learning process (Tavangarian et al, 2004). E-Learning tools may vary
from software developed for the purposes of teaching to general-purpose software, which can be used for
sharing presentations over the network or in the class. In particular, Virtual Meeting Tools (VMT) enable
real-time interactions through features such as chat tools, audio, video, and user interface screen sharing.
They have been used most extensively in education, for example, to arrange remote lectures (ELI, 2006).

Learning in the UML technology context

UML technology supports collaborative R&D processes such as requirements management and software
engineering. Kang and Santhanam (2003) identify three knowledge domains that user training should
deliver in the context of applications that support collaboration: application knowledge covering
commands and tools embedded in the applications; business context knowledge covering the use of IS
applications to effectively perform business tasks; and collaborative task knowledge covering how others
use the application in their tasks (Table 1).

Users of UML technology need to master all three knowledge domains. They need to understand the
business context because UML technology is applicable to many business processes. They need to know
collaboration with other users because UML technology mediates collaborative activities in distributed
system development. Knowledge of the UML modeling language is a necessary pre-requisite for mastering
all three knowledge domains. For example, creating new UML diagrams requires a detailed
understanding of the diagram structure. Table 1 illustrates UML technology related knowledge needs.
**Previous research on UML technology training**

A systematic literature review was conducted (Kitchenham, 2009) to verify to which extent existing studies cover e-Learning usage for UML technology training in industrial settings. We used broad words “training” and “learning” because the e-Learning literature refers to numerous keywords (e.g., online learning, web-based learning, computer-based training, Internet-based training, and web-based training). The review process is as follows:

1. The first criterion was to find UML training related articles by searching words “UML” and “training” or “learning” in the title, abstract, or keywords. Decision was based on the title and the abstract.

2. The second criterion was to categorize research according to whether the research reported industrial experiences or not. Decision was based on the title and the abstract of the article. The content was visited when it was impossible to determine otherwise whether the article reported industrial experiences.

3. The third criterion was to determine whether the research reported experiences related to e-Learning. Decision was based on the title and the abstract of the article. The content was visited when it was impossible to determine otherwise whether the article reported e-Learning related experiences.

<table>
<thead>
<tr>
<th>Knowledge Domain</th>
<th>Definition</th>
<th>UML example knowledge and skills example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Command based</td>
<td>1) Commands/ keystrokes needed to execute an operation</td>
<td>1) Commands/ keystrokes in order to create a UML element</td>
</tr>
<tr>
<td>2) Tool-procedural</td>
<td>2) Knowledge required to combine multiple commands and complete a generic task</td>
<td>2) Combine multiple commands to complete a UML diagram</td>
</tr>
<tr>
<td>3) Tool-conceptual</td>
<td>3) Knowledge to understand the bigger picture of what to do with a tool</td>
<td>3) How the tool facilitates the use of multiple diagrams together</td>
</tr>
<tr>
<td>Business context knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Business-procedural</td>
<td>1) How to apply the above levels of knowledge to execute a specific business task?</td>
<td>1) Which diagrams to apply and when to support a particular business process (e.g., requirements management)?</td>
</tr>
<tr>
<td>2) Business-motivational</td>
<td>2) What the tool can do for my job?</td>
<td>2) Which business processes of the organization are supported by the UML tool and why?</td>
</tr>
<tr>
<td>Collaborative task knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Task interdependencies</td>
<td>1) Interdependencies between tasks and their effects upon using a UML tool</td>
<td>1) How tasks completed through the UML tool affect and are affected by other users of the tool (and/or related tools)?</td>
</tr>
<tr>
<td>2) Collaborative problem solving approach</td>
<td>2) Collaborative problem solving effort between users</td>
<td>2) Knowledge sharing between users to solve problems</td>
</tr>
<tr>
<td></td>
<td>Interdependencies between UML and other modeling languages</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The content for training UML technology (Koivulahti-Ojala and Käkölä, 2012).

