eLmL 2013

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eLmL 2013 Editors

Stephen White, The University of Huddersfield - Queensgate, UK

eLmL 2013

Forward

The fifth edition of the International Conference on Mobile, Hybrid, and On-line Learning (eLmL 2013), held in Nice, France, February 24 - March 1, 2013, focused on the latest trends in e-learning and also on the latest IT technology alternatives that are poised to become mainstream strategies in the near future and will influence the e-learning environment.

eLearning refers to on-line learning delivered over the World Wide Web via the public Internet or the private, corporate intranet. The goal of the eLmL 2013 conference was to provide an overview of technologies, approaches, and trends that are happening right now. The constraints of e-learning are diminishing and options are increasing as the Web becomes increasingly easy to use and the technology becomes better and less expensive.

eLmL 2013 provided a forum where researchers were able to present recent research results and new research problems and directions related to them. The topics covered aspects related to tools and platforms, on-line learning, mobile learning, and hybrid learning.

We take this opportunity to thank all the members of the eLmL 2013 Technical Program Committee as well as the numerous reviewers. The creation of such a broad and high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to the eLmL 2013. We truly believe that, thanks to all these efforts, the final conference program consists of top quality contributions.

This event could also not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the eLmL 2013 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that eLmL 2013 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in eLearning research.

We also hope that Côte d'Azur provided a pleasant environment during the conference and everyone saved some time for exploring the Mediterranean Coast.

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Student Learning and Student Perceptions of Learning from Interactive Modules

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***Abstract*— The constructivist approach to online module design, whereby the learner constructs knowledge through activity, appears to offer instructors and students a way of achieving learning outcomes. However, analysis and evaluation of these new learning environments is lacking, especially in the area of how academic content in interactive environments impacts student actual learning and perceptions of learning. This paper documents the process to improve module design using focus groups and to test the effectiveness of the interactive elements based upon assessments of student learning outcomes tailored to online learning environments. Results from student learning assessments enable instructors to optimize instructional design to maximize learning opportunities and achievement in online environments.**

Keywords—multimedia instruction; interactive online modules; cognitive learning; student perceptions of learning; human geography

I. INTRODUCTION

By its very nature, geography is a visual and interactive subject [1, 2]. Traditional resources for classes in this subject area offer only limited interactive opportunities that challenge students to apply geographic concepts to real-world situations [2, 3]. For our introductory human geography course and as part of the development of a completely online textbook, we have developed a series of online interactive learning modules. These modules include imagery, custom videos, readings, discussions, animations, interactive exercises, and assessments. In these modules the integration of theory and applications takes place through activities in which theories and ideas are applied for use in practical situations to answer real-world geographic questions, bringing the course material "alive" for students. The purpose of this research is to investigate how these interactive e-learning activities affect student learning and student perceptions of their learning.

This paper begins with the literature associated with student interactivity and its importance related to student learning. Within the literature review, the theoretical framework for the design of the online interactive modules is presented. Specific examples of disciplines that have used interactive designs and how it has been applied to assist in student learning are included. Then, the design of the modules is detailed. Next, we outline the use of student focus groups and module testing using a control group experimental design. Finally, we conclude with the broader implications of this research on optimizing instructional design to maximize learning opportunities and achievement in future online and distance learning environments

II. LITERATURE

With the application of concepts in real-world situations, the intent is to engage students with the course materials to improve student learning. Much of the literature discussing interaction in online classes addresses either the interaction between student and instructor and among students [e.g., 4, 5, 6] or the level of interaction of students with the technology as determined by frequency counts and access rates [e.g., 7, 8, 9]. Less attention, however, has been given to studying the interaction between students and course content and achievement of learning outcomes. As technology has developed and become a more integral part of the distance learning environment, and, even in the traditional classroom setting, it has impacted the distribution of content, learning tasks, and assignments [10]. The ways by which information is presented and also the way in which students interact with that material is important. Furthermore, the medium employed can motivate and engage students as active and collaborative learners rather than just providing information to them. Multimedia instruction rather than "flat resources," such as static text documents, have been identified as an important element of high-level interactive engagement and student satisfaction [9].

The design of the online interactive modules for this study is based on a cognitive theory framework that supports multimedia design of educational materials [11, 12, 13]. Mayer's research on cognitive theory-based assumptions regarding the way that people learn from words and pictures indicates that animation and narration (what Mayer considers the two elements of the "Dual Channel Assumption) in computer-based multimedia presentations results in deeper understanding in learners [13]. Mayer also presented, but did not test, the "Active Processing Assumption" which states that students engage in meaningful learning when they actively process material through "selecting relevant words and pictures, organizing them into coherent pictorial and verbal models, and integrating them with each other and appropriate prior knowledge" [13]. This research seeks to study the impact on learning of actively processing content through interaction.

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Hence it attempts to expand upon the research that studies the link between cognition and instruction [13].

In the fields of computer programming, nursing, and biology, modules with various levels of interactive 'learning objects' have been designed to improve student understanding and learning [11, 12, 14]. In a Java programming course, Bradley and Boyle [14] made their learning objects optional resources. They found that students accessed the learning objects in large numbers and, in a survey students indicated that the learning objects helped them to learn the concepts being addressed. While they experienced an increase in the percentage points achieved on the modules, the authors felt that the exact contribution of the learning objects was difficult to assess because they were used as components in larger pedagogical systems [14]. Maag [12] found that while there were no statistically significant increases in math-test scores from the pre- and post-test with the use of interactive multimedia, those students who had used the interactive multimedia reported the highest satisfaction score. Black et al. [11] focused on the creation of interactive objects and did not report on the impact of the interactivity.

This concept of knowledge transmission is based on a constructivist point of view where knowledge is constructed by the learner through activity [10]. This construction has led to the development of "new learning environments" or what Martens et al. [10] call "constructivist e-learning environments" (CEEs) in which activities are created to challenge students and provide them with realistic contexts so that students become intrinsically motivated to explore and control their own learning process.

Guzley et al. [4] suggest that students' motivations are linked to their satisfaction with distance learning as a mode of instruction, in turn affecting their perceptions and influencing the overall effectiveness of the learning. This makes students' satisfaction with, and perceptions about, the learning environment and process critical [10]. Since measurements of the causal effect of pedagogical techniques on student learning can be difficult to isolate, student self-reported learning gains also have been identified as a useful indicator of actual learning [15, 16, 17, 18]. The literature on student perceptions of learning indicates that student perceptions may be more important than reality since decisions are often based on perceptions [15]. Furthermore, Chesebro and McCroskey [15] concluded in their research that, "students can provide reasonably accurate reports of the extent to which they are learning in their classrooms" (301).

Designing new learning environments is challenging. Much of the available research shows an emphasis on delivery of these new learning environments rather than on analysis or evaluation [20]. Designers of these tasks rarely gain knowledge of how students will perceive the tasks before they are delivered to the students. Greenberg [21] asserts that quality assessments should be taking place during the design of the course and include the course creators. Finally, while claims about the positive results obtained using these new learning environments have been made, strong empirical research regarding their influence on students' perceptions and the motivational impact of CEEs are lacking [10].

III. MODULE DESIGN

Each interactive multi-media module is designed using a similar structure, requiring approximately 30 minutes for completion. Using a web-based format, the module begins with a short reading providing an overview of the applied topic and lists the learning objectives. This reading is approximately 1-2 paragraphs in length. Next, a 3 minute narrated animation illustrates a key concept. This is followed by a five minute interview with an expert in the field discussing the geographic implications of the topic. Finally, a series of interactive exercises allows the student to explore the topic using geographic tools (e.g., visual examination, verbal descriptions, digital mapping, cognitive perceptions, and mathematical modeling). For each module element described above, an interactive textbox appears to the right where the student is encouraged to take notes. The module ends with a self-assessment. This self-assessment is required for completion of the module.

IV. MODULE IMPROVEMENT USING STUDENT FOCUS GROUPS

To improve the e-learning modules, we will use focus groups to investigate student perceptions of learning and teaching effectiveness [e.g., 22, 23, 24, 25, 26]. For example, Kingston *et al.* [23] utilized mobile technologies and virtual fieldtrips to teach physical geography. Students who had taken the old module and completed the new module were given questionnaires and then participated in a focus group to investigate the effectiveness of the new technologies. Lederman [26] also suggests that focus groups can be very useful for pre-testing educational materials as they "provide an opportunity for extensive commentary, unrestrained by the limits of a survey questionnaire or the student-teacher relationship which may affect course evaluations at the end of a class" (126).

The interactive modules will be tested with focus groups, comprised of approximately 5-7 student volunteers in each group. Each student in the group will be asked to complete a common module in advance of the focus group interview. Based upon established learning outcomes for the modules, students will provide feedback on how the interactive exercises affected their learning. The semi-structured focus group interviews also cover topics of engagement, clarity of concepts, ease and usefulness of exercises, and suggested improvements (Fig. 1). To ensure data acquisition both members of the research team will be present – one to serve

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Introductions
Facilitator introduces members of the research team and each of the group members introduce themselves. The facilitator provides the background and ground rules (confidential and anonymous reporting, honest opinions, etc.). The facilitator will inform the group that we would like to collect notes made by the participants during the session to ensure we collected as much feedback as possible, if the participants are willing.
Issues and Discussion Questions (Semi-structured)*
Overall Impressions
- *Please share with us overall how you felt about the modules?*
- *What did you like about the modules? What didn't you like about the modules?*

Engagement
- *What about the material (videos, photos, readings) did you find the most engaging?*
- *How did the interactive exercises affect your interest in the content?*
- *Did any of the material or exercises make you want to learn more about the topic? If so, which and how?*

Clarity and Ease of Use of Elements
- *What concepts or parts of the module were the most clear? The least clear?*
- *What aspect of the interactive exercises did you find the clearest/easiest? What aspects were unclear/more difficult?*

Learning
- *Overall, how useful did you find the exercises?*
- *How did the interactive exercises assist you in understanding course content? In applying course content?*
- *How did the interactive exercises challenge you?*

Improvements
- *What improvements could we make to improve the elements of the modules?*

Summary of what we have heard
- *Have we missed anything?*

Collect notes (to review later).
*Questions may be modified based upon results from post-module questionnaire.

Figure 1. Focus Group Questions

as moderator and the other as a note taker who records speakers, comments and significant non-verbal behavior [27]. A summary of the issues will be presented to the group at the conclusion to ensure no notable comments were excluded.

Concerns about the use of focus groups persist, including "groupthink" [28]. We have two mechanisms to minimize this. First, students will each fill out a short questionnaire at the completion of the module (Fig. 2). The questionnaire allows us to obtain individual feedback that may not come out in the group discussion but that may be vital to improving the e-learning modules. Second, we will ask the focus group members to jot down notes during the group interview. These notes will be collected at the end – in the event that members did not get a chance to share their comments.

For the analysis of the focus group interviews, we will code the data, create categories emerge and develop summary statements which capture the essence of the responses [26, 29]. The results of the coding offer two outcomes. First, the student responses will identify which of the interactive exercises have greater perceived value to students. We will compare these responses to student performance on the various assessments to see if there is a correlation between perceptions of learning and performance. The modules will then be revised to address weaknesses.

V. MODULE TESTING IN CLASSES

The revised modules will then be implemented using a pre-test/post-test control group design to test for effectiveness of the interactive components on student learning and perceptions of learning. In one semester, two separate classes (approximately 40 students in each class) will be presented with two of the applied geography topics. The control group (Class 1) will have access to only the multi-media elements and the experimental group (Class 2) will receive the full interactive module. The modules will be completed within 2 days to alleviate threats to external validity with exposure to the subject material from the pre-test. Both groups will be tested at beginning of the module and at the conclusion of the modules based upon the learning objectives. The pre-test will enable the researchers to determine existing knowledge base, which the post-test will allow for determination of learned knowledge. Differences between the control group and the experimental group will illuminate the effect of the interactive elements.

1. The interactive exercises helped me to (learning outcome #1).
| Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree

2. The interactive exercises helped me to (learning outcome #2).
| Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree

3. Overall, the interactive activities:
| Made no difference to how I learned | Helped me learn more | Were detrimental to my learning process

4. The interactive activities in these modules are challenging
| Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree

5. I am comfortable with the interactive activities in these modules
| Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree

6. I would like to have more interactive exercises in my courses
| Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree

7. Please comment on how specifically the interactive exercises can be improved.

Note: The questions will be modified to reflect each module's learning outcomes.

Figure 2. Perceptions of Learning Questions

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Independent t-tests will be conducted to examine the mean values of the control and experimental group scores and the gain scores for the control and experimental groups will be analyzed for ANCOVA (analysis of covariance) [30].

Beyond assessment of student learning from end of module quizzes, students from the experiment group will also be asked about their perceptions of learning using the questions from Fig. 2. The results of these questions will be presented as descriptive statistics. Finally, data from student notes recorded next to the module elements will be coded. The student perceptions of learning and engagement of students (documented through note-taking) will be compared to student post-test scores to look for correlations.

The researchers will then review the results from the pre-test/post-test control group design assessments of learning and perceptions of learning to complete final revisions of the interactive modules.

VI. CONCLUSION AND FUTURE WORK

Educational delivery models for college courses have changed from primarily the traditional lecture in the 1980s. Contemporary educational delivery models include online and distance education; however, there has been a gap in the assessment of these learning technologies of their impact on student learning [19]. As new generations of students arrive at institutions of higher education with, “a greater reliance on visual imagery and on participating actively in the learning process that probably stem from experience with electronic media during formative years” [11], this type of interactivity with course content has become increasingly important. Given the rising importance of the computer and interactive learning, how should multimedia be designed and integrated into teaching to promote deeper understanding and learning for students? Educational research of this nature tackles the fundamental question of how to optimize instructional design to maximize learning opportunities and achievement in online and distance learning environments [5]. Knowledge about the outcome of interactive activities in distance learning instruction will be valuable for educators and researchers to make more informed decisions about future online and distance learning course development and implementation [10]. Thus, by enlisting students in curriculum development, we expect to improve the module content and interactive activities by directing revision based on student perception of learning. More broadly, this research will be a contribution to the existing literature that has been limited in its analysis of how students learn in interactive e-learning environments. Future research will include a study to better understand the specific learning benefits and constraints involved in student interaction with a variety of interactive elements and combinations of interactive elements in the online environment.

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Classroom of the Future

A Purposeful Application of Technology and Context to Personalize Adult Learning, Foster Social Attachment, and Promote Collaboration

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***Abstract*—As a principal means of learning, the classroom of the future has to embody a barbell function. On one end, it has to leverage digital technology to make education more pervasive, increase quality of learning, and lower instructional costs. On the other end, it has to reduce theoretic dogma in favor of building proactive, strategic alliances with the nonacademic communities to deliver contextualized solutions addressing specific challenges facing human advancement and organizational development, while laying emphasis on the learning proclivities of adult learners. Grounded in empirical phenomenology and guided by three objectives, this paper explores the characteristics of a technology-enabled, context-rich classroom of the future. First, it investigates the specific features of the classroom supporting social collaboration, fostering communal connection, and tailoring academic experiences to learner preferences as well as real-world context. Second, it identifies extant obstacles to creation of an effectual classroom for adult learners. Third, it delineates approaches to surmount the obstacles, recognized and anticipated. A model of the classroom of the future is presented, along with framework of the components and constituents required for the realization of an innovative temple of learning that knows no boundaries. The results should prove valuable to scholars, theorists, and practitioners in the design and development of a future-oriented classroom that decisively conjoins technology and context to personalize learning, cultivate social attachment, and advance collaboration.** *(Abstract)*

Keywords-Classroom of the Future; Learning technologies; Online learning; Cohort; Adult learners; Adult learning; Social collaboration; Contextualized learning; Social attachment; Learning preferences; Academic-nonacademic alliances.

I. INTRODUCTION

Nietzsche once wrote, "The time will arrive when everyone's thoughts will turn to education" [1]. With recognition of knowledge as the unassailable source of wealth [2], education finds itself front and center on the agenda of policymakers. The dawn of technology has altered the Pythagorean notion that earth is round. Philosophically, the new world is flat in a way that not only renders opportunities equal for its dwellers, but also enables best minds to come together, without divisions or barriers, to collaborate in service of common missions [3]. With this new realization, nations are framing policies to raise educational standards, and organizations are fostering continuous education to help create competitive advantages of lasting value.

Organizational investments into the search of knowledge have turned employees into adult learners, who funnel part of their spare time into learning to boost their output and value, leveraging a pervasive accessibility of learning options in and out of their own organizations. An increase in the number of adult learners has also brought into focus the distinctions in learning proclivities. Whereas a traditional learner is used to the established pedagogical methods, the adult learner learns more effectively with andragogical approaches [4]. Based on the broader life experiences he or she brings onboard, the adult learner is capable of thinking abstractly with only some facilitation from an experienced coach or faculty, and is able to share and create knowledge more effectively in social collaboration with his or her peers.

The figurative change in the shape of the world is, however, defied by empirical reality in a telling way. The promise of a boundaryless technology-enabled learning system for knowledge-hungry businesses and adult learners has not been fully realized. An engaging technologically-enabled, context-rich classroom for adult learners is one that supports cognitive, emotional, entrepreneurial, and values-related aspects of learning. It facilitates adult learners to work collaboratively in the day to day. While even the extant patchwork of tools has been able to foster an increase in the quality of learning experiences, remove situational barriers in alignment with cross-border expansion of businesses, and make learning cost effective, a systematic enabling of spatially-, functionally-, and culturally-dispersed learners to collaborate effectively has remained a challenge. It is, therefore, important to isolate and examine the role of technologies utilized by adult learners in order to understand the features of 1) collaborative technologies that learners use well, 2) instructive technologies the learners consider valuable to an engaging learning experience, and 3) social technologies that instill a sense of community though learner interactivity, regardless of esoteric or exoteric obstructions.

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A. The Business of Knowledge

Learning and knowledge thrive in symbiosis, for the garden of knowledge blooms from the seeds of learning. Aristotle and Ibn Sina described learning as a process of actualization of the mind's potential [5]. While the principal tenets of education have remained unchanged, instructive media and methodologies have evolved. During pre-writing period, teachers used oral, visual, and observatory means to pass along lessons to their pupils. With development of writing methods, teachers facilitated the knowledge process through an accretive loop and enabled the understanding of natural phenomena to be accretively passed on from one generation to the next in the form of values, traditions, methods, and skills. The invention of the printing press further catalyzed knowledge propagation. Electronic technology, the fabric of modern life, delivered the next quantum leap, leading up to the Internet-based learning platforms. Information systems have liberated access to arrays of learning content in the form of text, images, lectures, animation, audio, video and games, while communication systems have enabled a platform for borderless collaboration. The proliferation of laptops, smart phones, tablets, and other mobile devices underscores the emergence and promise of virtual learning.

Reference [6] promoted the ideas of knowledge creation through conversations within an open community to deepen understanding of any phenomena of interest, attack common problems, and envision creative solutions. Referencing the Socialization-Externalization-Combination-Internalization or the SECI model, Reference [7] put forth a view that knowledge creation was a continuous, dynamic process and that the transfer of tacit and explicit forms knowledge could best be facilitated through social interplay among the participants. Reference [8] too held the view that knowledge resulted from a synthesis of minds and was an aspect of a social bustle embedded in cultural practices. The recognition of knowledge transfer as a social process augurs that the more effectively learner collaboration is supported, the more successful the learning outcomes.

B. Learning Proclivities of Adult learners

With talent management turning up as a vital part of the learning agenda of organizations, the role of corporate education and training has evolved in importance. Changing workplace technologies, the dramatic transition to frontierless knowledge work, and competitive world markets have heightened administrative complexities. Academia and training institutions have been building appropriate capabilities to be supportive. Universities have leveraged accessible e-learning platforms to offer convenient educational options for adult learners. One of the main obstacles to a sound educational strategy implementation has been the failure to recognize that the learning proclivities of adult learners are dissimilar. There is a temptation to ignore the peculiarities of learners, because doing so makes educational design a bit more tractable, but the result of such platonicity is creation of one-size-fits-all programs designed for en masse delivery [4]. Universalized education relies on broad strokes in favor of specific focus. To be more effectual, educational establishments would be better served by reducing theoretic dogma in favor of seeking to build alliances with nonacademic organizations to collaborate on addressing specific challenges facing human advancement and organizational development and increasing focus on the styles of adult learners.