ACM Portal, IEEE Explore, and ProQuest were searched. They covered IS journals and conferences. Seven articles related to UML technology training in industrial settings were found. Three of them focused on e-Learning. Whenever industrial experiences from UML technology training were reported, the cost effectiveness of training was emphasized (e.g. Anda et al., 2006; Bunse et al., 2006).

Anda et al. (2006) investigated the adoption of UML technology in a global corporation applying a UML-based development method in an international project with 230 system developers, testers and managers.
Adoption was supported by face-to-face training and mentoring. Maximum benefits from UML-based development were not achieved because training was (1) not adapted to the needs of the project and (2) too expensive to provide to people who were not directly involved with UML-based development. Andersson et al. (2010) researched the adoption of UML/SysML modeling principles and tools in an aerospace systems engineering project at Saab Aerosystems. The adoption required a clear strategy including just-in-time face-to-face training and mentor support. These articles did not mention usage of e-Learning tools for UML training. Bunse et al. (2005) studied two enterprises aiming at controlled software development processes that use standardized specification languages such as the UML. First, learning goals and skills were analyzed and face-to-face training sessions were joined in workshops. Online learning and coaching and face-to-face training were then provided. Finally, complex domain-specific exercises had to be solved by the participants in teams.

Bunse et al. (2006) analyzed the design and execution of a UML training program blending e-Learning and face-to-face training in a German corporation. First, the participants worked self-directed with the web-based courseware. This phase was a prerequisite for face-to-face training in the second phase. A several weeks long coaching phase concluded the program. The coach consulted the participants about applying UML in their work. No UML tool related training was included. Koivulahti-Ojala and Käkölä (2012) investigated how a global corporation leveraged VMT for UML technology training of hundreds of employees. However, the use of other e-Learning tools was beyond the scope of their research.

In sum, the extant research of e-Learning practices and tools for UML technology training consists of a few papers covering a limited number of e-Learning tools. Longitudinal studies are missing.

**Case study**

In case studies researchers find out the conditions of the target organizations by making observations, interviewing, archiving, and recording (Yin, 2013). Benbasat et al. (1987) state three reasons why case studies are suitable for IS research:

- The researcher can study the information system in a natural setting.
- The researcher can answer "how" and "why" questions.
- It is suitable for studying topics in which little formal research has been conducted previously.

All three reasons are valid in this research.

The case organization is a global high-technology corporation, developing products in multiple sites. A commercial UML modeling tool was being rolled out globally to support distributed product development. The name of the tool is confidential. Rollout had started in 2008. Users were working in various sites and different time zones. The number of users was approximately 1700 by the end of 2010 and, after organizational changes, 1300 by the end of 2013. Most users were from the R&D organization. The tool was supported by a virtual team consisting of personnel from the global IT department, the department responsible for process and IS development and support for R&D, and subcontractors working for the departments. The virtual team could decide which media to apply for various purposes within the budget available.

The primary sources of information for the case study were the content created for e-Learning tools by the virtual team and the internal documents (e.g., meeting memos of the virtual team; strategy and plans to improve tool support). Yin (2013) emphasizes the following data collection principles:

1) Prepare a case study database where the raw data and all the data and documents the researcher produces are entered. The case study database included all the material used in the analysis such as screen shots of wikis; entries in Intranet, discussion forums, and training calendars; meeting memos of the virtual team; training materials; draft reports, comments for reports, and final reports; interview plans and interview reports.

2) Use a case study protocol. Additional information was requested from virtual team members in relation to the use of e-Learning tools and the plans and decisions made related to e-Learning practices and tools. The members also reviewed and commented the analysis results.
The first author was previously involved in the UML technology deployment project of the case organization. She holds a managerial position in the department supporting UML technology. The preparation of the case study database and following the use case study protocol were of utmost importance to reduce possible bias caused by the involvement of the first author in the support organization. Second author of this paper reviewed all the phases of the study including the content of case study database and the case study protocol (e.g., conclusions made basis on meeting memos). The managerial position of the first author enabled the authors to access all internal materials, including meeting memos, e-mails, and project documents. As the corporate culture encouraged knowledge sharing, it was possible to receive feedback and deal with open issues easily.