Andragogical principles suggest four adult learner levels. Rational (Level I) learners are the kind of learners motivated by bounties, such as grades, diplomas, output, and career growth. These learners are interested first and foremost in acquiring knowledge that can immediately be applied to create measured outcomes. They are motivated by solving problems and finding innovative solutions that can get them acknowledged. Rational learners' motivation to learn can be escalated by a context-content application approach, where these learners are exposed to the big picture of the subject matter before the small picture is shared. For example, a course in strategy may be prefaced by a presentation of an organizational leader on how the lessons may relate to the company or functional approach. The big picture sets up a context for the nuts-and-bolts of subject matter. Before the course is wrapped up, concepts are tied back to applications, particularly as they relate to learners in their given roles. The context-content application approach stimulates rational learners by framing sturdy linkages across theory, practice, and application.

Emotional (Level II) learners have the same basic needs as rational learners, but their genuine motivators are relationships. These learners cherish personal interfaces. They are motivated to build enduring bonds that they believe will drive collective success. Emotional learners can be motivated by community-based learning systems (social networking, gaming, blogs, etc.) that encourage teamwork and collaboration, allowing them to tap into the group's explicit and tacit knowledge. The motivation of these learners can be boosted by assembling them into learning teams where they feel empowered to create their own goals in association with peers. An intimate atmosphere inspires emotional learners to open their minds to new perspectives and assume responsibility, resulting in a sustained cycle of positive changes and development over time.

Entrepreneurial (Level III) learners bear the seeds of rational and emotional learners, but it is action and risk play that truly motivates them. Every chance they get, these learners like use hands-on activities to acquire knowledge and build their confidence. They are motivated by nonacademic learning environments that allow them to express themselves physically and mentally. Simulations, role plays, game boards, and discussions are ideal tools to heighten the learning motivation of the entrepreneurial learners. The trick to engaging these learners is to foster a culture of sharing, sparring, and validation of ideas in a safe environment. Creative design of nonacademic learning approaches helps by instilling a sense of confidence that the

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entrepreneurial learners eventually need to apply capital and assume informed risks in the real world.

Spiritual (Level IV) learners are macrocosmic learners in that they encompass and embody the qualities of all other levels of learning. They are motivated by the aspiration to understand nature. These learners carry a profound yearning to reach beyond humdrum and mundane in search of self-realization. Spiritual learners can be motivated through facilitation focusing on the illumination of their personal values and engagement into learning with authenticity and congruency. Through the discovery of biases and mental paradigms, these learners can be assembled in trusting social interactions on a journey to discovery, transformation, and philanthropic contribution.

An employee-competency survey at certain large multinational companies found that key higher order skills, such as thinking strategically, managing change and conflict, communicating and collaborating across cultures, mentoring and leading, and innovating thinking have not kept pace with needs of business and pointed to a labor-to-talent gap. These institutions could benefit from adopting a barbell approach by keeping the goals, motivations, and proclivities of learners in mind and embracing alliances with business to develop and deliver effective learning content. By doing so, institutions could engage learners, open their minds to prepare to apply themselves in the real world, and bring increased meaning and performance to their alliance partners.

C. Problem Statement

Companies are investing heavily in the learning needs of their workforce in the face of changing organizational technologies, labor market shifts, and growing regulatory pressures. Talent development has been driving budget in excess of $2 trillion on training and education programs worldwide [9]. While success in this market requires catering to the needs of adult learners, comprehending industry- and company-specific workforce challenges and ever-evolving needs, and designing a classroom that enables spatially-, functionally-, and spatially-dispersed learners to come together in social collaboration, the response from educational institutions has been lagging [10]. The mitigation of this challenge requires a clear-cut understanding of how technology and context could be purposefully combined to result in personalized adult learning, greater social attachment, and increased borderless collaboration.

D. Purpose Statement

The purpose of this study was to explore the features of the technology-enabled, context-rich classroom for adult learners. Three objectives guided this research. The first objective was to investigate the specific features of the classroom supporting social collaboration, fostering communal connection, and tailoring academic experiences to learner preferences as well as real-world context. The second objective was to identify extant obstacles to creation of an effectual classroom for adult learners. The third objective was to delineate approaches to surmount the obstacles, recognized and anticipated. The findings of this research, grounded in empirical phenomenology, were based on the lived experiences of seven adult learners engaged in a cohort-based, online degree program.

E. Research Questions

This study posited that a classroom of the future that is capable of personalizing adult learning, fostering social attaching, and promoting seamless collaboration would consist of six key subsystems encompassing reading, collaboration, assessment, assimilation, application, and relationship building. The following six questions, as presented to participants, guided this study:

1. How effective did you find the “reading” tools in your learning process? For example, physical textbooks, web-based documents, PDF files, e-readers, etc.

2. How effective was the asynchronous classroom in fostering your interactions with other learners and with your faculty member?

3. What role did assessment/testing play in reinforcing and validating your learning in the classroom? Assessments may have included writing assignments, projects, multiple-choice tests, etc.

4. Did you use any formal/informal project management tools to manage collaborative/team-based projects? What was your overall experience?

5. Did your experience and learning in the classroom help you be more productive in your work? How? Has your experience helped you think or do things differently?

6. Did your interaction and collaboration in the classroom help you develop relationships with other employees across functions and sites? Have these relationships been useful in your day-to-day work life? If so, how?

F. Data Collection and Management

As part of an academic alliance between Cisco Systems, Inc. and University of Phoenix, a cohort-based Master of Business Administration degree program was chartered. This initiative was part of a broader portfolio of learning and development solutions offered to employees. The cohort program was contextualized for the company through collaborative content development and delivery. This cohort program was offered on an online learning system proprietary to the University and offered participation from employees worldwide.

The target population for this study was knowledge workers, defined as skilled, qualified, and experienced employees responsible for creating, modifying, and orchestrating knowledge. Ten cohort participants were identified for data collection and seven agreed to participate. These participants represented five functional business domains, namely Sales, Finance, Engineering, Services, and Supply Chain Operations. Based in the United States, these participants were geographically-dispersed with four coming from California and one each from Illinois, Georgia, and Missouri.

II. Findings and Conclusions

Learning and education are both interrelated sociological change processes. While the former is a process for preparing individuals to think differently, the latter is one for changing behaviors. As technology becomes increasingly pervasive and learning turns into a lifelong process, the paradigm of adult education must evolve. The future framework of the classroom of the future encompassing six dimensions, whose importance is underscored by the impact on knowledge building, business value creation, and social attachment formation. These dimensions are reading and intelligent search, collaboration, assessment, assimilation, application, and relationality.

The function of the reading and intelligent search dimension is to scan the environment for sources of learning. It is estimated that 2.5 quintillion bytes of digital data is being generated each day [11]. One key responsibility of this subsystem of the classroom is to not only make information available conveniently and comprehensively, but also act as a filter to noise in the environment. The collaboration subsystem is responsible for engaging diverse learners into social interplay, playing a critical role in knowledge sharing and transfer. Learner collaboration ensures that diversified learning of the cohort is more than the sum of each learner's learning. The assessment subsystem lends a safe environment in which learners could test ideas and validate knowledge. The assimilation subsystem enables learners to combine and synthesize the ideas shared in the classroom into internal knowledge through reflection process. The application subsystem is designed to ensure that the theory-to-practice gap is minimized. The context-rich, fit-to-purpose body of knowledge developed in collaboration between educators and practitioners helps shorten the link between learning and application. An engagement of diverse learners in the technology-enabled classroom provides a rich learning experience that strengthens social bonds. A culture of respect, trust, friendship, and cohesion in learning teams ensures long-term advantages for the learners as well as for their workplace sponsors.

A. *Effectiveness of the extant online classroom features*

Reading and intelligent search. The reading and intelligent search function is designed to facilitate a scanning of the environment—internal and external--for learning sources [12]. With an exponential growth in the volume of unstructured data in shape of images, videos, tweets, posts, and emails, this function is required to make information easily and expansively available and sift through the clatter associated with and around the sources.

The classroom deployed the portable document format (PDF) for text books. The PDF format is independent of application software, hardware, and operating systems. Journal articles, recorded video streams, and internet-based content was furnished via web pages. Both formats are designed provide accessibility across a range of devices from laptops to phones and tablets. In addition to the reading material in electronic format, learners could purchase physical text books to gain a traditional immersive reading experience. Emails and chat facilities in the classroom were used for exchange of content, such as faculty feedback and learner-to-learner communications. Learners received certain text-based instructional lectures or recorded audio and/or video content delivered on CD-ROMs or DVDs.

The participants primarily used laptops and tablets in their work and personal environment. Based on their existing device usage model, a majority of the participants felt satisfied with the accessibility of reading formats provided for by the current classroom. Access to online library was highly appreciated. A participant noted the University's e-library had the potential to be "one of the best resources in the world." Participants felt that online reading worked out just as well for them as physical books. A great benefit of the electronic format is that learners could purchase only the chapters they found useful.

Collaboration. The collaboration function is designed in recognition of the social nature of learning. Effective collaboration requires emphasis on the learners' ability to share, analyze, create, and assimilate knowledge. It reflects a desire to address the andragogical needs to encourage the interplay of tacit and explicit knowledge in the classroom [7].

The classroom was designed as a flexible e-learning platform with capabilities for course management. It enabled information sharing among a network of learners through location- and time-independent asynchronous interactions. The collaboration tools embedded into the platform included threaded discussions, chat rooms, learning team rooms, private rooms, email, and mailing lists. The classroom afforded learners the freedom to supplement capabilities of videoconferencing and telephone conversations to further coordinate learning activities.

Participants found the asynchronous classroom to work effectively in fostering more meaningful interactions among the learners themselves as well as between them and the faculty. Participants noted that their asynchronous interactions were much more involved than those in a traditional, synchronous environment. Given the temporal flexibility, participants were prone to carefully and deeply researching their answers to discussion questions before posting them to the classroom. As learning tends to arise in the context of relationship with others, the result of individual thoughtfulness was an enriched interaction with other participants. The time to research answers also helped participants exercise greater discipline with such things as recording references and citations, helping enhance the overall quality of the learning experience.

Assessment. Assessments are essential to making sure that learning has taken place as intended. It is a process of comparing actual results against expected results and ascertaining differences. In a traditional classroom, the visual and verbal feedback is readily available from learners, but in an online classroom, physical cues are unavailable. Therefore, implementing special assessment mechanisms becomes essential in an online classroom. For this study, participants were asked about assessment in a broad context of interaction in the classroom, writing assignments, and formal and informal tests.

The classroom was designed to help the learners demonstrate personal accountability and the ability to work independently as well as in learning teams. When learners failed to make a certain number of postings within a specified time, the built-in checks in the platform helped keep track and the learners risked being dropped. Learners were required to submit substantive answers to a set of discussion questions and encouraged to interact in meaningful ways under the watchful eyes of the faculty member. The course grade took into account the participation level and quality of individual contributions as well as learning team work. In some courses, the classroom included Assessment and Learning in Knowledge Spaces (ALEKS), a Web-based, artificially intelligent assessment and learning system to assess the knowledge of the learner.

Participants found individual and team essay papers to be beneficial when they were relevant and had some applicability to their day-to-day business. Although participants found writing papers—particularly, in APA format--a bit challenging, they saw it as a necessary evil to get and demonstrate a comprehensive view of the learning material. Some participants also found the tests administered in class to be beneficial in validation of acquired knowledge.

Assimilation. Assimilation of knowledge takes place through the process of learning-by-doing [13]. In a classroom, assimilation is accomplished by bringing learners cooperatively and competitively to work on projects that not only encompass required lessons, but also appeal to learner interests. Projects are a connection between planning and doing, and working on them affords learners the opportunities for both personal and professional growth by boosting their participation, exposing any defensiveness, encouraging constructive action, and motivation to reduce theory-to-practice gap.

The classroom was designed to encourage learners to assimilate knowledge through projects. A certain percentage of the course grade was earned by learners by completing projects with other members of their learning team. The classroom also gave the the learners the ability to leverage the differences among themselves to optimize the collective learning experience.

Participants consistently pointed out the organizing structures they put into place to work effectively on team-based projects. Some used Microsoft Excel to break down the execution of course assignments and document the delegation of tasks, while others used Evernote as a tool for capturing notes to assist with work assignments. Notes were taken during team meetings and published for easy access via email. While the projects in the classroom were not complex enough to warrant the use of formal project management tools, it appeared that learners were able to improvise with existing tools to get their project work done. Participants remarked having regularly scheduled meetings, use of agenda in team meetings, and publication of minutes that also included the division of responsibilities among team members. Project work helped the learners exercise and demonstrate trust and accountability.

Application. For the knowledge of the learners to be relevant, it can and must be applied. The concepts learned over the study period should, in some positive way, inform the learners' work in the day-to-day. Eventually, it is application of the methods to the design and operation of management systems and business processes that enables the learners to deliver the greatest value to stakeholders.

The classroom took a strategic, holistic, and tailored approach to learning. Based on an appraisal of the talent needs, the program curriculum was appropriately contextualized. Some of the courses in the program were fit to purpose and the accredited body of knowledge was covered along with an integration of industry- or company-related readings, simulations, and projects. The central objective of the cohort program was make courseware aligned to learners' careers and business, so as to enhance work-related skills, career progression, and impact on personal and professional growth.

Participants shared examples of knowledge gained in the utilization of productivity tools, such as WebEx Social. Some participants expressed how their participation had given them a different and broader perspective on business not only through knowledge gained in the coursework, but also through the social interaction with other learners in the project work, where everyone's knowledge was socialized to accomplish course assignments. Participants particularly valued the cross-disciplinary and cross-cultural social interactions, as part of their learning experience. A participant noted, "I am more productive in using my time and focusing my energy in important tasks. I also think more critically." Multiple participants noted not only thinking more critically about business and managerial related issues, but also their tendency for a more thoughtful and reflective approach in their interactions with other employees. A participant conveyed, "I am thinking much 'deeper' and more thoughtfully on just about every topic…I am absolutely more measured in my responses, do more research on things I am working on, and believe the quality of my work has improved because of this Cohort." Another idea expressed by several participants was about the time it took them to their acquired knowledge. Using the Human Resource Management (HRM) course as an example, one participant said, "I have used the content from HRM most significantly. The overall recruiting, selection, and celebration of diversity I used [immediately]… as I have been adding headcount."

Relationality. If business is a function of interconnectivity and interdependence, the seeds of borderless collaboration must be sown continuously [14]. Since learning is social, classrooms are the best venue for formation of solid and lasting relationships. The spread of globalism will continue to require business to break down silos and necessitate employees to form global alliances to be able to deliver to growing expectations of investors and customers [15].

Using online modality, the extant classroom provided a capability to assemble spatially-, functionally-, and culturally-diverse learners. The social nature of the platform along with the interactive structure of the course enabled employees to share, debate, and synthesize diverse ideas. The focus on team projects was directed to encouraging learners to engage in collaboration.

Participants discussed how personal and professional bonds being formed among the learners during the program. More importantly, the participants felt that their relationships extended beyond the program. Participants specifically noted how they expected their relationships to continue to grow on the strength of mutual trust. One of the participants said, "The relationships are very close and our level of trust is very high." Participants shared job openings with one another across business functions. Such sharing could serve the company in growing general management capability by developing cross-disciplinary leaders. In addition to socialization within the work-team construct—in service of project-based deliverables—the participants also reached out to one another to leverage the domain expertise of other team members. Technology is inclusive of personalities. Whether one is an extrovert or an introvert, there is a way to engage in conversation. Age barrier, which could be an issue when individuals work in person, is blurred in the online environment.

B. Obstacles presented by extant classroom features

Reading and intelligent search. Participants noted that while the access to reading content was satisfactory on their laptops, they faced significant difficulties accessing the files on mobile devices, such as phones and tablets. A participant noted a paradox that a great feature of online classroom is its accessibility over spare time; however, when reading material requires a laptop to access, it defeats the purpose of using spare time, when a laptop is not normally unavailable. The richness of the online library was noted, but issues with organization of data and search capability were flagged. Without proper organization of data and absent an effective user interface, access to library was noted to be difficulty and time consuming. The PDF-based text books were password protected for copyright reasons. Participants found password authentication to be a major hurdle as they tried to access reading material across different devices. Specifically, a tablet version of PDF reader did not even permit the authentication mechanism, which ended up becoming a source of frustration for learners. Further, neither the PDF-based text books nor the web pages allowed learners to take notes in the margin and highlight reference content.

Collaboration. Participants had to resort to external applications, tools, content, and services, such as WebEx, Skype, FlashMeeting, Telepresence, and/or email to coordinate certain learning activities. Missing in the current platform, these tools helped built camaraderie, foster deeper understanding, and promote teamwork. Participants missed live lectures in the asynchronous classroom, and, with it, the benefit of learning from a trustworthy source, asking questions, and receiving real-time responses. Participants noted missing a sense of urgency in the asynchronous classroom. For instance, responses from faculty member to urgent questions were delayed. The assignments were found to be vaguely written, and participants found it difficult to align their expectations with the faculty over online conversations. A part of the difficulty was attributed to the short duration of the course and timing of interactions that do not always keep pace with the assignment timelines.

Assessment. Participants found open-book, multiple-choice tests to be of little value, as these types of tests became an exercise in finding the right answers rather than learning the material. To that end, one participant summarized group sentiment saying, "Quite honestly, the final exam/assessment provided little to no value…it bec[ame] a 'check box' and simply finding the answers in the text is just time consuming rather than learning." While some participants found essays to be helpful in reinforcing learning, others did not find much value in them. Effort needs to be made to require only as many essays from learners as productive to learning, otherwise they can be perceived as forced chores rather than a valuable exploration of the subject matter content. The assessment of essays is a

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subjective exercise, so, based on the faculty load, there could be a large degree of bias in feedback.

Assimilation. Participants expressed dissatisfaction with the project-related tools available in the classroom. As a result, participants resorted to external applications, tools, content, and services, such as WebEx, Skype, FlashMeeting, Telepresence, and/or email to coordinate project efforts. These tools were deemed essential for successful project collaboration and, hence, for knowledge assimilation. Ill-conceived project assignments not relevant to interests of the participants were judged wasteful.

Application. Participants noted that time constraints imposed by course load prevented them from more systematically applying their knowledge. While the contextualization of program proved to have the capacity to enrich learners' understanding, critical thinking, and productivity impact, the benefit was limited by each course being contextualized on its own. Instead, if each learner came into the program with one significant problem to solve in his or her organization or business unit, and then was allowed to figure out solutions progressively through each course in the program in collaboration with other learners and the practitioner faculty, the learner's benefit could be more significant and holistic.

Relationality. Certain esoteric courses like human knowledge and philosophy are more difficult to integrate in the online modality. Because the online classroom relies on the intrinsic motivation of learners, there is a risk that learners needing a more personal interface could fall through the cracks. Further, online classroom has not evolved enough to accommodate the needs of learners with certain disabilities.

C. Strategies for the improvement of classroom

Reading and intelligent search. Participant feedback suggested that the reading and intelligent search feature could be improved by: 1) providing generous technical support for learners using reading tools to ensure effective usage across the gamut of prevailing devices, 2) creating a copyright mechanism for electronic content to work uniformly and efficiently across devices, 3) developing device-independent and portable reading formats that enable learners to highlight reference points and make notes in the margin with the ability for the learners to port the notes across their devices, 4) deploying cloud to store reading files, so that learners working on devices without local storage (for example, phones) could access files, 5) integrating immersive reading with features, such as explanatory videos and audios clips and maps into the reading files to enrich the learner experience, 6) inserting text-reader programs and word-prediction software to empower learners with learning disabilities, 7) integrating intelligent search to enable filtering through noise on the Web and large databases and provide access to assistance, communities, and expertise.

Collaboration. Participant feedback suggested that the collaboration feature could be improved by: 1) incorporating on-demand collaboration, online meeting, web conferencing, and video conferencing capabilities, such as WebEx, Skype, FlashMeeting, and Telepresence into the learning platform, 2) integrating the ability for learners to start their own blogs in their areas of interest and engage other learners to build social knowledge networks through collaborative tagging and folksonomies, 3) providing generous technical support and training for learners and faculty using the platform across a gamut of prevailing devices, 4) combining some face-to-face (blended) classroom time with the asynchronous activities to balance out the learning process for both learners and faculty, 5) addressing learning preferences of all age groups, namely Boomers, Gen X, Gen Y, etc. via collaborative approaches and social networks.

Assessment. Participant feedback suggested that the assessment feature could be improved by: 1) increasing deployment of artificially intelligent assessment and learning tools across courses to assess the learners' before-and-after knowledge of subject matter, 2) taking advantage of technologies (for example, podcasts, wikis, blogs) to help learners demonstrate their acquired knowledge, 3) instituting writing labs and plagiarism checkers to facilitate writing skills and ensure academic honesty, 4) requiring projects, simulations, and essays that are contextualized in workplace skills, 5) engaging with business to ensure that work-related skills are enhanced to achieve specific objectives and 6) eliminate assessments that are perfunctory in the learning process, adding little value beyond preserving institutional dogma.

Assimilation. Participant feedback suggested that the assimilation feature could be improved by: 1) promoting functional, spatial, and cultural diversity within learning teams to optimize interplay and assimilation of knowledge, 2) incorporating on-demand collaboration, web conferencing, and video conferencing capabilities into the learning platform, 3) designing multiplayer simulations and games to engage members of the team in a safe, social experience, 4) creating fit-to-purpose projects that learners could work with through their entire course of study instead of having a set of dissimilar, per-course projects, 5) encouraging the use of blogs, wikis, and rich site summaries (RSS) to fast and wide sharing of information not only across the learning teams, but also across the learners' organizations, 6) providing generous training to learners on pod/vodcasting to share audio and video recordings with others.

Application. Participant feedback suggested that the application feature could be improved by: 1) including program-level customizations, where possible, and where those are not possible, tailored individual courses to shorten the link between knowledge and application, 2) working out licensing deals to open access to multimedia content from the massively open online course (MOOC) sources, such as Coursera, Udacity, MIT, Stanford, and Yale, as applicable

[16], 3) deploying new adaptive learning technologies to lower costs and improve learning outcomes by more effectively linking knowledge to application.

Relationality. Participant feedback suggested that the relationality feature could be improved by: 1) integrating blended programs, where technology-mediated activities are complemented with face to face methods, 2) addressing learning preferences via collaborative approaches and social networks, so that learners can succeed, regardless of demographic factors or level of proficiency with technology, 3) including features and accommodations to support the needs of those with learning disabilities.

III. CLASSROOM OF THE FUTURE

"The future ain't what it used to be," Yogi Berra said [17]. The increasing complexity of the world may limit our ability to model and predict [17], but the only way to be prepared for the future is through investments in constant learning. Interdependence and interconnectivity define the future of business and society. Investments in learning are necessary, and involvement of community is essential. Based on strategies gleaned from participants in this study, Figure 1 illustrates the model of the classroom of the future encompassing the recommended features for reading and intelligent search, collaboration, assessment, assimilation, application, and relationality.

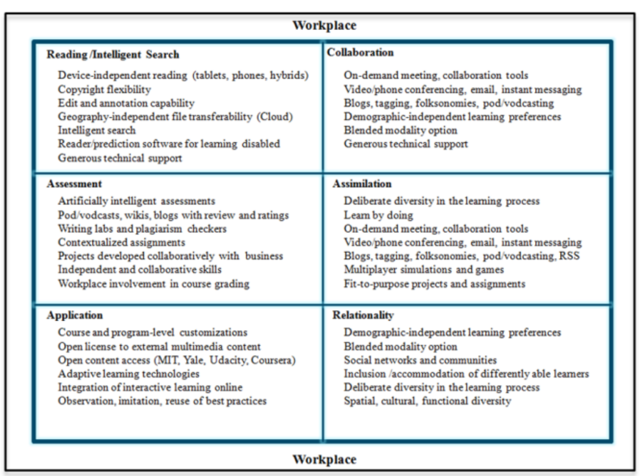

Figure 1. The classroom of the future

The realization of the classroom without boundaries will necessitate deployment of advanced social and collaborative technologies, active participation of business in learning, a constructive remodeling of academia for the future, and shared responsibilities on part of the content provider community. Reference [19] argues that traditional classrooms are a fragile system. Only if they are imbued with a real-life essence do they stand a chance to evolve into antifragile bodies that can withstand changes and emerge stronger. Figure 2 binds these players/forces into a common platform.

Three types of institutions will cover all of higher education in the future: traditional schools (public and private universities), nontraditional schools (private for-profit and not-for-profit universities), and free MOOCs (Udacity, Coursera, edX, etc.). The degree to which these institutions succeed will depend on the extent to which they are willing, able, and ready to create academic alliances to meet the needs of learners and ensure that the challenges facing businesses are addressed through relevant, context-rich learning solutions.

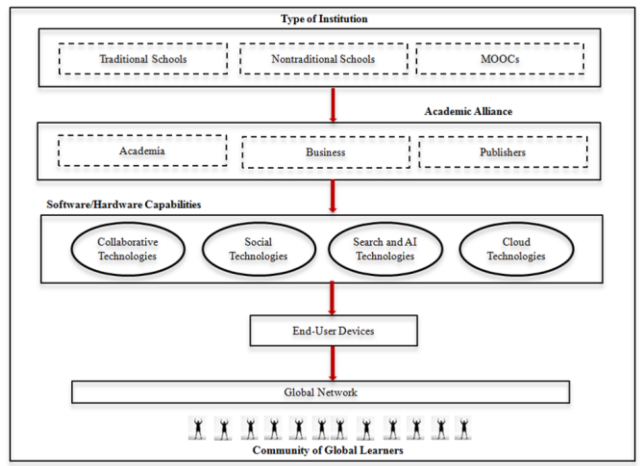

Figure 2. Components for realization of classroom without boundaries

Further, alliances among the institutions of higher learning and publishers and copyright holders will be essential to ensure that content could be readily and instantly made available to learners across the gamut of end-user devices (phones, tablets, laptops, and hybrids). Content publishers would have to evolve open yet profitable business models that enable integration of as much rich, multimedia content into the classroom as possible [18]. The role of hardware and software technologists will be to ensure that educational devices are not only affordable, but also support the needs of dispersed learners. Only through a purposeful deployment of collaborative, social, intelligent search, artificial intelligence (AI) software/applications, and cloud technologies can a personalization of adult learning, promotion of social attachment among learners, and enabling of borderless collaboration be enabled. Finally, it will be up to learners and professors to help the evolution of the technology-enabled, context-rich classroom by constantly lending their voice.

The great mystic Jalaluddin Rumi described learning attainment through a sublime parable. A grocer has an abundant supply of sugar in his store, but the amount that can be doled out depends on the capacity of the shopper's bag. Sugar is the metaphor for learning, and the bag is the metaphor for degree of learning. There are vast sources of learning available to hungry learners, but the amount that can be delivered to them depends on the capacity and effectiveness of our classrooms.

SUMMARY

The purpose of this study was to explore the features of the technology-enabled, context-rich classroom for adult learners. Three objectives were accomplished with this study. The first objective was to investigate the specific features of the classroom supporting social collaboration, fostering communal connection, and tailoring academic experiences to learner preferences as well as real-world context. The second objective was to identify extant obstacles to creation of an effectual classroom for adult learners. The third objective was to delineate approaches to surmount the obstacles, recognized and anticipated. The findings of this research were based on the lived experiences of seven adult learners engaged in a cohort-based, online degree program. The model of the classroom of the future was proposed. The results should prove valuable to scholars and practitioners in developing an effective classroom of the future that purposefully applies technology and context to personalize adult learning, fosters social attachment, and promotes collaboration.

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The O_3 Project - Implementing Support For The Transition To Distance Learning

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***Abstract*—This paper describes design and implementation of an institutionally supported initiative to convert Continuing Professional Development courses for health and social care professionals, from traditional face-to-face, to an online delivery method. E-learning specialists are used to mentor subject specialists, in producing effective, high quality online courses. Processes and tools have been created to promote staff development, for long-term sustainability of the initiative. Evaluation of both staff and student experiences will take place once the initial courses within the project have completed.**

Keywords - Online learning; Distance learning; e-Learning; Higher Education; HE; Institutional change.

I. BACKGROUND

Health and Social Care professionals within the United Kingdom are expected to maintain the currency of their skills and knowledge through a process known as Continuing Professional Development (CPD).

The term 'CPD' is commonly used to describe a concept also denoted as Lifelong Learning, Continuing Professional Education, Continuing Vocational Training, and Post Qualification Development [1,2]. CPD has been defined as, *'a process of lifelong learning for all individuals and teams which meets the needs of patients and delivers the health outcomes and healthcare priorities of the NHS and which enables professionals to expand and fulfill their potential'* [3].

Courses that facilitate this process are provided either within the individual's workplace, or by an external provider; this is usually a Higher Education (HE) institution, where the courses are delivered at postgraduate level, and are credit bearing.

However, increased workload pressures from the clinical environment are making attendance at external activities increasingly difficult [4,5]. This requires institutions to consider alternative methods of delivery to provide CPD.

This paper begins by describing a system that has been implemented to promote wide-scale transition from traditional to online delivery of CPD courses within a HE institution. An overview is presented of the potential benefits within the system and issues that may be encountered. The paper concludes by confirming that future evaluation of the implementation will be undertaken.

II. INTRODUCTION

Online learning (used synonymously with e-learning in this paper) has the potential to "*improve the quality of learning, improve access to education and training; reduce the cost of education; and improve the cost-effectiveness of education*" [6]. However, these factors should not take priority over the quality of the process, and importantly, research comparing online and on-campus education tends to find few significant differences in outcomes and satisfaction ratings between on-campus and off-campus learners [7-14].

This project, named **O_3** (**O**nline, **O**ff campus, **O**ut of hours), is based on an institutional teaching and learning strategy that includes a vision for e-learning. This is important, as institutions have been shown not to have overall foresight or a cohesive approach to e-learning; and if they do, many people are unaware of it [15]. The broad aim of the project is to facilitate the long-term sustainability of quality online delivery of CPD courses for health and social care professionals. In promoting sustainable development, teaching and learning in HE organisations can be transformed [16]. However, sustainability of e-learning initiatives is a common challenge, regardless of the scale and focus of the project [15, 17].

Adopting online delivery and its related technology requires an investment in faculty time and resources [18]. Many academics report being too busy to prioritise exploring new approaches to teaching and learning, with its associated problems in finding and learning how to use related resources [15]. Sait et al. [19] also identified that some tutors are against using technological methods as a replacement for face-to-face instruction, which is a type of internal resistance that should be taken into consideration. As a way of resolving this, supportive leaders are cited as a positive influence, although this tends to be based on personal relationships rather than determined by policy or institutional practice [15].

Teaching and learning online also requires a different pedagogy and unique set of skills from that of the traditional classroom [20-25]. Despite awareness of this, it is widely acknowledged that most development work in this area is currently being done "*by faculty with no formal training in […] any of the related e-learning fields*" [26]. Academics using online delivery methods "*are faced with new pedagogical issues surrounding student interactions, course content design and delivery, multiple levels of communication, defining new types of assignments and performance expectations, and different assessment and evaluation techniques*" [26]. The result is courses being prepared and delivered with a "*systemic lack of awareness*" in appropriate uses of technology for online education [24].

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For a programme to be online in design, not just delivery, there needs to be an intentional, informed approach to instructional design. Therefore, any system that establishes a framework that could be used to guide the process, will greatly simplify the task of implementing online learning.

III. THE O_3 PROCESS

The principle behind the O_3 project is to utilise academic staff with expertise in e-learning, to mentor subject specialists in the process of moving their traditionally taught courses online. This may not, at first glance, appear to be an innovative approach, however, the institutional investment to the process, is what sets it apart. This support took the form of resource allocation and workload accounting, with the mentoring activity being recognized within the roles of the individuals concerned, demonstrating institutional commitment to the activity. A supportive organizational structure has:

- *an overall teaching and learning strategy that includes a vision for e-learning with accountability measures at both management and practitioner levels; and*
- *a vision for e-learning that is relevant, coherent and shared* [15].

The e-learning specialists are the enablers within the system, and sit at the centre of the process, as can be seen in Figure 1. The process begins with meetings between them and the subject specialists, where the current course curriculum, timetable, materials and methods of interaction are identified and discussed; at this point they form what could be termed an O_3 working group. This activity, in itself, has identified a previously 'invisible' outcome to the process, whereby the subject specialists have found themselves challenging and questioning what they have already been doing, in the traditional delivery of the courses.

At these meetings, the materials and processes that can be immediately transferred online, with little or no change, are identified, and a technical support team carries this out, as directed by the e-learning specialist. The remaining elements of the course form the foundation for discussions between the members of the O_3 working group, with the e-learning specialist providing suggestions on possible online alternatives, but it is the subject team who ultimately make the decision regarding which of these are used. This partnership approach aims to achieve a balance between the priorities of the project and the autonomy of the subject team to define the direction this emergent e-learning course will take, resulting in less potential for the 'not invented here' syndrome to occur [27].

Rapid authoring software (Rapid Intake eLearning Studio) is used as the vehicle to produce and present the course materials. The files exported from this tool are SCORM compliant, which enables them to be embedded within the institution's Virtual Learning Environment (VLE). Both the VLE layout, and the course delivery interface that is produced by the rapid authoring software,

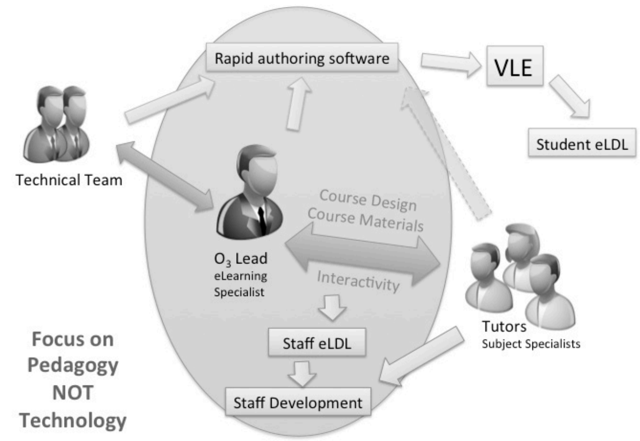

Figure 1. O_3 Structure

are the same for all courses produced within the O_3 process. This aims to promote automaticity in its use, so that students do not have to focus on how to use the technology when they should be devoting their attention to what they are expecting to learn. This prevents students from cognitive overload, which may decrease learner motivation by inhibiting their attention to the actual instructional material [28, 29]. This is consistent with the assertion that motivation is adversely affected when students feel overwhelmed by the mental effort necessary to learn [30], and that cognitive overload contributes towards high attrition rates in the first few weeks of online courses, especially for students undertaking them for the first time [31]. The same, although in a slightly different context, applies to the academic staff, where familiarity through repeated use of the same interface promotes confidence in its use.

In the early stages of the O_3 programme, the e-learning specialist and technical support team carry out the production of the materials within the rapid authoring software. By doing this, they are relieving the subject specialists of this added burden on their already full workload. It is, however, anticipated that over time, the subject specialists will develop the skills to do this, and will produce resources specifically for online delivery, rather than converting materials originally created for face-to-face delivery. The partnership process is facilitated by this software, through an online interface that allows the subject team to review the course materials in their 'new' format, and provide feedback; again, allowing them to retain control of their course and its associated materials.

As the transition discussions develop, methods and tools for online interaction are usually identified that the subject team are unfamiliar with, or have little or no experience in using; these are noted, and become the focus for staff development sessions. Professional development that teaches tutors the strategies of online teaching have been cited as beneficial in helping faculty members overcome difficulties encountered in adopting new teaching and learning strategies [32]. It has also been suggested that universities need to investigate how to better support faculty in acquiring the knowledge, skills, pedagogical strategies, and dispositions that are needed for building more effective, interactive, and multi-modal online learning communities [33]. Further, it is essential for the faculty to be able to deliver online as comfortably as they do in a face-to-face setting. Such comfort with the use of e-learning tools and methods will ensure effective execution of pedagogy for enhancing learning, ensuring the focus remains on the teaching role [34].

Researchers argue that online delivery increasingly demands a shift for tutors to take on roles such as mentors, coordinators, and facilitators of learning rather than conveyors of information [21, 35]. As such, the tutor provides students with experiences that challenge their higher-order cognitive skills **"***as opposed to simply transferring content to them***"** [21]. A change in roles, such as this, can be a challenge for many faculty members who typically rely on lectures to engage and instruct students [24].

To support this transition towards online learning, two e-learning driving licenses were created, one for faculty, the other for students. The student license is designed to act as both institutional induction, and as a tool to develop familiarization with the online systems that are being used. The staff license provides information on the pedagogy of online learning, and explores the many tools available to facilitate this. A self-assessment by the tutor also informs awareness of which staff development sessions may be required.

As indicated earlier, staff development activities were carried out primarily, but not exclusively, aimed at those methods that have been identified for use within the course, thus developing the tutors' knowledge and understanding of them prior to actual implementation. It is of note that these sessions are facilitated through the medium that they are developing, e.g. forums are used for staff development sessions on 'how to use forums'. Researchers agree that interaction increases learning satisfaction in online courses [18, 36, 37]. Zhao et al. [38] found that low tutor involvement resulted in less positive outcomes, and similarly courses where limited interaction with others takes place have been described as being less helpful than those courses that were more interactive and incorporated the use of multimedia [33]. One of the greatest challenges for online courses is to **"***provide a sense of community […] with feelings of friendship, cohesion, and satisfaction among learners***"** [24], because building a community of learners where students cooperate and learn together can become a **"***powerful motivator and a powerful mechanism***"** for extending learning [39]. For this reason, the staff development sessions particularly focus on helping the subject team to redefine their facilitation skills, to promote effective interactions with off-campus learners [40].

Significantly, the O_3 process also ensures that the new online mode of delivery has the same learning outcomes, as the previous face-to-face course, to ensure that it maintains the quality and standards that it previously did. The O_3 system has also been reviewed against recognized educational Standards for e-learning, which are clearly met, as indicated in Table 1.

TABLE I. O_3 PROCESS MAPPED AGAINST THE QAA 'CODE OF PRACTICE FOR THE ASSURANCE OF ACADEMIC QUALITY AND STANDARDS IN HIGHER EDUCATION: COLLABORATIVE PROVISION AND FLEXIBLE AND DISTRIBUTED LEARNING (INCLUDING E-LEARNING)' [41]

QAA code precepts		**O_3 compliance**
B1	'students need information ***before they start their programme*** of study to enable them to make appropriate preparations for an FDL approach' (p.58) 'study materials, whether delivered through…web-based or other distribution channels, meet ***specified expectations'*** (p.59)	✓ - Students complete an e-learning driving licence which is available through the institution's website ***before enrolment*** which introduces them to the online approach used in the O_3 system. ✓ - Staff developing online materials are ***supported to meet specified expectations*** by specialist academic and technical staff. Key to this is the supported use of a common format across all modules. Therefore students will NOT suffer an additional cognitive burden when navigating on-line provision.
B2	'FDL study materials are subject to the same ***rigour of quality assurance*** as the awarding institution would use for any of its programmes of study' (p.60)	✓ - This institution's validation process is ***more rigorous*** for online delivery than traditional programmes as it requires scrutiny of all course materials by an external assessor. In addition materials are scrutinized through O_3 ***pre-submission*** to this external assessment.
B3	'Prospective students whose only experience of learning is through directed teaching… may need some introductory support, possibly involving ***access to on-line learning environments prior to the start of the course'*** (p.61)	✓ - Students complete an e-learning driving licence which is available through the institution's website ***before enrolment*** which introduces them to the online approach used in the O_3 system.
B4/ B5	Learning support	✓ - These precepts outline requirements that are standard practice within the institution e.g. clarity of expectations about learner support; student experience feedback mechanisms
B6	'Staff who provide support to learners on FDL programmes ***have appropriate skills, and receive appropriate training and development'*** (p.64)	✓ - O_3 process diagnoses staff skill deficits through a staff e-learning driving licence, which leads to ***specific training programmes*** focused on the needs of their own course delivery. ✓ - The e-learning specialist provides the necessary pedagogical expertise and through the partnership process of exploring the course design, this is developed in the subject specialists
B7	Assessment	✓ - This precept outlines requirements that are standard institutional practice e.g. statements of criteria to be used in assessment; timeliness of formative and summative feedback

IV. Conclusion and Future Work

Combining the specific skill set of the e-learning specialists, with those of the subject specialists, facilitates a process that produces high quality, effective, pedagogically focused online courses. Transparent and realistic institutional support encourages faculty members to adopt online learning. This in turn will promote confidence in using new methods and tools, positively influencing the delivery approach.