**Analysis and findings**

Classes of tools applied in the case organization for e-Learning are listed in Table 2. Content of the knowledge shared through the tools was evaluated with respect to the proposed model for UML training (Table 1).

**Wiki**

Users could access a wiki to share application knowledge (e.g., commercial plug-ins and their installation instructions) and collaborative task knowledge. The virtual team made most updates in the wiki. The usage of the wiki by other stakeholders was modest. Later on, the virtual team abandoned the wiki and placed the same material in Intranet not only due to the modest use but also because the case organization had had three mutually incompatible technical implementations of wikis running in parallel and with varying functionality for several years. It was technically easier to deal with one Intranet site than the incompatible wiki implementations.

**Intranet**

Users could access Intranet pages for application knowledge (e.g., self-study materials), collaborative task knowledge (e.g., contact information for teams applying UML technology), and business context knowledge (e.g., best practices in terms of business targets fulfilled by leveraging UML technology). The virtual team updated Intranet partly based on discussions and meetings with users. Intranet became increasingly important when the virtual team had to abandon the wiki and the discussion forum due to technical reasons and their modest usage.

**Discussion forum**

Users had access to a discussion forum to share application knowledge and to solve problems collaboratively. The topics discussed were, for example, questions related to UML technology, feature improvement proposals, and tips and tricks for using UML technology more effectively. The intensity of the discussion forum usage was modest. For example, only eight messages were sent between June 2010 and November 2010. Later on, the virtual team abandoned the discussion forum mainly due to the modest usage.

**E-mail**

The virtual team used e-mail to share application knowledge with all users. It sent business-critical messages to all users (e.g., concerning maintenance breaks) and other messages (e.g., related to training events) to those who had requested information sharing e-mails. Users did not use the distribution list for sharing collaborative task knowledge and business context knowledge. The number of messages sent within a certain period varied significantly. For example, 33 e-mails were sent during a six-month period (June 2013-November 2013).

**Virtual Meeting Tool (VMT)**

VMT was applied to share application knowledge, collaborative task knowledge, and business context knowledge. Tens of training sessions were organized and users shared best practices of tool usage with other teams. Application knowledge was shared in training sessions provided in co-operation with the...
The vendor provided training, consultancy, and technical support for its products globally. Each session lasted 1-2 hours including the time for questions and answers. The sessions covered these subjects: Introduction to UML, Introduction to UML Tool, Class Diagrams, Sequence Diagrams, Composite Structure Diagrams, State Machine Diagrams, Use Case Diagrams, Introduction to Collaboration Capabilities of UML Tool, and Introduction to Publishing Models. All the sessions apart from Introduction to UML and Introduction to UML Tool offered application knowledge from three perspectives: 1) command-based, 2) tool-procedural, and 3) tool-conceptual. For example, in the Class Diagrams session, basics of a UML Class diagram were introduced (tool-conceptual), examples how to create an element in a class diagram were given (command based), and examples how to complete a class diagram were provided (tool-procedural). Business context and collaborative task knowledge were also shared. For example, Introduction to UML Tool communicated the status of UML deployment in the case organization (e.g., in which parts of the organization UML technology had been deployed and for what purposes).