Whilst currently implemented for health and social care courses, this model is not exclusive to these subjects. Grounding in the e-learning pedagogy is an important design feature of the O_3 process; initiatives such as this should be considered as exemplars in institutional capacity development initiatives.

Initial informal feedback from both tutors and students currently involved in courses being delivered within the O_3 system, is very positive; formal evaluation will be undertaken and published, once the courses have been completed.

Expressions of interest for collaborative development of the distance learning provision at other HE institutions have already been received, and others would be favourably considered.

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A Pathway to Inquiry-Based Teaching:

Digital Knowledge Transfer from Natural History Museums to School Classrooms

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Abstract— **The objective of the three-year European project (acronym: PATHWAY) with its 25 partner organizations is to set the pathway toward a standard-based approach to teaching science by inquiry. The project focuses on (i) supporting the adoption of inquiry teaching by demonstrating ways to reduce the constrains presented by teachers and school organizations, (ii) demonstrating and disseminating methods and exemplary cases of both effective introduction of inquiry to science classrooms and professional development programs, as well as (iii) delivering a guideline set for the educational community to further explore and exploit the unique benefits of the proposed approach in science teaching. In this way, the project team aims to facilitate the development of communities of practitioners of inquiry that will enable teachers to learn from each other. Out of about 50 selected Best Practice examples within the Pathway project, one specific approach labeled Natural Europe is linking museums and school classrooms, and thus harvesting the potential of digital libraries in natural history museums as a very attractive option. An impressive abundance of high quality digital contents still remains largely unexploited due to a number of barriers, such as: the lack of interconnection and interoperability, the lack of centralized access as well as the inefficiency of current content organization and the metadata used. First empirical evidence supports this pathway to bridge the gap between formal and informal education by specifically using the proposed digital bridge.**

Keywords-*E-leaning; inquiry-based learning; inquiry-based teaching; teaching practice; teacher education; professional development,; classroom teaching; informal learning.*

I. INTODUCTION: THE PATHWAY PROJECT DESIGN

Our study approach aims to contribute to a quality improvement of science teaching. Three main axes are supposed to facilitate the uptake of Inquiry-Based Science Education (IBSE): It a) proposes a standard-based approach to teaching science by inquiry that outlines instructional models that will help teachers to organize effectively their instruction, b) deploys a series of methods to motivate teachers to adopt inquiry based techniques and activities in their classrooms and c) offers access to a unique collection of open educational resources and teaching practices (linked with the science curricula) that have proven their efficiency and efficacy in promoting inquiry based education and that are expanding the limitations of classroom instruction. All stakeholders (teachers, teachers' trainers, curriculum developers, policy-makers) are supposed to examine their individual practices in the light of the best performing approaches that set the standards on what can be achieved and provide them with a unique tool to bring about improvements in their everyday practice [2]. A close collaboration with teachers may develop a set of support services which help teachers to implement the necessary changes, to develop the diagnostics and intervention skills necessary to best plan and then diffuse innovation in their own contexts. An effective training approach provides the starting point for equipping teachers with the competences they need to act successfully as change agents, developing a language/terminology necessary to describe the dynamics of change processes, and making them able to recognize different forms of resistance and addressing it in their own context.

Most discussions of teaching science by inquiry begin with the assumption that inquiry is a teaching strategy. Science teachers ask, "Should I use full or partial inquiries? Should the approach be guided by the teacher or left to the student?" Introducing a Standard-Based approach views the situation differently and may overcome this dilemma: Such a perspective begins with the educational outcomes and then identifies the best strategies to achieve the outcome. In developing examples, a clear understanding of the realities of standards, schools, science teachers, and students is needed. Science teachers must teach the basics of subjects. The science curriculum content for physical, chemical, life, earth and space sciences, provides teachers with an excellent set of fundamental understandings that could form their educational outcomes. After identifying the educational results, teachers must consider the effective teaching strategies and recognize that we have a considerable research base for the concepts that students hold about basic science. We also have some comprehension of the processes and strategies required to bring about conceptual change [1, 4, 8, 11-14]. The teaching strategies include a series of laboratory experiences that may help students to confront current concepts and reconstruct them so they align with basic scientific concepts and principles of the educational curricula. For teaching science by inquiry, a variety of educators have described methods compatible with such a standard-based approach to teaching science by inquiry (for instance, going back to [16]). By using individual

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investigations when learning about new issues, first opportunities may arise for students to develop abilities necessary to do scientific inquiry.

For teaching science concepts, a the use of technology may encourage to improve investigations and communications, the formulation and revision of scientific explanations and models by use of logic and evidence, and the communication and defense of a scientific argument. Another example is the use of the idea that reading authentic scientific texts is considered as inquiry by itself [15, 18-20], and especially those that are adapted to the students' cognitive abilities [6]. A second educational outcome, closely aligned with learning subjects, is developing competencies necessary to do scientific inquiry. Laboratories provide many opportunities to strengthen them as well as computer-based learning environments that simulate authentic scientific research (e.g., [9]). Science teachers could indeed base the activity on content, such as motions and forces, energy in the earth's system, or the molecular basis of heredity, but they could make several of the fundamental competencies the explicit outcomes of instruction. Over time, students would have ample opportunities to develop all of them. This approach to teaching science by inquiry overlaps and complements the science teacher's effort to cultivate an understanding of science concepts. The teacher structures the series of inquiry activities and provides varying levels of direct guidance. A further result also sharpens competencies necessary for scientific inquiry; but now students have opportunities to conduct a full inquiry, which they think of, design, complete, and report. They experience all of the fundamental abilities in a scientific inquiry appropriate to their stage of sophistication and current understanding of science. The science teacher's role is to guide and coach [24]. The classic examples of this range from the organization of a science fair or a science contest to guiding of a whole inquiry project performed by the students.

Finally, we come to the aspect of teaching science by inquiry that is most frequently overlooked, namely, developing understandings about scientific inquiry [1, 2]. On the face of it, this seems like an educational outcome that would be easy to accomplish once the science teacher has decided to instruct by means of an activity or laboratory and has gained an understanding of inquiry. Numerous ways are available of having students identify, compare, synthesize, and reflect on their various experiences founded in inquiry. Case studies from the history of science provide insights about the processes of scientific inquiry. Developing students' understanding of scientific inquiry is a long-term process. Questions of time, energy, reading difficulties, risks, expenses, and the burden of the subject should not be rationalizations for avoiding teaching science by inquiry. Nurturing the abilities of inquiry is consistent with other stated goals for science teaching, for example, critical thinking; and it complements other school subjects, among them problem solving in mathematics and design in technology. Understanding science as inquiry is a basic component of the history and nature of science itself.

II. OBJECTIVES: ESSENTIAL FEATURES OF INQUIRY

To begin shifting toward a more inquiry-oriented classroom, we highlight five essential features: (i) Learners engage in scientifically oriented questions. (ii) Learners give priority to evidence in responding to inquiry questions. (iii) Learners formulate explanations from evidence. (iv) Learners connect explanations to scientific knowledge. (v) Learners communicate and justify explanations.

(i) Learners Engage in Scientifically Oriented Questions

Scientifically oriented questions centre on objects in the natural world; they connect to the science concepts described in the school curriculum. They are questions that lend themselves to gathering and using data to develop individual explanations for scientific phenomena. Scientists recognize two primary kinds of scientific questions. Existence questions probe origins and include many "why" questions: Why do objects fall toward Earth? Why do humans have chambered hearts? Although many “why”-questions cannot be addressed by science, there are causal and functional questions, which probe mechanisms and include most of the "how"-questions: How does sunlight help plants grow? Students often ask “why”-questions. In the context of school science, many of these questions can be changed into “how” questions and thus lend themselves to scientific inquiry. Such change narrows and sharpens the inquiry and contributes to being scientific. In the classroom, a question robust and fruitful enough to drive an inquiry generates a need to stimulating additional questions of how and why a phenomenon occurs. The initial question may originate from the learner. The teacher plays a critical role in guiding the identification of questions. Fruitful inquiries evolve from questions that are meaningful and relevant to students, but they also must be answerable by student observations and the scientific know-ledge they obtain from reliable sources. The knowledge and procedures students use to answer the questions must be accessible and manageable, as well as appropriate to the students' developmental level.

(ii) Learners Give Priority to Evidence in Responding to Inquiry Questions

Science distinguishes itself from other ways of knowing through the use of empirical evidence as the basis for explanations about how the natural world works. Scientists concentrate on getting accurate data from observations of phenomena. They use their senses and instruments, such as microscopes, to enhance their senses; and instruments that measure characteristics that humans cannot sense, such as magnetic fields. In some instances, scientists can control conditions to obtain their evidence; in other instances, they cannot control the conditions since control would distort the phenomena, so they gather data over a wide range of naturally occur-ring conditions and over a long enough period of time so that they can infer what the influence of different factors might be. The accuracy of the evidence gathered is verified by checking measurements, repeating the observations, or gathering different kinds of data related to

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the same phenomena. The evidence is subject to questioning and further investigation. In their classroom inquiries, students use evidence to develop explanations for scientific phenomena. They observe plants and animals, or individually measurements of temperature, distance, and carefully record them.

(iii) Learners Formulate Explanations from Evidence

Although similar to the previous feature, this aspect of inquiry emphasizes the path from evidence to explanation, rather than the criteria for and characteristics of the evidence. Scientific explanations are based on reason. They provide causes for effects and establish relationships based on evidence and logical argument. They must be consistent with experimental and observational evidence about nature. They respect rules of evidence, are open to criticism, and require the use of various cognitive processes generally associated with science— for example, classification, analysis, inference, and prediction—and general processes such as critical reasoning and logic. So explanations go beyond current knowledge and propose new understanding. For science, this means building on the existing knowledge base. For students, this means building new ideas on their individual current understandings. In both cases, the proposed result is new knowledge. For example, students may use observational and other evidence to propose an explanation for the phases of the moon, for why plants die under certain conditions and thrive in others, and for the relationship of diet to health.

(iv) Learners Connect Explanations to Scientific Knowledge

Evaluation, and possible elimination or revision of explanations, is one feature that distinguishes scientific inquiry from other forms of inquiry and subsequent explanations. One can ask questions such as: "Does the evidence support the proposed explanation?", "Does the explanation adequately answer the questions?", "Are there any apparent biases or flaws in the reasoning connecting evidence and explanation?", and "Can other reasonable explanations be derived from the evidence?" Alternative explanations may be reviewed as students engage in dialogues, compare results, or check their results with those proposed by the teacher or instructional materials. An essential component of this characteristic is ensuring that students make the connection between their results and scientific knowledge appropriate in their level of development [21, 22]. That is, student explanations should ultimately be consistent with currently accepted scientific knowledge.

(v) Learners Communicate and Justify Explanations

Scientists communicate their explanations in such a way that their results can be reproduced. This requires clear articulation of the question, procedures, evidence, and proposed explanation and a review of alternative explanations. It supports a further skeptical review and the opportunity for other scientists to use the explanation to go on to new questions. Having students share their explanations provides others the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations. Sharing explanations can bring into question or fortify the connections students have made among the evidence, existing scientific knowledge, and their proposed explanations. As a result, students can resolve contradictions and solidify an empirically based argument.

III. RATIONALE & RESULTS: NATURAL EUROPE AS A SELECTED BEST PRACTICE

Numerous Best Practices gather under the Inquiry-Based umbrella, originating from school settings or from collaboration initiatives or from connecting the gap between formal and informal settings [3]. The latter is presented example in more detail. Hereby, engagements of hands-on physical activities with virtual educational ones are combined to support a student’s understanding. Main activities concentrate on designing stimulating lesson plans following an existing syllabus and adapting as many individual needs as possible. Those lesson plans are based on a museum visit (physically or virtually) and they are supposed to engage students’ hands-on activities leading to realistic experiences directly connected to a classroom-taught lesson.

For a selection of appropriate Best Practices (BP), a template is needed to allocate “success stories”. Thus, ten principles are labeled: (1.) BP should aim systematically to develop and sustain learners’ curiosity about the world, enjoyment of scientific activity and understanding of how natural phenomena can be explained. (2.) BP have to focus on all learners, both those who may later become scientists or technologists or take up occupations requiring some scientific knowledge and those who may not do so. (3.) BP must have multiple goals aiming to develop: (i) understanding of a set of big ideas in science which include ideas of science and ideas about science, (ii) scientific capabilities concerned with gathering and using evidence, (iii) scientific attitudes. (4.) The implementation of the BP should be a clear progression towards the goals of science education, indicating the ideas that need to be achieved at various points, based on careful analysis of concepts and on current research and understanding of how learning takes place. (5.) The themes of the BP should result from study of topics of interest to students and relevance in their lives. (6.) BP should reflect a view of scientific knowledge and scientific inquiry that is explicit and in line with current scientific and educational thinking. (7.) BP should deepen the individual understanding of scientific ideas as well as contributing to others, such as fostering attitudes and capabilities. (8.) The initial training and professional development of teachers should be consistent with the teaching and learning methods required to achieve the goals set out in Principle 3. (9.) Assessment needs to provide an integral part of the BP. The formative assessment of students’ learning and the summative assessment of their progress must apply to all goals. (10.) Finally, BP may promote cooperation among teachers and engagement within a community which even may include the involvement of scientists which otherwise would be out of reach for the group such as school students.

The proposed aims are threefold: Firstly, it's the increase of student involvement into the educational process as their role is regarded as most significant. Teachers just act as facilitators while students see their activities follow their individual educational needs. Secondly, it's the connection of formal and informal learning in real-world and digital environments); this approach allows students to enjoy an educational experience tailored to individual needs, preferences and expectations, again under the guidance of the teacher. Thirdly, it's providing fascinating opportunities for interaction with natural history (for both, physically and digitally). Since museums exhibits just because of its originality, authenticity grabs a student's interest and curiosity, the door to a self-sufficient learning more easily opens up [5]. Digital and physical museum objects, thus, enhance interests towards natural science [7, 8].

First empirical data interestingly point to a cautious optimism: Although the numbers of up to now involved participants just allow first conclusions merely on a case study level, however, 27 participants significantly learned by following the above described procedures (while 11 control participants did not). These first empirical numbers just begin to support our expectations compared to the already existing solutions but cannot yet substantiate a final prove. After completing our data collection (which is expected with both projects' ending after 2013 and which surely will easily outnumber case study levels), deeper conclusions will be drawn from an expectedly much broader data basis of so many partner institutions contributing.

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Social Computing Solutions for Collaborative Learning and Knowledge Building Activities in Extended Organization

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***Abstract*—The research presented aims to support Learning and Knowledge Building (LKB) activities of adult learners that act under specific contexts within Extended Organizations. Under Extended Organization is understood a community that emerges as a temporal integration of two or more different business, educational communities and organizational cultures (industrial, research and educational) and leverages ICT technologies to support LKB activities. The objective of the research is to explore supportive social computing based technologies for (cross-)organizational collaborative LKB activities. The technological developments are embedded in a pedagogical framework that puts a special focus on the harmonization of individual and organizational objectives. The proposed extended organizational concept and SW services developed to support such concept were investigated within two different cross-organizations: one including a large industrial company and a research institute and a university and the second one including a small industrial company and a department of a university. The results of testing and evaluation are presented and key lessons learned are discussed.**

Keywords-collaborative learning; social computing; cross-organsiational learning; organizational learning; ontologies; semantic wikis

I. INTRODUCTION

An organization aiming to be an intelligent learning organization faces a key problem of how to motivate the employees for continuous learning and knowledge building (LKB) activities to engage them in an active innovation process. The research approach presented in this paper is based on a new and developing paradigm of Extended Organization (EO). The model proposed emphasizes two types of creative cross-over conditions for LKB – vertical and horizontal within a single organization a, and horizontal between different organizations [2]. This represents the paradigm of an Intelligent Learning Extended Organization (IntelLEO) which constitutes a temporal alliance among different organizations (industrial, research, educational etc.) in order to share resources, skills and costs in supporting LKB activities [3]. The responsiveness of a learning environment within such a complex learning organization is crucial and can be strengthened by different means, e.g. by: better supporting collaborative learning with an extended offer of learning content, assuring better harmonization of the individuals' (members of the organization) and the organizational LKB objectives, providing more personalized learning paths directed to the organization strategic objectives, effectively combining learning and knowledge management approaches and systems within the organizations, etc. While each of these means has been subject of intensive research, their combination and synergy has not been sufficiently investigated.

In order to effectively support both collaborative LKB and harmonization of individual and organizational objectives within dynamic, flexible (often geographically distributed and international) IntelLEOs, efficient technology for management (i.e. access, delivery) of content within such an IntelLEO is 'conditio sine qua non'. The research presented aims to investigate how such a technology may bring added-value regarding overall responsiveness of the LKB environments in an IntelLEO. This concept of IntelLEO requires technologies to support sharing, harmonization, building, and extension of knowledge among individuals, industries and universities, and effective combination of content and organizational knowledge systems (at both universities and industries).

The paper is organized as follows: Section 2 provides a brief overview of the state-of-the-art of the technology relevant for a support of the LKB activities within EOs. Section 3 explains the basic concept, while Section 3 provides a brief description of the implemented social computing services. Section 5 is dedicated to the testing of the concept and technology within two real EOs, where lessons learned are discussed as well. Section 6 includes conclusions and indications of the future research activities.

II. OVREVIEW OF THE RELEVANT STATE-OF-THE-ART

As explained above, the proposed concept of an IntelLEO requires technology aiming to motivate employees to actively take part in collaborative LKB activities. Several topics are identified as being of key relevance for such technological support [3].

Extensive research and technology development has been performed in last decade to support the collaborative work of learners which may be applied also for an EO. However, since cross-organizational collaborative LKB activities are much more complex than collaborative work within single departments/organizations, more powerful technological support is needed. Current solutions are not context-sensitive and related to explicit models and ontological frameworks allowing for e.g. context sensitive recommendations of people appropriate for collaborative LKB within an EO etc.

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Another relevant area is Monitoring of Human-Computer Interaction (HCI) to derive possible meaning and relevance of information to the learner. Although such monitoring services have been subject of several research initiatives (not only within technology enhanced learning domain) the solutions to effectively extend contextual data user profiles through monitoring of active & passive interactions with explicitly & implicitly interacted data to build/deduce a possible relevance & meaning of data to user, and thus improve performance of other services are not available to support LKB activities within an EO.

Ontologies for formal representation of knowledge objects, learning activities and resources are available, but they are not well integrated to support LKB within an EO. There is no widely accepted model for representing competencies. The complexity of the existing models makes them difficult to apply in real world settings.

A relevant area for the presented research is also services to support definition of organizational policies for LKB activities. Existing organizational policy tools are typically focused on only one of the aspects such as organizational structure, access control policies, and intra-organization competency management and do not provide support for LKB activities within an EO.

ePortfolio software (e.g. Elgg) provides learners with a Personal Learning Environment (PLE) and social networking tools to focus on their individual learning and participate in collaborative LKB activities. Current approaches assume that the learning process happens in one system only, which does not correspond to the nature of workplace learning and does not respond to the needs for integration of informal and formal learning. There is no support for personal learning planning which stimulates harmonization with organizational competencies, and allows for managing and sharing learning activities/experience happening in different systems. The existing research considers a competency gap-analysis approach; however, it relies on a list of available defined competences and does not act as a learning organization in this regard. Competences are tied a specific context-of-use within one organization. In existing solutions, learning paths are static and cannot be adapted based on the dynamics of users' context and/or learning objectives [3].

Social software tools, Semantic Wikis (e.g., Semantic MediaWiki) enable seamless semantic annotation for 'regular' users [5]. However, knowledge that these tools capture is typically unstructured and encoded in proprietary formats, not allowing effective sharing of learning and knowledge objects within an EO.