<table>
<thead>
<tr>
<th>E-Learning tool</th>
<th>Knowledge</th>
<th>Content</th>
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</thead>
<tbody>
<tr>
<td>Wiki</td>
<td>Application knowledge</td>
<td>Sharing commercial plug-ins and related installation instructions/training materials</td>
</tr>
<tr>
<td></td>
<td>Collaborative task knowledge</td>
<td>Sharing plug-ins made by users and related installation instructions/training materials</td>
</tr>
<tr>
<td></td>
<td>Business context knowledge</td>
<td>List of contact persons for teams using UML technology</td>
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<td></td>
<td></td>
<td>Contact information for tool support team</td>
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<tr>
<td></td>
<td></td>
<td>Recorded training sessions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Material from other sessions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Best practices in the form of business targets, UML modeling conventions, and deployment activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recorded training sessions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Material from other sessions</td>
</tr>
<tr>
<td>Discussion forum</td>
<td>Application knowledge</td>
<td>Shared application knowledge</td>
</tr>
<tr>
<td></td>
<td>Collaborative task knowledge</td>
<td>Solving problems collaboratively</td>
</tr>
<tr>
<td>E-mail</td>
<td>Application knowledge</td>
<td>Informing all users about maintenance breaks, new features, training and other sessions to be organized</td>
</tr>
<tr>
<td></td>
<td>Collaborative task knowledge</td>
<td>Training sessions</td>
</tr>
<tr>
<td></td>
<td>Business context knowledge</td>
<td>Sessions where active users shared best practices and application knowledge with other teams about applying the tool</td>
</tr>
<tr>
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<td></td>
<td>Sessions where active users shared best practices with other teams about applying the tool</td>
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<tr>
<td></td>
<td></td>
<td>Sessions where active users shared best practices with other teams about applying the tool for modeling, including collaborative task knowledge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sessions where active users shared best practices with other teams about applying the tool for modeling, including business context knowledge</td>
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</table>

Table 2. E-Learning tools the virtual team applied for e-Learning in the case organization.

Trainers were either vendor personnel or specialists of the case organization experienced in both training and VMT. Sessions were organized using standard conference calls and a VMT. Most users had several years of experience in using both conference calls and VMT. During a six-month period (June 2010-
November 2010), 29 1-2 hour-sessions were organized. After three years, VMT was still extensively used. During a six-month period (June 2013-November 2013), 29 1-2 hour-sessions were organized. Users increasingly proficient in UML technology still found it beneficial to join sessions because the sessions supported both novice and advanced learners and the ongoing improvement of ways of working. Users also encountered new business contexts requiring them to use, for example, UML diagrams unfamiliar to them.

Collaborative task and business context knowledge were mainly shared in 2-4 sessions organized in a year for local contact persons responsible for supporting their teams in UML technology usage. For example, sessions offered business context knowledge about on-going UML technology deployment projects and asked users to share their modeling practices (i.e., collaborative task knowledge). In sum, VMT was mostly used for application knowledge training but some business context and collaborative task knowledge were also shared. The virtual team had plans to apply VMT to share business context knowledge more intensively, for example, by communicating business needs and proposals for more advanced ways of using UML technology.

Face-to-face training sessions were also organized. UML technology experts, for example, suggested suitable diagrams, structured the models, and provided tailored training to meet specific modeling needs. Users participated in on-line training sessions before and after face-to-face training sessions, respectively, to get familiar with the subject and to refresh their memories. Surveys, conducted to understand users' backgrounds before training, revealed that users' previous UML technology experiences varied from none to several years.

**Evolution of e-Learning over time**

Rather than viewing training as an activity confined to coaching users before the deployment of a system, training activity has to extend to coaching users for a period during the actual use of the system (Kang and Santhanam, 2003). Therefore, we extended the analysis to the phase when the UML technology deployment was started and probed future training plans. Table 3 summarizes the e-Learning tools involved in different phases.

The application of e-Learning tools first extended over time in terms of (1) application knowledge, business context knowledge, and collaborative task knowledge and (2) the number of e-Learning tools applied. When the deployment project started, VMT was used only for meeting purposes. During deployment, a user satisfaction survey was organized (Islam et al., 2010). Training, communication, and user guides were improved based on the survey results. VMT was applied for training as well, because users were working in distributed sites and the travelling costs needed to be cut down. All e-Learning tools were used for sharing application knowledge when the deployment started. There are two main reasons for this. First, the deployment was made on a volunteer basis so organizational units were able to decide about UML technology deployment. There was thus limited collaborative task and business context knowledge available to train or share in the early phase of deployment. Second, the virtual team members were mainly experienced in the area of application knowledge sharing. They felt most comfortable to start applying e-Learning tools in application knowledge sharing and training.