III. Motivation

As explained above, the aim of this research is to elaborate and provide technology to support the new paradigm of IntelLEO (Fig. 1). An IntelLEO leverages intelligent technologies to support LKB activities of a community that emerges as a temporal integration of two or more different business and educational communities and organizational cultures. Various technical solutions to support university/industry collaboration, as required within an IntelLEO, are developed. However, the key problems of how to motivate learners at both 'sites' to share learning objects and knowledge resources are still not solved, especially taking into account complex issues of different learning contexts, organizational objectives and IPR issues. Portfolio software that can be used both in industry and in higher education is of a key importance. An IntelLEO model emphasizes that the creativeness of organizations, and motivation of individuals to contribute into organizational knowledge and proactively learn, depends on the possibilities of creating and sharing tacit knowledge across various boundaries, externalizing such knowledge and grounding it in collaborative groups, and reusing it for organizational and individual growth. Shared organizational vision and rules among individuals guarantee the directed development and enable to keep organizational identity. The continuous harmonization of organizational and individual rules, values and objectives is the prerequisite to simultaneous co-building of organizational knowledge and keeping the individual motivation to proactively learn. Theoretical models of IntelLEOs, the activities and processes in these, and the means of achieving responsiveness are still in the phase of intensive development and investigation. By investigating the assumed increase of IntelLEOs' responsiveness by providing appropriate ICT services, the research actually explores how technology creates conditions for effective IntelLEOs.

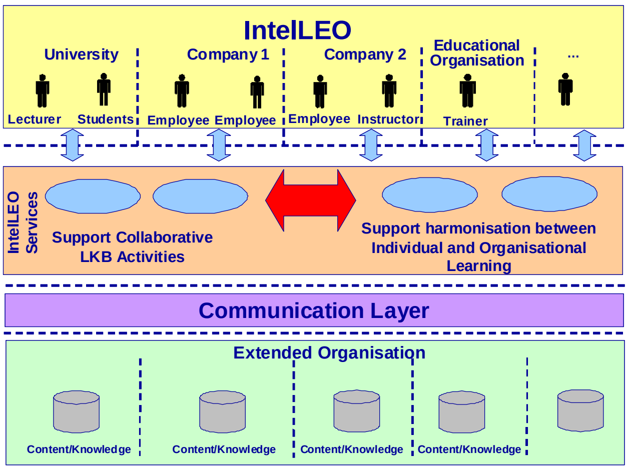

Figure 1 IntelLEO concept [3]

IV. Proposed Concept

The presented research aims to enhance cross-organizational LKB practices at the workplace, where under LKB practices are understood activities that involve the Knowledge building process (the individual and social constructive process of creating new cognitive artifacts, which result in the formation of various forms of Knowledge) as well as Learning activities. It aims at increasing motivation towards LKB in organizations, externalization of tacit knowledge individually for personal development, participation in collaboration and knowledge combining practices in EO, and frequent harmonization of individual- and organizational objectives when planning, conducting and reflecting about work practices.

To support such EO concept the following methodological and technological means are developed:

• A new Implementation Framework on how to use technology to motivate employees to take part in collaborative LKB activities in an EO, taking into account the best social constructivist and situated learning practices in collaborative LKB,

• Ontological framework for LKB context representation,

• Generic and widely applicable so-called core services, fitting SOA principles, for managing collaborative LKB activities and contents in an IntelLEO.

The proposed ICT environment (Fig. 2) [6] consists of several layers,focused around the Core Services (CS) and the Ontology Framework. The different layers are the following:

• The layer 'Knowledge Resources' represents the resources and communication layer in an EO. It serves as resource basis for e.g. Process Knowledge, Portfolios, etc.

• The CS layer consists of several services: Organizational Policy (OP), Learning Planner (LP), Content Knowledge Provision (CKP), Human Resources Discovery (HRD), Working Group Composition (WGC), User Monitoring & Collaborative Traceability (UMCT).

• The Orchestration layer serves as the service integration environment. It combines the CS within Application-specific Services needed by the different collaborating organizations and users. Specifically, this layer links the CS and application specific SW solutions used within an EO to ensure Application-specific services which support the users in LKB activities. It is to distinguish that CS comprise the generic set of services, while Application-specific Services comprise services for the organizations in an EO (e.g. services to support new-comers in an EO).

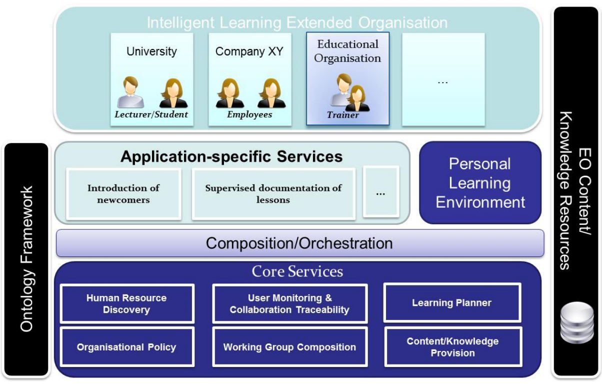

Figure 2 – Proposed ICT environment [6]

The Ontology Framework spans over the whole environment and serves as a model foundation and common base structure for specific knowledge. The IntelLEO ontology set consists of eight ontologies: Learning Context, Activities, User Model, Workflow, Competences, Organization Structure, Annotations, Competence Management ontology.

To guide the cross-organizational LKB within an EO, models that integrate self-regulated learning (reflecting, setting/monitoring learning goals) with collaborative knowledge sharing activities is investigated. The innovative approach is to use the so-called SECI-Model [7] as pedagogical framework - Socialization (implicit to implicit knowledge), Externalization (implicit to explicit knowledge), Combination (explicit to explicit knowledge) and Internalizations (explicit to implicit knowledge). Although SECI model is initially the model for organizational knowledge management, enabling knowledge conversion in organizations, this model has been effectively used for organizing learning at workplaces. Therefore, approach applied to the creation of the concept is that all segments of the solution focus around the SECI model. While intuitively attractive, there has been limited empirical investigation of the SECI model in practice, with this being especially true within the context of multi-organizational projects [8].

V. IMPLEMENTATION

The solution has been implemented as a generic system thanks to the ontology framework [9], making it easy to adapt it for different organizations and contexts. For this, different knowledge base could be produced to adapt the system usability in a specific context. Specific tools can be connected to the CS to respond to the specific organizations' needs, e.g. Semantic MediaWiki and Elgg can be used as a collaborative tools and PLE. Then, the solution can be deployed in different contexts.

Organization Policy CS is used to specify the context and priorities at the organizational level. OP CS is consisting of five functional modules. One of the aims is harmonization of individual learning goals of employees with the goals of organization. OP is a tool that is meant to be used by managers of organization, in order to define and promote contextual settings, policies and priorities of the organization. These settings, policies and priorities will then be utilized by other CS [8].

The Learning Planner (LP) CS allows users to have ubiquitous access to their personal learning spaces. Through this service, users can manage and attain their learning goals harmonized with those of their organization, by receiving support from the social context of their EO, and also contributing back to it through sharing their learning experiences. Managing Learning Goals functionality supports users in planning and managing their personal learning goals, choosing/creating the competences to be acquired and building learning paths to acquire each specific competence. It also helps users to harmonize their learning goals with organizational objectives. Contrary to other competence-based approaches, here users are not limited to choose their learning goals from only a set of predefined goals provided by their organization; they can create new competences which they desire to achieve or browse the list of available competences within their EO and choose the ones that they find relevant to their goals [9].

Based on the contextual data about a user's tasks, learning goals, competences and other relevant information, this functionality recommends learning paths for achieving a certain target competence to the user. A LP is comprised of a sequence of LKB activities along with descriptions (metadata) of assets required for performing those activities.

Analytics functionality is responsible for processing and analyzing the data about users' learning activities and their interaction with diverse kinds of learning resources (e.g., learning goals, target competences, activities and knowledge assets). It makes use of the interaction data stored in the RDF repository to provide users with feedback, primarily through different kinds of visualizations, to support them in planning and monitoring their learning process. Browsing the Analytics of a certain available competence, updates the managers of an organization on how frequently this competence has been used within the organization, in the context of which learning goals, by users of what organizational positions, and what the main issues regarding this competence are. This allows managers to apply any necessary modifications in the definition of the competence itself or learning paths associated with it. Social Wave receives information about the events occurring in the LP and other connected tools, e.g. MediaWiki, and updates the social (activity) stream of users who might be interested in those events. Semantic annotation and indexing of learning resources provides two types of annotations: manual and automatic. Semantic Search aims at enabling effective retrieval and reuse of stored learning resources, i.e. learning goals of other users, competences, LPs, learning activities or knowledge assets [10].

Content/Knowledge Provision (CKP) service aims at locating and retrieving appropriate learning and knowledge objects and making them accessible either to members of an EO or to other services, taking into account the specifics of the user's learning context. CKP offers the web browser-based user interface. It provides three major functionalities: (a) bookmark/upload knowledge objects into a designated repository, (b) manage uploaded knowledge objects, c) perform semantic search of knowledge objects repository.

Human Resource Discovery and Working Group Composition CS offer several functionalities related to context sensitive finding human resources and establishing temporal working groups with them. These CS offer search for persons, working groups or organizations, based on several criteria. CS provides contextual recommendation of people. CS can select relevant person for collaborative LKB, where the recommendations are based on algorithms computing the similarities between different kinds of resources.

The User Monitoring and Collaboration Traceability (UMCT) service implements functionality to monitor user interaction, in particular over MediaWiki. The UMCT service works in the background of the legacy system, in this case MediaWiki (or Elgg), and does the monitoring of a specific set of interactions that the user has with the MediaWiki in question. These interactions include: open a page, create a page, edit a page, upload a document, bookmark a page, delete a page or performing a search. This set of interactions may be extended and may vary according to the system being monitored and the use of the monitored data. The information is collected by an extension installed on the MediaWiki side and passed to the UMCT web service where the activities performed by the user are then saved in the ontologies repository. The main objective of these services is to extend user profiles through the monitoring of active and passive interactions with explicitly and implicitly interacted data to build and deduce a possible relevance and meaning of data to a user, and improve performance of other core services by making the monitored information available to these services. The functionality that monitors the main activities records certain events occurring during the use of other services, such as the creation of a learning goal, addition of a competence to a learning path or the creation of a learning group by a certain user. The monitored data may be visualized in different ways: in the social wave panel in the LP or in the end-user environments, MediaWiki. This functionality has as a main objective to build and deduce a possible relevance and meaning of data to a user. It is possible for the user to define in a fine-grained way what information the service is allowed to collect.

The integration of all developed services was included in the conception and implementation of the services and Ontology Framework by basing the ICT concept on service-oriented architecture principles. This principle was applied by implementing a set of CS, as explained above. At the same time – adhering to SOA's principle of loose coupling – the ICT concept allows for integrating/orchestrating one or more of CS – and optionally external systems from the existing learning environment – into Application Specific Services that provide the combined functionalities to implement a specific use case. This integration/orchestration is facilitated through the well-defined interfaces, which allow each service (as well as external tools) to synchronously invoke another service's functionality – in some cases extended to the according user interfaces – e.g. a user requests forming a learning group for a particular competence in LP, which causes the corresponding user interface of WGC Service to open. This synchronous integration between services was complemented by an extensive event model allowing services and external systems to asynchronously notify each other of pre-defined events. This event system was especially used when integrating the services with existing tools of the learning environment – MediaWiki, e.g. (a) When a user starts acquiring a competence in the LP this competence is automatically added to the user's profile page in MediaWiki, including information about how far the user has progressed in acquiring the competence, (b) Creation of a working group triggers the creation of a corresponding page in MediaWiki, which contains links to the profile page of each user. All services work on a central shared data repository, modeled through the Ontology Framework. Universal and transparent access to this shared data repository is realized through the services of the Ontology Framework.

VI. EXPERIMENTAL VALIDATION

As the research was following a participatory design based research approach an active involvement of all actors and especially the future core users is being pursued. Based on this approach, the user requirements and scenarios for use of the developed services within specific EOs were defined

[11, 12]. The users were involved in intensive testing and evaluation of the results. All test-participants were provided with the same set of IntelLEO services during the test-period, while the scenarios for the usage of these services were adapted to the specific needs and requirements of each EO. All test participants were provided with the same set of quantitative (pre- and post-evaluation questionnaires) and qualitative (focus-groups, expert interviews) evaluation instruments to collect their feedback.

The first case is settled within the big multinational corporate in the automotive sector. The specific instances are located within the product development department. External research cooperation and education/training partners such as a RTD institute and University were involved in the cross-organizational activities. The main challenge in this case is related to the issue of motivating employees to document and share their experience within and across the departments and organizations. In addition, time to competence is of high importance for the company, especially in the case of the involved department, where there is no specific formal educational program for obtaining the specific knowledge, skills and competences needed in this department. One of the main requirements is the integration of any solution with MediaWiki and Semantic Wiki, which is used for LKB.

The second case is involving an SME providing IT services especially for the e-Engineering and e-Manufacturing sector, and its collaboration partner, a University department dealing with software engineering. The cross-organizational activities in this case are focusing on the specific innovation-driven demands of the SME and the relevant scientific expertise at the University department. Current cooperation activities between the two organizations have been carried out in a rather non-transparent one-to-one exchange between staff members. With a more transparent approach, supported by ICT, to knowledge exchange and collaboration the individual as well as the organizational benefits shall be considerably increased.

The objective of this evaluation was to test and validate the prototype of services and implementation framework, collect feedback concerning the usability and usefulness of the services and to test how these services increase the individual motivation for LKB activities, a pre-requisite of organizational responsiveness. Both quantitative (and qualitative evaluation has been carried out. The analysis comprises detailed comparison of the results of evaluation in the two different cases. Due to the lack of space, here the conclusions made based on these evaluations are briefly presented. More detailed results can be found in [6, 8].

Based on the thorough testing of the services a number of improvements in the services were proposed by the users. The required improvements have been carefully analyzed, lessons learned regarding the developed services have been identified and the actions to improve the services to assure effective use of the services in the future have been carried out. A number of useful conclusions regarding pedagogical aspects have been identified as well.

The results show the importance of collaboration services for an increased motivation for learning and knowledge building (LKB) activities. The participants who got involved in collaboration activities often were amongst the most motivated for LKB and showed also the highest self-efficacy. This result was confirmed by the correlation analysis of data on learning and knowledge sharing attitudes, which highlighted the relationship between collaboration and the motivation to learn, the willingness to share knowledge and also the self-efficacy for LKB. A strong positive correlation between the motivation to learn and self-efficacy for LKB is found, meaning that the more self-confident a person is with respect to LKB the more motivated s/he is to actually learn. Thus the studies confirm outcomes from existing studies on self-efficacy & learning motivation [12].

The acceptance of the developed services in real-life environments depends very much on the organizational context of the test participants. Participants from the large company coming from a very competitive work-environment are not used to work with prototypes. Thus, feedback is more critical than the feedback from the second case. The willingness for the further usage of the services for promoting LKB after the testing period in the EOs appeared to be influenced by the initial organizational LKB culture differences. The high motivation to learn, as well as to share knowledge with partner organizations in the second case, remained high. On the other hand, despite the fact that participants in the first case have a high individual motivation to learn from other organizations, this motivation was extenuated by organizational barriers in form of existing policies that impeded e.g. sharing of knowledge.

The evaluation of the services revealed several interesting and useful insights concerning the most important drivers and barriers for cross-organizational learning. Cross-organizational learning in such a continuous and structured way, as it is supported by the services, was seen as an important benefit from managers and employees in research institutions, while users involved in the industrial organizations reflected critically on this approach. The main potential barriers to apply this approach were the privacy regulations of large companies, which constrain the transparent use of individual competencies across department and organizational borders. The fear to lose intellectual property and knowledge-able workers through an increased transparency and cross-organizational learning cooperation were mentioned as relevant obstacles [12].

The participants identified several benefits of the developed services for workplace learning: The requirement to structure and document one's work-relevant knowledge and learning processes has been highlighted. The important requirement was that the services should support learners to stay on the learning track. Therefore, the Social Wave was one of the most important features. This functionality helps learners to quickly be informed about the latest activities involved, the most urgent learning goals, new resources, and latest resources book-marked/stored to the system for a later enhancement. The challenge for learners is to know which of the huge amount of available learning resources are relevant at a specific time point to continue one's learning process towards successful achievement. From an organizational point of view one of the main contributions was the process of documenting the competency needs of the involved

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organizations. The services are perceived as especially useful for newcomers, as they replace a "mentor" [6].

VII. Conclusion

The proposed approach, including the pedagogical framework and developed services, offers a novel perspective on supporting LKB in organizational settings: it brings together elements originating from and necessitated by the social, organizational and informal context of organizational learning, along with motivational and self-regulatory aspects that aim for the individual learning of knowledge workers. The services were designed to not only support and promote organizational learning in terms of all the aspects set forth by the pedagogical framework, but also to integrate the various tools and services that employees often interact with during their everyday practices. To address this challenge, the tools relied on a network of ontologies as their common (linked) data model. These ontologies provided a basis for all the functionalities of the tools, as well as a ground for data linking and exchange among the tools integrated. The network of ontologies, in particular, facilitates formal representation and seamless integration of data about individuals' learning experiences (i.e. learning activities and their context), the knowledge being shared, as well as different kinds of annotations that capture either individual or collective reflections on the shared content/knowledge. Moreover, in the last few years the affordances offered by the Social Web, i.e. Web 2.0, paradigm have affected the existing learning pedagogies, bringing forth the concept of Social Learning, mostly in formal educational settings [5, 13]. The evaluation of the developed services (and accordingly the pedagogical framework) reconfirmed the role and importance of social learning in informal organizational learning.

It may be concluded that the main innovation is the approach to align (cross-) organizational LKB policies with personal user-centered goals, applying social computing approach. Although the research addressed a wide spectrum of RTD topics relevant for collaborative LKB activities within an EO, many aspects are open for further research. Attention in future RTD work will be given to e.g. quality of TEL services for collaborative LKB activities in EOs, privacy and security issues, further aspects relevant for context modeling, etc. Especially privacy issue from technical point of view will be addressed in detail (e.g. as the Ontology Framework is defined in the OWL language, it has to be investigated how such a formal nature of ontologies can be leveraged to reason over the various security/privacy policies within EO, etc.). The implemented services and the Implementation Framework support further use of the proposed concept and services. Since the services are developed to suit very distinct EOs, it can be assumed that the Framework is applicable in various organizational settings, not only in EOs but also in complex single organizations (e.g. large manufacturing companies for collaborative LKB activities among departments/ subsidiaries) or smaller organizations (where appropriate selection of the services and aspects relevant for an SME could be made).

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Imputation of Missing Values for Unsupervised Data Using the Proximity in Random Forests

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***Abstract*—This paper presents a new procedure that imputes missing values by random forests for unsupervised data. We found that it works pretty well compared with k-nearest neighbor (kNN) and rough imputations replacing the median of the variables. Moreover, this procedure can be expanded to semi-supervised data sets. The rate of the correct classification is higher than that of other conventional methods. The imputation by random forests for unsupervised or semi-supervised cases was not implemented.**

***Keywords*-Ensemble learning; k-nearest neighbor; R; rfImpute; impute.knn.**

I. INTRODUCTION

A method of random forests [1] is a substantial modification of bagging techniques that builds a large collection of de-correlated trees and then averages them. Therefore, it is mainly used as an accurate classifier or regression tree. The latest Fortran77 code programmed by Breiman [2] is Version 5.1, dated June 15, 2004. Since Version 4 contains modifications and major additions to Version 3.3, replacement of missing predictor values has been enabled [3]. Breiman offers two options. One is the "missquick" (Ver. 4), which replaces all missing values by the median of the non-missing values in their column, if real, and by the most numerous value in their column if categorical. Another is "missright" (Ver. 5). This option starts with "missquick" but then iterates by using proximities and does an effective replacement even with a large amount of missing data. Missing values are presented by a proximity weighted sum over the non-missing values.

On the basis of these ideas, Andy Liaw implemented their varieties in statistical environment R [4], calling them "na.roughfix" and "rfImpute" [5]. The advantage is that these R functions work for both regression and classification, but unfortunately cannot be applied for unsupervised (unlabeled) cases as a training data set [6]. Only predictive variables in supervised learning are allowed missing.

However, Breiman's ideas could be extended to unsupervised data if we could obtain the proximity of the unsupervised data. The new proximities can be obtained by starting the rough imputation for missing data ("na.roughfix") and repeating to run random forests. The artificial occurences of response variable are given by the method described later (Section 2). In the case of supervised data, Breiman [3] found that an estimate error of a bootstrap train sample (called "out-of-bag", or oob) tends to be optimistic when run on a data matrix with imputed values.

Related works are follows: Pantanowitz and Marwala [7] evaluated the impact of missing data imputation by using human immunodeficiency virus (HIV) seroprevalence data. Rieger et al. [8] provided an implementation of random forests with missing vales in the covariates. Nicholas [9] extended the random forest to handle multi-response variables, and presented another imputation method called "yaImpute." But all the methods described above are not allowed for unsupervised or semi-supervised data.

In this paper, we present a new procedure for proper missing values imputation, which can avoid the overfitting of the estimated model for unsupervised data. In Section 2, we summarize the elements of a technique that imputes the missing values for unsupervised data. In Section 3, we show a new procedure for imputing the missing values. In Section 4, two examples, iris and spam data sets, are illustrated. We assume these data to be unsupervised by dropping the response variables; nevertheless, both are supervised. Section 5 shows the expansion of our method to semi-supervised data sets. Section 6 is the summary.

II. RFIMPUTE

A. Proximity measure

Breiman [3] defines the data proximity as follows: The (i, j) element of the proximity matrix produced by a random forest is the fraction of trees in which elements i and j fall in the same terminal node. The intuition is that "similar" observations should be in the same terminal nodes more often than dissimilar ones. The proximity matrix can be used to identify structures in the data, and for unsupervised learning with random forests.

B. An unsupervised learning example [10]

Because random forests are collections of classification or regression trees, it is not immediately apparent how they can be used for unsupervised learning. The "trick" is to call

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the data "class 1" and construct "class 2" synthetic data, and then try to classify the combined data with a random forest. There are two ways to simulate the "class 2" data:

1) The "class 2" data are sampled from the product of the marginal distributions of the variables (by an independent bootstrap of each variable separately).
2) The "class 2" data are sampled uniformly from a hypercube containing the data (by sampling uniformly within the range of the variables).

The idea is that real data points that are similar to one another will frequently end up in the same terminal node of a tree — exactly what is measured by the proximity matrix. Thus, the proximity matrix can be taken as a similarity measure, and clustering or multidimensional scaling that uses this similarity can be used to divide the original data points into groups for visual exploration.

C. R procedure

Missing values are indicated by NAs in R [4]. A function returning a result of random forests is "randomForest" developed by Liaw [5]. The algorithm starts by imputing NAs by using "na.roughfix." Then, "randomForest" is called with the completed data. The proximity matrix from the "randomForest" is used to update the imputation of the NAs. For continuous predictors, the imputed value is the weighted average of the non-missing observations, where the weights are the proximities. For categorical predictors, the imputed value is the category with the largest average proximity. This process is iterated a few times.

A function returning the imputed values by random forests is "rfImpute," coded by Liaw [6]. We should note that Liaw's imputation is only available to supervised data without any missing response values.

III. New Procedure to Impute the Missing Data

A. Missing value replacement on the training set

Our procedure as well as Liaw's "rfImpute," has two ways of replacing missing values. The first way is fast. If the mth variable is not categorical, the method computes the median of all values of this variable in class j, then it uses this value to replace all missing values of the mth variable in class j. If the mth variable is categorical, the replacement is the most frequent non-missing value in class j. These missing values are replaced or filled by "na.roughfix."

The second way for replacing missing values is computationally more expensive but performs better than the first, even with large amounts of missing data. It begins by doing a rough and inaccurate filling in of the missing values. Our key technique is to estimate the missing values on the basis of not all non-missing proximities but k-nearest proximities, which include missing data. Then, it runs a forest procedure and computes proximities.

If $x(n, m)$ is a missing continuous value, we estimate its fill as an average over the k-nearest neighbor values of the mth variables weighted by the proximities between the nth case and the other case. If it is a missing categorical variable, we replace it by the most frequent non-missing value where frequency is weighted by proximity.

In summary, we use, in case of a missing continuous value,

$$\widehat{x}(n,m) = \frac{\sum\limits_{\substack{i \neq n \\ i \in \text{neighbor}}} \text{prox}(i,n)x(i,m)}{\sum\limits_{\substack{i \neq n \\ i \in \text{neighbor}}} \text{prox}(i,n)}, \tag{1}$$

instead of rfImpute's

$$\widehat{x}(n,m) = \frac{\sum\limits_{\substack{i \neq n \\ i \in \text{non-missing}}} \text{prox}(i,n)x(i,m)}{\sum\limits_{\substack{i \neq n \\ i \in \text{non-missing}}} \text{prox}(i,n)},$$

where $\text{prox}(\cdot,\cdot)$ is the proximity.

In case of a missing categorical variable, we use

$$\widehat{x}(n,m) = \underset{C_m}{\text{argmax}} \sum_{i \neq n} \text{prox}(i,n), \tag{2}$$

instead of

$$\widehat{x}(n,m) = \underset{C_m}{\text{argmax}} \sum_{\substack{i \neq n \\ i \in \text{non-missing}}} \text{prox}(i,n),$$

where C_m means the mth categorical variables.

Now, iterate-construct a forest again by using these newly filled in values, find new fills, and iterate again. Our experience is that 4–6 iterations are enough.

The reason we use only k-nearest neighbor data in (1) is that the missing imputation of this method would be robust. Even if proximities to the target are rather small, the other continuous values may be outlying. In this case, some outliers will affect the estimate of the target toward ill direction. Our numerical investigation shows that our procedure, the mixture of kNN and random forests, is better than using only random forests. This technique leads the estimates to avoid overfitting of the random forest model.

In (2), however, all data besides k-nearest neighbor data are treated. Because majority votes were adopted, outlying values of x would be unregarded. While, we should regard the proximity associated with missing data, especially when the missing rate is high.

B. Missing value replacement on the test set

When there is a test set, there are two different methods for replacement depending on whether labels exist for the test set.

If they do, then the fills derived from the training set are used as replacements. If labels do not exist, then each case in the test set is replicated "number of classes" times. The first replicate of a case is assumed to be class 1 and the class 1 fills used to replace missing values. The second replicate is assumed class 2 and the class 2 fills used on it.

This augmented test set is run down the tree. In each set of replicates, the one receiving the most votes determines the class of the original case.

C. Algorithm

The procedures are summarized as follows.

1) Impute NAs by using “na.roughfix.”
2) Repeat following steps for “iter” times. Compute the proximities between all cases by using “randomForest.” Then, impute the missing values. If the imputed values are converged, break the loop.
3) Output the data that include estimated (imputed) data.

The procedure will stop when either of the following conditions is satisfied.

1) The number of iterations reaches pre-determined reputation times; the default is 5.
2) The relative differences between the imputed missing values are sufficiently small, less than 1.0e-5.

The R program used in this paper should be referred to Appendix (Fig. 6). Fairly detailed comments are included in the program. The format is in accordance with the tradition of unix or R codings.

IV. Numerical Examples

A. E-mail database indicating spam or non-spam

We use a spam data set [11] collected at Hewlett-Packard Labs, which classifies 4601 e-mails as spam or non-spam. In addition to this class label, there are 57 variables indicating the frequency of certain words and characters in the e-mail. That is, a data frame with 4601 observations and 58 variables. The first 48 variables contain the frequency of the variable name (e.g., business) in the e-mail. If the variable name starts with num (e.g., num650), it indicates the frequency of the corresponding number (e.g., 650). Variables 49–54 indicate the frequency of the characters “;”, “(”, “[”, “!”,“$”, and “#”. Variables 55–57 contain the average, longest, and total run-length of capital letters. Variable 58 indicates the type of the mail and is either “nonspam” or “spam,” i.e. unsolicited commercial e-mail.

The data set contains 2788 e-mails classified as “nonspam” and 1813 classified as “spam.” The “spam” concept is diverse: advertisements for products/web sites, make money fast schemes, chain letters, pornography, and so on. This collection of spam e-mails came from the collectors’ postmaster and individuals who had filed spam. The collection of non-spam e-mails came from filed work and personal e-mails, and hence, the word “george” and the area code “650” are indicators of non-spam. We would have to blind spam/non-spam indicator, because we are focusing unsupervised data in this numerical experiment.

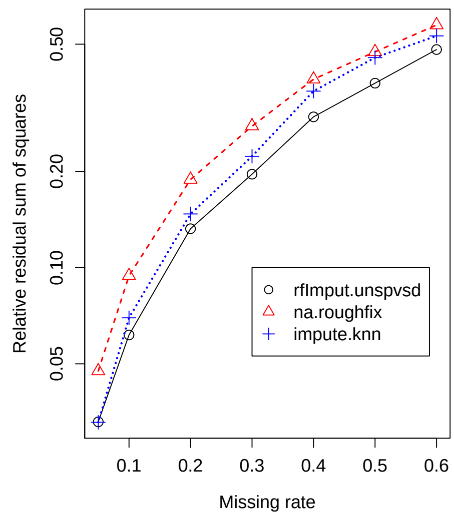

Figure 1. Relative residual sum of squares for unsupervised spam/non-spam data

To illustrate the performance of our method, we compare it with two conventional methods: “na.roughfix” and “impute.knn.” The former is used as the baseline of our method. The latter is a typical kNN method [12] stored at biocLite library in R. We set k as the number of neighbors to be 10, the default value of this library. We name our method “rfImput.unspvsd”, which means “an imputation method by using random forests for an unsupervised data set.”

Missing data for 57 variables are randomly dropped. The missing data rates are 5%, 10%, 20%, 30%, 40%, 50%, and 60%. Fig. 1 shows the relative residual sum of square errors (RSS) between dropped true values and the estimates, depending on missing data rates. Three methods, “na.roughfix”, “impute.knn” and “rfImput.unspvsd,” are compared with each other. Less RSS shows better performance of their imputations. We found that our method is not inferior to the other two methods irrespective of the missing data rate. Roughly speaking, our method improves the performances 20–30% compared with “na.roughfix” and 5–10% compared with “impute.knn.”

B. Edgar Anderson’s iris data

The next example is the famous Fisher’s or Anderson’s iris data set, which gives the measurements in centimeters of the variables sepal length and width and petal length and width, respectively, for 50 flowers from each of three species of iris. The species are “Iris setosa,” “versicolor,” and “virginica” [13]. In R, “iris” is a data frame with 150 observations and 5 variables.

Since this data set was treated as an example of discriminant analysis by Fisher, it became a typical test case for

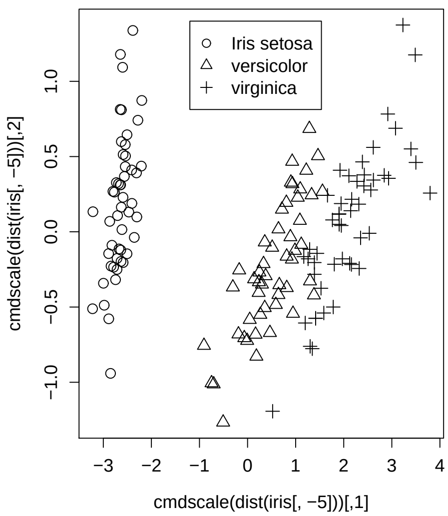

Figure 2. Actual species visualized by MDS

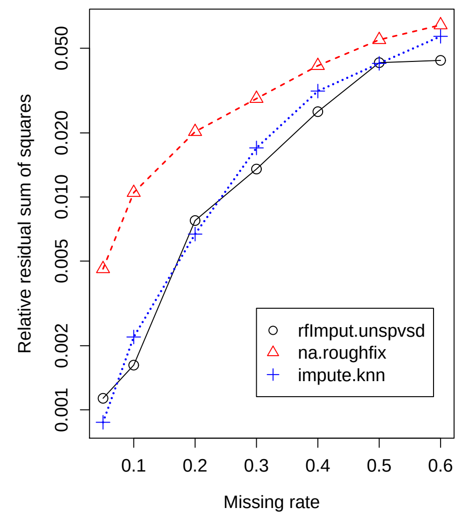

Figure 3. Relative residual sum of squares for unsupervised iris data

many classification techniques in machine learning. Note that the data set only contains two clusters with rather obvious separation. Fig. 2 shows the actual iris species by using multidimensional scaling (MDS), which is used in information visualization for exploring similarities. We assign a location to each observation in 2-dimensional MDS space.

One of the clusters contains Iris setosa, while the other cluster contains both Iris virginica and Iris versicolor and is not separable without the species information Fisher used. This makes the data set a good example to explain the difference between supervised and unsupervised techniques in data mining.

In the same framework of the previous experiment for spam/non-spam, three methods are investigated. Here, we pretend that iris spaces (5th variable) are not measured. Fig. 3 shows the results.

The identical data set corresponding with the missing rate are used to evaluate three methods. Since the missing data structure depends on a seed of the randomization, RSS does not always increase monotonously. It may also be caused by the small sample size of 150. Despite the lack of monotonicity, our method ("rfImput.unspvised") is the best of the three, irrespective of the missing data rate. Rough imputation ("na.roughfix") is worst, naturally enough.

V. Semi-supervised Learning

We point out that our method is easy for expanding to a semi-supervised data set, where both predictor (x) and response variables (y) may include missing values. In general, semi-supervised learning, including large amounts of response variables (y), has a potential to cover the real-world data considerably. A good semi-supervised learning method gives us many benefits. Our proposed procedures are as follows.

1) By starting the rough imputation for missing predictor (x), we estimate the missing response variables ($\hat{y}$) by running a random forest.
2) We replace the missing predictor ($\hat{x}$) by using the proximities between cases, and estimate the response variables ($\hat{y}$).
3) If the imputed vales ($\hat{x}$) are converged, we output them ($\hat{x}, \hat{y}$).

We call this procedure "rfImput.smspvsd," which means "an imputation method by using random forests for a semi-supervised data set." We found that the repetitive operation of 2) does not contribute significantly to improvement.

To evaluate the performance of "rfImput.smspvsd," we compare it with the following two methods.

1) Liaw's "rfImpute" [6]: Since "randomForest" does not work for y that includes missing responses, "rfImpute" functions as well. Therefore, we configure the forest model for non-missing response cases (y) by obtaining imputed predictor ($\hat{x}$) by using "rfImpute." Then, using this model, we estimate the response values ($\hat{y}$) for their missing y.
2) kNN [14]: We start the rough imputation of $\hat{x}$ for non-missing y, and a training kNN model is configured. Then, using this model, we estimate the response values ($\hat{y}$) for their missing y.

In semi-supervised as well as supervised learning, the prediction or estimation of y based on x is accomplished.

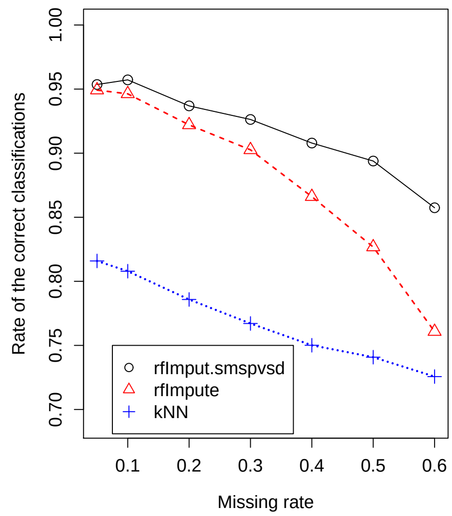

Figure 4. Correct classification for semi-supervised spam/non-spam data

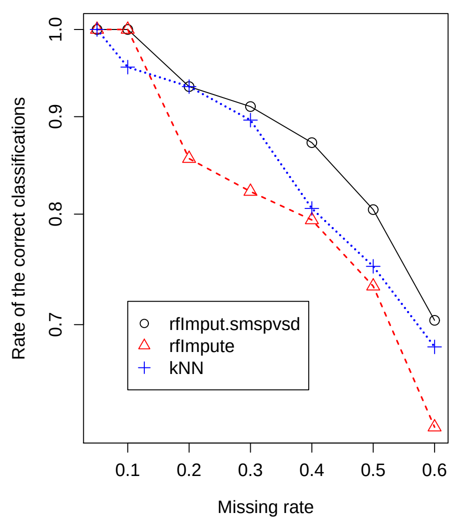

Figure 5. Correct classification for semi-unsupervised iris data

Therefore, as a criterion for evaluating the performance of learners, we use the precision, that is, the rate of the correct classifications.

The values of three methods are shown in Fig. 4 (spam/non-spam data) and Fig. 5 (iris data). A larger value on the vertical axis indicates a better performance. A value of 1 means that all missing y are completely predicted.

In general, the larger the missing data rate on the horizontal axis, the smaller the value on the vertical axis becomes. Due to the randomization of the missing data, the lines on the graph do not always decrease monotonously. Nevertheless, our method ("rfImput.smspvsd") is always the best of the three, irrespective of the missing data rate. In particular, in the case of the high missing data rate, e.g., 60%, the advantage of our method is remarkable.

Whereas spam data is alternative, iris data is a threefold choice. Therefore, the slopes of decreasing lines in the latter (Fig. 5) are sharper than those in the former (Fig. 4).

VI. Summary

For unsupervised data sets, the proposed method ("rfImput.unspvsd") works pretty well compared with the other conventional method: k-nearest neighbor imputation ("impute.knn") as well as the replacement by column median ("na.roughfix"). For semi-supervised data sets, our method ("rfImput.smspvsd") is also superior to the other two methods ("rfImpute" and "knn").

Since data imputation enables us to handle missing data the same as complete data, even statistical beginners can use this type of data easily. Speaking from a statistical point of view, our method makes an assumption called "missing at random (MAR)"[15], wherein the missing depends on only observations and not non-observations. The MAR is a more general assumption than "missing completely at random" wherein the probability of missingness is the same for all cases.

We should note that, even at a low missing data rate, e.g., 5% for spam/non-spam data, a complete case is rare. The occurrence probability is only $(0.95)^{57} \approx 0.0537$. The missing data rate of 10% in turn, yields an occurrence of 0.00246. If we use only complete cases by removing missing data, almost all cases should be avoided. Our method works effectively under the condition that the number of variables is rather large.

Moreover, our method does not take account of the effects on the data selection biases, because all cases can be available as they were. The situation or condition under which the complete data are obtained is often restricted. We hope that our method can be widely used in the future.

Indeed, the limitations of this method should be investigated. Especialy, the influence of cases in which MAR assumption is not satisfied, as well as the dependency of missing ratio and the number of variables, are significant. Because our method is based on the MAR assumption.