Over time e-Learning was used to support also the creation and sharing of business context and collaborative task knowledge. During the analyzed period, the wiki and the discussion forum, applicable to sharing both application knowledge and collaborative task knowledge, were in limited use for those purposes whereas VMT was extensively used for application knowledge training and, to some extent, for sharing collaborative task knowledge and business context knowledge. When the number of UML users started to reduce, the virtual team stopped using the wiki and the discussion forum mainly due to the modest usage. However, the wiki and the discussion forum had been used during the deployment to create and share some highly relevant collaborative task knowledge. The virtual team transferred this knowledge to Intranet. Without the wiki and the discussion forum, this knowledge might never have been created. Therefore, these two classes of tools may be valuable to other organizations even if the use of their instances was stopped during the case study. To deploy UML technology more extensively, VMT was used even more for the training of business context knowledge. During 2013, users were increasingly competent with UML technology and needed little face-to-face training. VMT was the main tool to deliver application, collaborative task, and business context knowledge.
### Table 3. E-Learning tools the virtual team applied for e-Learning over time.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Wiki</td>
<td>Virtual team used it for sharing application knowledge.</td>
<td>Virtual team and users used it for sharing application and collaborative task knowledge.</td>
<td>Wiki was no longer used. Its most relevant knowledge had been transferred to Intranet.</td>
</tr>
<tr>
<td>Intranet</td>
<td>Virtual team used it for sharing application knowledge.</td>
<td>Virtual team used it for sharing application knowledge, collaborative task knowledge, and to some extent business context knowledge.</td>
<td>Virtual team extended its use for business context knowledge sharing more extensively.</td>
</tr>
<tr>
<td>Discussion forum</td>
<td>Virtual team used it for sharing application knowledge.</td>
<td>Virtual team and users used it for sharing application knowledge and collaborative task knowledge.</td>
<td>Discussion forum was no longer used. Its most relevant knowledge had been transferred to Intranet.</td>
</tr>
<tr>
<td>E-mail</td>
<td>Virtual team used it for sharing application knowledge.</td>
<td>Virtual team used it for sharing application knowledge.</td>
<td>Virtual team used it for sharing application knowledge.</td>
</tr>
<tr>
<td>VMT</td>
<td>It was only used for meetings.</td>
<td>Virtual team used it for sharing application knowledge.</td>
<td>Virtual team extended its use for business context knowledge creation (e.g., creation of UML models).</td>
</tr>
</tbody>
</table>

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**Evaluation of the deployed e-Learning tools**

Based on the case study, face-to-face training and support were accompanied by a wide variety of e-Learning tools including wiki, discussion forum, Intranet, e-mail, and a VMT. The application of e-Learning tools for software application training focused first on application knowledge training but extended over time to include business context knowledge and collaborative task knowledge. The number of e-Learning tools applied increased for some time and then reduced to a few. In the beginning, the UML tool vendor and the virtual team responsible for the global deployment of UML technology produced most learning content but over time the community using the technology became a more and more prominent content contributor.

The evaluation of the success of e-Learning tools in the case organization was conducted both directly and indirectly. VMT tool use was evaluated in on-line training sessions covering UML technology. According to the study, skills, knowledge, and motivation of users were improved and learners were satisfied with the training (Koivulahti-Ojala and Käkölä, 2012). In addition, two user satisfaction surveys were conducted in 2009 (Islam et al., 2010). The team analyzed the results of the surveys; concluded that instructions, user guides, and training practices had to be improved; and initiated improvement activities during 2009. Table 3 reflects pre-survey and post-survey status. The user satisfaction improved after the VMT was deployed in training and the usage of Intranet was extended to support the sharing of all three types of knowledge.