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APPENDIX

```
# Description:
#   Unsupervised data imputation using the
#   proximity from random forests.
# Usage:
#   rfImpute.unsupvsd(x, iter=10)
#
# Arguments:
#   x: An unsupervised data frame or matrix,
#      some containing 'NA's. Response vector
#      is not needed.
#   iter: Number of iterations needed to run
#      the imputation.
# Details:
#   The algorithm starts by imputing 'NA's
#   by using 'na.roughfix'. Then, 'randomForest'
#   is called with the completed data. The
#   proximity matrix from the randomForest is
#   used to update the imputation of the 'NA's.
#   Note that rfImpute(), developed by Andy Liaw,
#   has not (yet) been implemented for the
#   unsupervised case.
#
# Value:
#   A data frame or matrix containing the
#   completed data matrix, where 'NA's are
#   imputed by using the proximity from .
#   randomForest
#
# See Also:
#   'rfImpute', 'na.roughfix'
#
# Example:
#
# library(randomForest)
# data(iris)
# iris.na <- iris
# set.seed(111)
# ## artificially drop some data values.
# for (i in 1:4)
#   iris.na[sample(150, sample(20)), i] <- NA
# x <- iris.na[,-5] # Remove the `Species'
# set.seed(222)
# irisImpute.unsupvsd <- rfImpute.unsupvsd(x)

rfImput.unsupvsd <- function (x, iter=5){
  x.roughfix <- na.roughfix(x)
  rf.impute <- x

  while (iter){
    x.rf <- randomForest(x.roughfix, ntree=100)
    x.prox <- x.rf$proximity

    for (i in 1:ncol(x)){
      rf.impute[,i] <- nafix.prox(x[,i],
         x.roughfix[,i], x.prox)
    }
    diff.rel <- dist.rel(rf.impute, x.roughfix)
    if (diff.rel < 1e-5){
      break
    }else{
      x.roughfix <- rf.impute
      iter <- iter -1
    }
  }
  return(rf.impute)
}

# Return relative distance between `x.impute'
#   and `x.org'
# Arguments:
#   x.impute: imputed data
#   x.org: original data
dist.rel <- function (x.impute, x.org){
  max.x <- lapply(abs(x.org), max) # normalize
  if (FALSE){ # available for only numeric
    diff.x <- (x.impute - x.org) / max.x
    diff.rel <- sum(diff.x^2) /
        sum((x.org / max.x)^2)
  }else{
    ncol.x <- length(max.x)
```

```
    mat.x.impute <- matrix(as.numeric
        (unlist(x.impute)), ncol=ncol.x)
    mat.x.org <- matrix(as.numeric
        (unlist(x.org)), ncol=ncol.x)
    max.numx <- as.numeric(unlist(max.x))

    diff.x <- sweep((mat.x.impute - mat.x.org),
         2, max.numx, FUN="/")
    size.org <- sweep(mat.x.org, 2, max.numx,
         FUN="/")
    diff.rel <- sum(diff.x^2) / sum(size.org^2)
  }
  cat ("diff.rel =", sum(diff.x^2), "/",
         sum(size.org^2), "=", diff.rel, "\n")
  return(diff.rel)
}

# Impute or revise NA elements by using the
#   data proximity.
# Arguments:
#   na.vales: data vector that includes NA;
#     unchanged.
#   rough.vales: rough data vector to be
#     replaced; NAs cannot be included.
#   x.prox: data proximity matrix; each
#      element is positive and <= 1.
nafix.prox <- function (na.vales,
         rough.vales, x.prox){
  if (length(na.vales) != length(rough.vales)){
    stop( "'na.vales' and 'rough.vales'
         must have the same length")
  }else if(length(rough.vales) != ncol(x.prox)){
    stop("'rough.vales' and 'x.prox' size
         incorrect")
  }
  # NA imputation ONLY for NA data
  na.list <- which(is.na(na.vales))
  replaced.vales <- rough.vales
  for (i in 1:length(na.list)){
    j <- na.list[i]
    x.prox[j,j] <- 0 # imputed datum itself
    replaced.vales[j] <- kWeighted.mean
          (rough.vales, x.prox[,j])
  }
  return(replaced.vales)
}

# Return k-neighbor weighted mean for numeric
#   variables or most weighted frequent factor
#   element for factor variables.
# Arguments:
#   value: vector; numeric or factor variables.
#   weight: vector; numeric.
#   k: the number of neighbors.
kWeighted.mean <- function(value, weight, k=10){
  if (missing(weight))
    w <- rep.int(1, length(value))
  else if (length(weight) != length(value)){
    stop("'value' and 'weight' must have the
         same length")
  }
  k <- min(k, length(value))
  if (is.numeric(value)){ # weighted mean
    order.weight <- order(weight, decreasing=T)
    ww <- weight[order.weight]
    vv <- value[order.weight]
    ret <- sum(ww[1:k] * vv[1:k]) / sum(ww[1:k])
  }else if (is.factor(value)){
    wgt.sum <- tapply(weight, value, sum)
    # most weighted frequent factor element
    ret <- names(subset (wgt.sum,
         wgt.sum == max(wgt.sum)))
  }else{
    stop("'value' is neither numeric nor
         factor")
  }
  return(ret)
}
```

Figure 6. R program to impute the missing unsupervised data

AmI-RIA: Real-Time Teacher Assistance Tool for an Ambient Intelligence Classroom

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Abstract— **This paper discusses a learner-centric approach towards supporting instructors on improving the learning process in ambient educational environments. The proposed system introduces an intelligent multi-agent infrastructure that monitors unobtrusively the students' activities and notifies the teacher, in real-time, about potential learning weaknesses and pitfalls that need to be addressed. For that to be achieved several applications have been developed: (i) a real-time classroom activity visualizer, (ii) a behavioral reasoner that aims to identify common behaviors by analyzing classroom statistics records, and (iii) various mini-tools like the classroom attendance record, the schedule manager, etc. Following the system's description, findings of the preliminary expert-based evaluation are presented and future extensions are proposed.**

Keywords- ambient intelligence; education; smart classroom; teacher assistance; student monitoring.

I. INTRODUCTION

Ambient intelligence (AmI) is an emerging technological paradigm that defines sensitive digital environments that monitor their surroundings through pervasive sensorial networks and automatically adapt (i.e., AI) to facilitate daily activities [1], [2]. AmI initially benefited mainstream areas such as home and office automation. During the past few years remarkable efforts have been made towards applying AmI in a variety of domains such as education, health, etc.

In a "Smart Classroom", typical classroom activities are enhanced with the use of pervasive and mobile computing, artificial intelligence, multimedia content and agent-based software [3]. Traditional artifacts like the desks and whiteboards are replaced by technologically enhanced equivalents aiming to support the educational process. The most prevalent realizations of the Smart Classroom paradigm include applications for automatic adaptation of the classroom environment according to the context of use [4], automatic capturing of lectures and teacher's notes [5], enhancement of the learner's access to information and personalization of the classroom's material [6] and finally, supporting collaboration among the participants in the classroom [7]. However, the majority of current research approaches address issues focusing on the learner's activities, without much attention to the role of the teacher. Among others, teacher's duties include: (i) implementation of a designated curriculum, (ii) maintenance of lesson plans, (iii) assignment of tasks and homework, (iv) monitoring of performance, and most importantly (v) assistance provision when necessary. In general, curriculum activities outweigh monitoring and assistance tasks, especially in crowded classrooms, thus an automated method of observing students' behavior and identifying common problems is needed to enable effective and personalized tutoring [8].

Towards this end, a tool named AmI-RIA has been implemented, targeted to support the teacher in the context of a learner-centric ambient intelligence classroom. The AmI-RIA system monitors and analyzes students' activities in real-time so as to identify potential difficulties, either at a personal or at a classroom level, and notify the teacher accordingly (e.g., through the teacher's frontend application). The teacher can therefore concentrate on the lecture and rely on the system to monitor the classroom and prompt for an intervention only when necessary (e.g., a student is out of task or performed poorly in a quiz). In addition to real-time monitoring, AmI-RIA offers a performance analysis tool that provides extensive metrics of students' progress (based on previously collected data) that the teacher can use to identify topics that require further studying or even adaptation of the teaching methodology. Finally, AmI-RIA integrates tools that automate common procedures like attendance record keeping, quiz assessment and preparation of lesson's curriculum.

The rest of the paper is structured as follows: Section 2 presents related work on student monitoring in real classrooms or e-learning environments, Section 3 provides a description of the AmI-RIA system design, Sections 4 and 5 present system implementation details, Section 6 reports the evaluation results, and finally Section 7 summarizes the described work and highlights potential future enhancements.

II. RELATED WORK

The widespread use of ICT in learning environments has urged researchers to take advantage of the presence of technological equipment inside classrooms in order to enhance the learning and teaching process. Towards this objective, various intelligent systems that monitor students' activities and report valuable insights to the teacher have

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been developed, aiming to enhance either real or virtual (i.e., e-learning environments) classrooms.

A. Student monitoring in real classrooms

Retina [9] aims to assist instructors that offer computer science courses to improve their curriculum by reporting the difficulties that students are facing during programming. To that aim, Retina collects information about students' programming activities (e.g., compilation and run-time errors, time spent for each assignment, etc.) and generates informative reports for students (i.e., self-evaluation) and instructors, whereas live monitoring enables instructors to either address issues immediately during a lecture or adjust forthcoming assignments. In [10] a system that aims to improve programming courses is presented. It monitors students' behavior within a learning environment on introductory programming (e.g., compilation errors, error messages, source code, etc.) in order to detect students' frustration -a potential factor for disengagement- and notify instructors to intervene providing help.

In [11] it is argued that teachers working in robotic classes have problems in keeping track of students' activities. As they claim, the real challenge for the instructors is to know when and how to intervene. Thus, they propose a system that collects data from the robotic environment and inform the teacher about what students are doing and how they are progressing. The design of the system relies on the LeJOS programming platform for Lego Mindstorms, where two agent modules are used for the data collection, one embodied into the robot and the other deployed on the programming environment.

MiGen [12] is a related intelligent environment designed to support students learning algebraic generalisations. The system aims to assist the teaching process by informing teachers of students' progress, the appearance of misconceptions and disengaged students. To do so, MiGen visualizes the students' progress based on their attainment of specific landmarks as they are working on mathematics generalisation tasks.

The aforementioned systems can partially provide real-time information to the instructor, however they have two major drawbacks: (i) they are targeted to specific contexts of use (e.g., programming course) and (ii) they offer rather poor user interfaces, in terms of usability, that hinder information extraction.

B. Student monitoring in e-learning environments

Similarly, various approaches exist that support instructors within e-learning environments through student monitoring. In [13] a web-based environment is proposed, capable of collecting students' traces during interaction in order to visualize the virtual classroom and help teachers keep classroom control. Participants are represented by Chernoff faces, whose facial characteristics evolve over time according to their activities.

In [14] the CourseVis tool is presented, which generates graphical representations of what is happening in the classroom (i.e., social, cognitive and behavioral aspects of the learners) by analyzing students' activities data collected in a course management system (CMS).

Likewise, [15] is an intelligent agent system that supports teachers in supervising learners in LAMS (Learning Activity Management System). It is capable of notifying the instructor for common problems about participation and contribution of students during their activities. However, for that to be achieved, the instructor is required to determine expectations for the attendance and contribution of the learners for each activity (e.g., typical execution time, contribution level on collaborative activities, expected score, etc.). Finally, a notification agent is used to deliver messages and information to the supervisor of the lesson and to the learners as well.

The systems discussed above either lack intuitive user-interfaces (i.e., Chernoff faces are a useful tool for indicating student inactivity, but in complex situations their expressiveness is limited) or they do not offer an effective real-time assessment method needed in such intelligent learning environments [16]. Thus, there is a clear need for a system that can: (i) be deployed in a real classroom, (ii) monitor unobtrusively the students, (iii) produce valuable insights about their behavior in real-time, and (iv) deliver them through an intuitive, yet rich, user interface to the teacher.

III. SYSTEM DESIGN

The teacher assistance tool proposed in this paper aims to inform the teacher about students' activities and identify potential weaknesses by monitoring interaction and generating classroom-wide performance metrics. For that to be achieved, a distributed architecture (Figure 1) is introduced that consists of two major components: (i) an intelligent agent deployed on the students' desks to monitor interaction named *Desk Monitor*, and (ii) an intuitive frontend application deployed at the teacher's desk named the *Teacher Assistant,* that facilitates monitoring overview and simplifies classroom control (e.g., assignment submission, exam distribution, etc.).

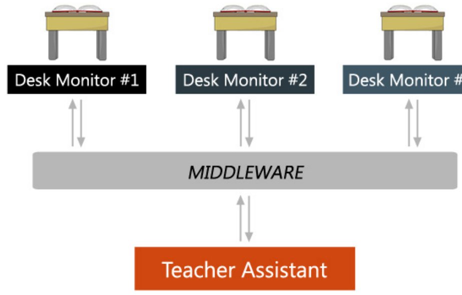

Figure 1. AmI-RIA overall architecture

Every Desk Monitor agent collects the monitoring traces that students generate when working on their desks and through a reasoning process draws conclusions about students' behavior. Both the collected and the inferred knowledge is transmitted in real-time to the *Teacher Assistant* application, which is responsible to present them appropriately (e.g., highlight inactive students, prompt teacher action, etc.). Data exchange is performed through a generic services interoperability platform, named FAMINE (FORTH's AMI Network Environment).

A. Data Collection

The proposed system is employed in a Smart Classroom [3] and is supported by the classroom's backbone infrastructure named ClassMATE [17]. ClassMATE monitors the classroom environment and orchestrates its various artifacts (e.g., augmented school desks [18], interactive whiteboards, etc.). The augmented desk is an enhanced school desk, which uses computer vision technology in order to recognize books and book pages and provide physical and unobtrusive interaction without requiring any special device. The ClassMATE infrastructure in collaboration with the PUPIL framework [19] controls the augmented desks and the whiteboard (e.g., SMARTboard) and provides the required facilities to monitor the students' interactions during the learning sessions.

The activities of interest for the AmI-RIA system include: (i) login when a student sits on a desk, (ii) course book page fanning, (iii) launch of an exercise session, (iv) answer submission, (v) use of contextual help provided by the learning system and finally, (vi) browsing and sharing of multimedia galleries. These activities along with related data become available to the *Desk Monitor* agent by ClassMATE through a FaMINE-enabled bridge interface.

B. Data Management and Reasoning

Ontologies are widely accepted as a tool for modeling contextual information about pervasive applications [20], as they not only address the problem of data heterogeneity between applications and support data interconnection using external vocabularies, such as FOAF and Dublin Core metadata, but also enable knowledge inference using semantic reasoners whose rules are implemented by means of ontologies.

AmI-RIA aims to exploit those features thus it makes extensive use of ontologies. An RDFS schema has been implemented that defines classes for the relevant entities (e.g., Teacher, Student, Book) and the activities (e.g., Open book, Start exercise) that can potentially take place in a classroom environment, while a set of taxonomies has been defined, based on RDFS properties, to associate classes and create activity hierarchies (e.g., Submit_Exercise isA Student_Act). Collected data are stored internally in the form of RDF triplet statements.

The reasoning process of the AmI-RIA system is supported by the SemWeb library for .NET. SemWeb supports SPARQL queries for information retrieval over the data and incorporates the Euler engine, a popular backward chaining inference engine. The rules used by the Euler engine are written in external files using the Notation3 syntax, an RDF syntax designed to be human friendly. Rule decoupling facilitates system maintenance and scalability as insertion of new rules or modification of existing rules can be done without affecting the core of the AmI-RIA system.

IV. Desk Monitor Agents

The Desk Monitor agents constitute the core components of the AmI-RIA system, as they execute the inference rules over the collected interaction data to identify potential troublesome situations (e.g., inactive or off-task students, etc.). To that end, the agents make use of the developed taxonomies that describe such situations and through a goal-driven method (i.e., backward chaining inference) try to confirm their existence based on contextual knowledge. The list of currently detected situations include: (i) off-task students, (ii) inactive students, (iii) students that face difficulties during exercise solving, (iv) students that face difficulties during exercise submission and (v) students that misuse the contextual-help of the learning system.

A. Off-task

According to Caroll's Time-On-Task hypothesis [21], the longer students engage with the learning material, the more opportunities they have to learn. Therefore, if students spend a greater fraction of their time engaged in behaviors where learning is not the primary goal, they will spend less time on-task and as a result learn less. In [22] the authors argue that off-task behavior indeed has a negative impact on students' performance. To identify off-task students, the system checks the material displayed on a student's desk (e.g., the currently opened book, the opened pages, etc.) to determine if it is relevant to the topic discussed in the classroom based on the activity in hand.

B. Inactivity

During classroom activities, especially exercise solving, it is common for students to start working on an exercise and after a while give up because they get bored or distracted. Inactivity is defined as a type of off-task behavior where the student does not interact with the learning object at hand. According to [22], inactivity indicates that a student is disengaged with a certain task and can be used as a quite accurate performance predictor. AmI-RIA exploits the typical learning time describing the amount of time that a student is expected to work with or through a learning object [23], to specify if and when a student's interaction is taking too long to be executed. For that to be achieved, AmI-RIA gets notified by ClassMATE about the actions that a student performed when interacting with a learning object (e.g., an exercise, a text passage, etc.).

C. Problems during an Exercise

The PUPIL framework offers personalized tutoring in the form of contextual help (i.e., hints) for each question of an exercise to help students find the right answer, where the last hint provides the maximum amount of help that can be provided. AmI-RIA monitors the amount of help asked and the selection made afterwards to calculate student's performance. In case a student uses the maximum amount of help, but still does not answer correctly, then the system infers that the student has difficulties regarding this question and the concept it refers to.

D. *Problems on Exercise Completion*

Identifying whether a student faces difficulties during exercise solving is quite challenging, since a single pass/fail indicator does not always reveal the actual progress of a learner on a specific topic. To this end, instead of generalizing conclusions based merely on the score of the exercise in hand, the student's previous performance on relevant topics/similar exercises is taken into consideration. Thus, detecting sparse declines of a learner's statistics does not necessarily indicate a weak student.

E. *Misusing the Learning System*

Sometimes students interact with exercises according to a set of non-learning-oriented strategies described in [22] known as "gaming the system". Such strategies involve behaviors aimed at systematically misuse the help provided by the system in order to advance in exercise instead of actually making use of the material of the intermediate hints. A set of rules has been created to track students who repeatedly ask for help within a small time frame until they get the maximum one.

Figure 2. The Teacher Assistant User Interface

V. TEACHER ASSISTANT

As aforementioned, AmI-RIA offers an intuitive frontend application (Figure 2) deployed at the teacher's computer (or portable tablet device) named *Teacher Assistant*, through which the instructor can monitor at real-time via live feed the activities that take place in the classroom and identify occurring issues. For that to be achieved, every Desk Monitor Agent propagates its inferences through the classroom's middleware to the Teacher Assistant application to present them accordingly.

In terms of design, Teacher Assistant adheres to the natural mapping rule [24] that leads to immediate understanding because it takes advantage of physical analogies. As such, each student present in the classroom is represented by a *Student Card*, non-occupied desks are represented by semi-transparent empty cards, whereas the layout resembles the layout of the physical desks. As a result, the teacher can easily locate a student in the classroom through the virtual class map or access the attendance record to see the absent students.

A. *The Student Card*

The Student Card contains both personal information, such as the name and the profile picture, and information regarding the current activities and status of the student. During the course the student might be engaged with various activities such as reading a passage from a book, solving an exercise, browsing a multimedia gallery, etc. Providing specific details on such classroom tasks would allow the teacher to be constantly informed about the students' attention levels and potential learning difficulties. To this end, each Student Card adjusts to represent the learner's status at any given moment. For instance, when a student is reading, the card displays the book title and the respective page numbers; during an exercise, additional information is displayed regarding the topic, difficulty and the student's progress, finally when a student launches a multimedia gallery, a small set of relevant keywords is displayed on the card.

However, during a lecture the students might lose interest and deviate from the teacher's suggestions. This kind of information could ideally prompt the teacher to investigate the reasons of such attention lapses and try to maintain the student's interest. For that purpose, the Student Cards are enriched with visual cues (e.g., different border color of the cards, intuitive icons) to mark on-task, off-task and inactive behaviors. Finally, since the implemented system targets large and crowded classrooms, the visual information may become too large to be handled easily. To overcome this difficulty, a filtering mechanism that allows the teacher to focus on specific student groups is incorporated.

B. *Assesment*

Exercises are considered to be a key aspect of the learning process in a classroom as through performance monitoring potential learning gaps can be revealed and the domains where the teacher should focus on are highlighted. AmI-RIA ensures that the teacher will be able to watch students' progress during exercise sessions by adjusting the student card appropriately to display the exercise's name, the related topic and the student's current score, whereas more detailed information about student's performance is available through two special-purposed windows.

The first one presents in more detail aspects of the exercise at hand; in particular, (i) the type (e.g., multiple choice quiz, fill-in the gap, etc.), (ii) the difficulty level (e.g., easy, medium, hard), and (iii) the typical learning time as defined in the LOM metadata. The second window (Figure 3) presents a complete log of student's actions regarding that exercise: (i) the number of answers given, (ii) the number of hints used per question, (iii) the current score, (iv) the ratio of correct and wrong answers, and optionally (v) a problem indicator as generated by the Desk Monitor.