This study was conducted within one case organization, limiting the generalizability of the results. The analysis also concentrated on the e-Learning content, tools, and practices provided by the virtual team. The community using UML technology may have leveraged other e-Learning content and practices as well but it is beyond the scope of this paper to analyze the content and practices created by several thousands of UML technology users in depth longitudinally.
Conclusions and future research

Little longitudinal scientific research has been conducted to help practitioners to deploy e-Learning practices and tools in industrial settings for teaching and learning complex technologies such as the UML technology. This paper probed through a case study, which classes of e-Learning tools organizations should leverage for organizing and delivering technology training scalably so that large numbers of learners learn application, business context, and collaborative task knowledge in order to master complex technologies. In addition to face-to-face training sessions, the case organization experimented in large scale with instances of several classes of e-Learning tools including wiki; discussion forum; Intranet; e-mail and a VMT. Interestingly, the case organization used most tools to support the application, collaborative task, and business context knowledge learning and sharing as called for by Kang and Santhanam (2003). E-Learning improved user satisfaction with UML technology (Islam et al., 2010). The discussion forum and the wiki proved ineffective over long-term use in comparison with Intranet, email, and VMT and were abandoned. In sum, Intranet, email, and VMT proved the most effective classes of tools for learning application, business context, and collaborative task knowledge. VMT was the most crucial class of tools because the VMT instance not only contributed to the sharing of all three types of knowledge in the case organization but also improved the motivation of the users to use UML technology.

Organizations planning to apply e-Learning for complex technology training should consider the following lessons. 1) Adopting e-Learning tools stakeholders are unfamiliar with requires substantial effort over time. For example, during the case study, the UML tool vendor needed to invest significantly in learning and installing the needed set of tools. Organizations must ensure those planning and sharing content will get familiar with the tools. If an organization already has widely used e-Learning tools, those tools are good candidates for creating and sharing e-Learning content. 2) Face-to-face training and e-Learning need to be planned and delivered in a coordinated fashion especially for sharing collaborative task and business context knowledge. Trainers, e-Learning tool specialists, and tool support personnel need to work together to plan, implement, and deploy e-Learning and face-to-face training. 3) Training sessions need to be organized so the content is meaningful from the users’ perspectives and the sessions are short enough to fit most user schedules. In the case organization, the VMT-supported training sessions were running for several years successfully in terms of increased knowledge, skills, and motivation. The sessions were planned especially for the target group, helping learners to reach their learning objectives. 4) Whenever the use of the technology requires application, collaborative task, and business context knowledge, training must enable the sharing of all three types of knowledge. In the case organization, the UML training was extended during the five years of longitudinal study to cover the three types of knowledge.

Future research is needed to determine which combinations of tools and face-to-face training are the best to support the learning of complex technologies in ways that learners are satisfied with the training and the training positively impacts the skills, knowledge, and motivation of the learners. The use of e-Learning tools evolved over time in the case organization with respect to the number of tools deployed and the coverage of not only the application knowledge training but also the business context knowledge and collaborative task knowledge training. The usage of various classes of e-Learning tools should be studied in future longitudinal studies to understand these phenomena better. For example, the classes of wiki and discussion forum tools need to be investigated further because during this study they were initially found useful but eventually abandoned. Several theoretical lenses are applicable to understand better the evolution of e-Learning tool use over time. The innovation diffusion theory is a possible lens because e-Learning practices and tools can be seen as a technology, which is adopted and reconstituted over time. The diffusion of technology can be conceptualized in terms of organizational learning, skill development, and knowledge barriers (Attewell, 1992). Application of diffusion theories in studies of e-Learning could provide researchers and practitioners with a better understanding to successfully adopt e-Learning in industrial settings.
References