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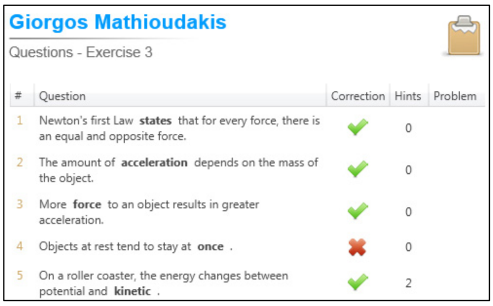

Figure 3. The exercise progress window

In addition to exercises, tests are also integral part of the learning process. Tests are a type of exercise where every student is obliged to answer and no help is provided. As soon as a test is initiated from the Teacher Assistant application, it automatically launches on every desk while the use of any other application [19] is prohibited (e.g., Thesaurus, Multimedia, etc.). During tests, the teacher can monitor students' progress as with common exercises and is able to request its submission at any time. At that point, any tests that have not been submitted yet are automatically collected and a summarizing report is presented with an average score for the entire classroom and a precise score for each student.

C. *The Classroom Monitor*

Individual statistics are automatically generated for each student by the respective Desk Monitor agent; however, accumulated statistics for the entire classroom are invaluable tools for teachers as through them behavioral patterns can be identified; an activity is considered to be a pattern if it is observed in a certain number of students in the classroom. For instance, if 85% of the students faced difficulties and performed poorly in an exercise, then either that particular exercise is too difficult or the teacher has to adapt the class' schedule to further elaborate on the related concepts. Similarly, if more that 80% of the students are off-task at the same time, then either a break might be helpful or the teacher should attract their attention and enhance their motivation. In any case, when AmI-RIA identifies a pattern, a special alert is generated to notify the teacher.

D. *Statistics*

The information gathered about the students' activities is used to build a rich history record, which combined with the defined RDFS schema constitutes a vast source of semantic information. This information is exploited to generate statistics for the progress and performance of the students during short or long periods of time. Based on these statistics the teacher detects the topics that need to be revisited or adapted and identifies the thematic areas that seemed to have troubled each student.

The statistics component offers two alternative views, one for the classroom and another one for individuals (Figure 4). Both provide information about performance, topics with the highest/lowest scores and rankings on students and lessons. The generated statistics can be printed and handed-out to parents as an unofficial progress report for students.

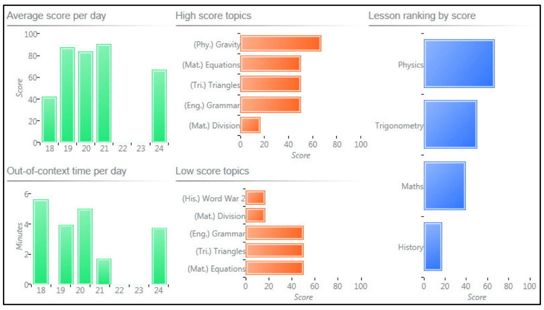

Figure 4. The individual statistics component

VI. EVALUATION

As a first step towards the evaluation of the system, an expert-based heuristic evaluation was conducted in order to identify usability errors. The heuristic evaluation requires a small set of evaluators (3-5) to examine the interface and judge its compliance with a set of recognized usability principles. An observer notes down the issues and creates an aggregated list which is delivered at the end to the evaluators in order to provide severity ratings on each issue.

Four evaluators took part in the evaluation of Ami-RIA and identified 22 usability problems, out of which 11 were marked as severe (rated above 2.5 on a 0-4 scale). The identified usability errors were related mostly to the flexibility in access to the several components (e.g., the attendance access button) and the perceived user friendliness when operated on touch-enabled devices (e.g., the sidebar option buttons were difficult to press due to their size). Additionally, some issues were identified regarding the aesthetic design and accessibility of the user-interface such as the insufficient color contrast between the main visual components (e.g., the main menu buttons and the footer's information). The released prototype of AmI-RIA effectively addresses all the identified errors.

VII. CONCLUSIONS AND FUTURE WORK

This paper presents AmI-RIA, a real-time system that aims to assist teachers in the context of an intelligent classroom by exploiting the available ambient technology from their perspective. The proposed system monitors the students' activities in an unobtrusive way and generates valuable insights in order to assist teachers keep track of the classroom's performance. Thereby, the teacher is supplied with the needed information to decide when and how to provide help or adapt the teaching strategy. For that to be achieved a statistics component performs queries across the entire history record and retrieves information regarding the students' progress and performance. Furthermore, a set of tools have been developed and deployed on the teacher's desk, targeted to enhance typical procedures that can be found in conventional classrooms (e.g. class attendance record, tasks assignment, etc.).

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The next step of this work will be to conduct a full-scale user-based evaluation in a real classroom. The evaluation is planned to include 20 different teachers and their students [25], where typical classroom activities will be observed to: (i) assess whether AmI-RIA recognizes problems successfully, and (ii) determine how instructors use the system to identify problems and provide assistance. The evaluation's findings are foreseen to extend the currently implemented rule set and improve the user interface of the teacher's frontend application in terms of usability.

Additionally, some relevant topics are being investigated for future upgrades. A great addition to the system would be to make the students' desks aware about the inferences produced during the reasoning process. This way, the students will be informed about their performance during the various learning activities and will feel more comfortable with the monitoring process. The feedback provided could be used by the students to adjust their activities accordingly, while communication between the teacher and the students could be also enhanced with an application that blends seamlessly with student activities application. For example, the teacher using the application could reward some students for achieving great scores on a task or provide extra material to those who had problems in a topic. Finally, an important extension to the system would be the development of a graphical tool that will facilitate the intuitive modification of the rules used to identify students' states or create new ones.

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Integrating Serious Games in Adaptive Hypermedia Applications for Personalised Learning Experiences

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***Abstract*—Game-based approaches to learning are increasingly recognized for their potential to stimulate intrinsic motivation amongst learners. While a range of examples of effective serious games exist, creating high-fidelity content with which to populate games is resource-intensive task. To reduce this resource requirement, research is increasingly exploring means to reuse and repurpose existing games. Education has proven a popular application area for Adaptive Hypermedia (AH), as adaptation can offer enriched learning experiences. Whilst content has mainly been in the form of rich text, various efforts have been made to integrate serious games into AH. However, there is little in the way of effective integrated authoring and user modeling support. This paper explores avenues for effectively integrating serious games into AH. In particular, we consider authoring and user modeling aspects in addition to integration into run-time adaptation engines, thereby enabling authors to create AH that includes an adaptive game, thus going beyond mere selection of a suitable game and towards an approach with the capability to adapt and respond to the needs of learners and educators.**

Keywords - Adaptive Hypermedia; Adaptation; Serious Games; Educational Games; Education; Personalization.

I. INTRODUCTION

In recent years computer games have increasingly been used for training purposes. Frequently cited benefits of so called serious games include increased learner motivation through increasing learner engagement, achieved by a combination of education and entertainment [1]. However, learning styles can prove diverse: for example some learners are happy to find solutions by trial and error, while others prefer to first learn about what the solutions are and why, before trying them out [2]. Games and Simulations may also be more or less suitable depending on the sub-topic. For example skills commonly improved through drill and rehearsal, such as emergency evacuation, are well suited to a game-based learning environment which can recreate an evacuation scenario whilst providing motivation for rehearsal through game play. By comparison, low-level cognitive transfer [3] may be more suited to other instruction methods. The success of a serious game is also directly related to the effectiveness of the interactive learning experience responding to the evolution of learners' needs and requirements. Although a major game design concern, focuses on learning experience often jeopardize the game developers' efforts to fulfill the intended serious goals. Serious games are often content-rich and can use high fidelity visual and audio learning objects with diverse pedagogic approaches. This means that development costs can be prohibitive compared to other media.

Reducing costs of designing and developing a serious game is essential. Sharing and reusing or re-purposing (re-using for a different purpose) is therefore particularly important. The mEditor [4] is a novel tool which allows re-purposing of serious games and offers the potential to significantly reduce the development cost of serious games.

Education is also a popular application area of adaptive hypermedia (AH). In order to adapt to different learning styles, it is important that the learning capabilities, styles and progress of users is captured. User modeling methods and AH have been widely used in Tutoring Systems [5], but, are not common in serious games.

Studies such as Pierce et al. [6] demonstrate that integrating serious games with Adaptive Learning Systems can be very effective, however while both authoring of AH and of serious games have been active research areas, work towards the integration the two in all aspects: authoring, user modeling and delivery remains limited. Addressing this gap requires developing techniques and tools that allow for games to be effectively adapted and pedagogically integrated whilst retaining their unique benefits in areas such as motivation and engagement.

The mEditor tool demonstrates a step towards addressing some of these issues around reuse and repurposing. In Section 2, a detailed examination of the mEditor tool through an illustrative scenario illustrates how it uses a graph of game dialogues with certain conditions attached to represent individual scenarios within the game. Both the dialogue and the conditions can be changed, allowing rapid and accessible

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refinement, or repurposing of content without requiring a high level of programming skill, and is thus more accessible than the bespoke development required for adapting most existing serious games.

To consider the mEditor tool alongside a range of approaches, the rest of this paper is organized as follows: Section II expands upon the concepts of AH and serious games, and examines relevant developments. Section III contrasts the different components of authoring game scenarios with those used by existing authoring tools for AH. Section IV outlines how an authoring tool for adaptive games, integrated into an AH could be achieved; finally Section V highlights the future challenges.

II. Background

Educational authoring tools allow educators and domain experts to prepare courses and presentations, often relying on the concept of learning objects (LOs) [7]. A LO is a unit of instruction for e-learning and should be auto-consistent and modular making them reusable. Learning Management Systems (LMS) are software platforms that provide didactic materials assembling LOs. Discovering and reusing LOs is facilitated by the existence of a standardized description format the IEEE Learning Object Metadata (LOM) [8] and the existence of repositories for sharing LOs, such as ARIADNE [9]. The Sharable Content Object Reference Model (SCORM) [10] is a collection of standards and specifications for web-based e-learning. However, these specifications offer some support for personalization, mainly based on adapting the notion of sequencing of content (i.e. the order in which content is presented to the student). IMS-Learning Design (IMS-LD) is another set of standards, which describes what it calls the learning design. Its aim is to be able to represent all major pedagogies and it models roles and activities within an environment that consists of LOs.

In recent years, serious games have been recognized for their educational potential. In particular they can increase learner motivation due to increased levels of engagement. However developing games is costly and time consuming. Various efforts have been made to apply the concepts of adaptivity and personalization to serious games. RETAIN is a serious game design paradigm aimed at applying instructional strategies concurrent to game development [11]. It highlights the importance of the presentation and feedback of the didactic choices to the player and their linkage to reinforce the lesson and test the transfer of knowledge. Riedl et al. [12] presents a framework for creating interactive narratives for entertainment, educational, and training purposes based on an experience manager agent, which is a generalization of an automatic drama manager. Bellotti et al. [13] present an Experience Engine (EE), which exploits computational intelligence algorithms to schedule tasks matching the requirements of a teaching strategy that can be expressed by an instructor, the needs estimated by profiling the user performance and with the aim of keeping the flow. Based on the user feedback, the EE learns a strategy that aims to maintain the performance of learners in a “narrow zone” between too easy and too difficult, maintaining “flow” [14]. This relies on a model of the user that the EE builds and of the instructional tasks features that keep into account both of the entertainment and educational aspects (e.g., learning styles [15]) typical of serious gaming. Moreover, the teaching strategy itself must be modeled, so to allow educators to express their educational line. The EE uses machine learning algorithms to adapt its strategy based on the user profile that is updated from the user feedback. Dynamic assembly is important also to support long-term playability, since missions will be different, without repetitions (if not required for learning purpose set by the learning strategy).

Repurposing of learning resources refers to changing the learning resource to suit a new educational context [16] rather than reuse which merely refers to using the learning resource in its original context without any changes [17]. The changes made to the content can be for various reasons such as the use of different pedagogies, different technologies, or different contexts and learners. Protopsaltis et al. [18] propose a methodology for serious game repurposing games and introduce a practical tool [4], the mEdictor tool, for repurposing serious games, integrated with a commercial game engine. Dunwell et all. [19] suggest that serious games are especially suited to a type of learner called intuitive learners [2], although it indicates that serious games could be useful for other learners as well, especially if the teaching approach is adapted to suit the different learners individually. Part of this is deciding when to present the game to students, but adapting the game itself, for example by changing the dialogues, difficulty level, and language used within the game are all important parts of this adaptation. Games authoring tools such as the mEditor tool, see Figure 2. allow this sort of adaptation, in order to use the serious game with different types of learners or in different contexts. The approach relies upon an educator to actively repurpose the game. The tool uses a graph-based paradigm, in which educators can change game scenarios by changing connection, conditions and nodes in a graph, requiring little or no programming knowledge (though some technical insight may still be needed).

In recent years various efforts have already been made to create authoring tools for serious games, however a full integration with AH is still lacking. eAdventure [20] aims to facilitating the integration of serious games into educational processes and LMSs in particular. While it focuses mostly on LMSs such as moodle [21], its aims are very similar to our aims of integrating serious games and AH. eAdventure contains a graphical authoring tool for authoring adventure games. Its main focus is point & click games and it offers customizable menus and interfaces, artwork and scenarios. Just like the mEditor it uses a XML based notation for describing games that are deployed to a java based games engine. It allows editing of the main elements that make up a game such as scenes, characters, dialogues and navigation. It has built in assessment mechanisms and some support for adaptive learning scenarios. Editing dialogues is done by creating flow diagrams using a graph-based editor.

StoryTec [22] is a digital storytelling platform that features a comprehensive authoring tool.It can be used for creating serious games and features a story editor, stage editor, action set editor, property editor and asset manager. The story editor is based on the use of the Unified Modeling Language (UML) [23] a popular modeling language among software engineers. UML uses a standardized set of graphic notations resulting in graph structures. Hence this approach is somewhat similar to the approach taken by the mEditor and eAdventure. While other authoring tools exist the use of these graph-based structures is a clear trend, hence using the mEditor as an example for this paper is justified.

AH systems build a model of their users and use this to adapt the hypermedia corpus to the user's knowledge, needs or goals [5]. The dimensions of adaptation are well known and various models have been defined such as AHAM [24], based on the Dexter [25] Hypertext model, Munich [26] a UML extension to AHAM, GAHM [27], and more recently GAF [28] in addition to the more traditional hypermedia (text, images and videos etc.). Adaptive games such as the e-Game have been integrated into AH effectively. Simulations [6] have also been integrated into personalized learning environments. A possible integration of a game and a Learning Management system has also been shown [19].

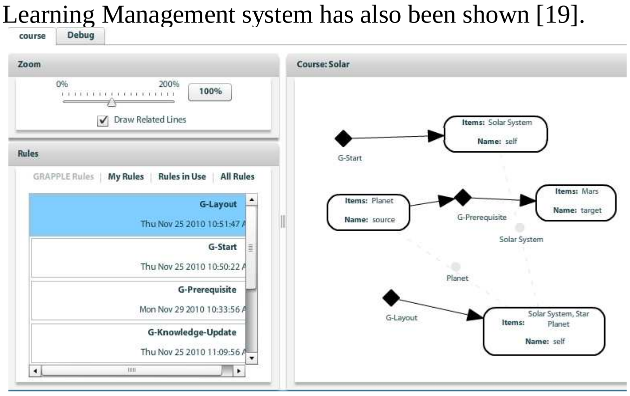

Figure 1. The GRAPPLE authoring tool is graph-based [29]

Authoring of AH is an active research area. Various different models have been proposed such as [24, 29–31]. Authoring of AH consists not only of content creation but also of specification of adaptation strategies that dictate when to show what content and in which way to show it. Various methods have been tried for this part of the authoring process, from a pre-defined selection of strategies [32], to domain specific programming languages [33]. Another method that has been tried with some success is one based on a graph structures [24, 29], see also Figure 1. , where authors can edit strategies by changing the connections, conditions and nodes in a graph interface, with limited programming knowledge. While many graph based editors exist the strength of the GRAPPLE authoring tool lies in the use of a library of adaptive strategies (or Pedagogical Relationship Types) containing adaptation code. This is quite similar to the way the mEditor uses containers and functions.

However while games and simulations have been integrated into personalized learning systems with some success, little work has been done on the integration of games into the authoring and user modeling process. Gaffney et all. [31] propose a simulation authoring tool, but the simulations authored consist mainly of hypermedia elements, rather than being integrated into a game engine as is often the case with serious games or game-based simulation. The use of such a game engine is often necessary to achieve the representation required, for example when designing 3D games or virtual environments. De Troyer at all. [34] have designed an authoring environment for Virtual Reality. This gives the opportunity to include 3D virtual objects in an AH; however the focus is on integrating these objects in the web-based environment. Our work does not integrate objects into the web pages, but rather allows launching a personalized version of a full serious game, with the possibility for in-game adaptation.

A. *Motivating example*

In this section we showcase the repurposing process for serious games using the mEditor tool, and contrast it with the authoring process of an AH object. As a representative of AH we use the CAM model [29]. As an example we use a serious game devised for healthcare, developed by Succubus within the mEducator project. The game allows a medical student to rehearse a session with a patient. The student takes on the role of the doctor and can move around the office, ask the patient to sit down, describe his symptoms, undress lie on the bed, or administer drugs from a selection of available drugs. He can also ask a nurse, to take the blood pressure or make an Electrocardiography (ECG). There is a beginner mode where the player will be corrected when making mistakes and an advanced mode where feedback is only received at the end, allowing mistakes to be made ranging from misdiagnoses through to patient mortality.

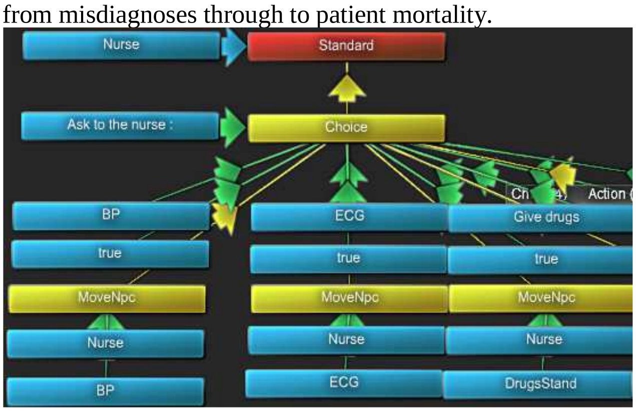

Figure 2. The mEditor [4]for scenario-based repurposing is graph-based

Figure 2. illustrates a part of the scenario as visualized by the mEditor tool, showing the main elements that are used in building scenarios. The example shown describes the interaction with the doctor and the nurse present in the session. The resulting game is show in Figure 3. . There are three characters, the patient doctor and nurse and the player can click on either of them to communicate or on some of the objects in the room, such as the chair and the bed.

In the context of repurposing this game, consider a tutor, who wishes to use the game's multimedia resources, but rather than for cardiac conditions which it is currently aimed at, wants to use it to support teaching on lung conditions. Prior to having the mEditor tool, the tutor would have been

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required to gain access to and edit the games source code, engaging in extensive bespoke development, or commission a new game with its associated costs.

In all these cases, technical development would incur substantial costs in time or outsourcing, and could result in a game-based approach being disregarded due to these prohibitive factors. With the mEditor however, the tutor can repurpose the game so as to use it in a scenario where the patient has a different condition without as much need for technical development or significant investment. For more extensive repurposing some understanding of boolean logic and functions is still needed.

Figure 3. The doctor training game by Succubus Interactive

Imagine now that the tutor also wants the game to automatically adapt the difficulty level to learner's background and knowledge. Let's assume we are working in the context of an advanced LMS, which builds a learner profile and allows the tutor to author an AH [35]. The mEditor tool can be used to quickly develop a range of adapted games to suit various learner needs and ability levels. The tutor may also feedback the students' performance to the learning environment and update the students' level of understanding.

III. COMPARING AUTHORING LANGUAGES

Figure 1. shows the main elements the mEditor uses to create game scenarios. Below we discuss them and particularly how they can be represented in AH authoring frameworks. As mEditor uses a graph based authoring paradigm, it seems reasonable to focus on graph based AH authoring frameworks.

A. Events

mEditor responds to the user via events, similarly to AH systems. Many models rely on so called event condition action rules (ECAs). These connect events and actions via certain conditions. Within the mEditor the author adds events and connects these to actions. In most scenarios there will be containers in between, especially the IfThenElse container, effectively constructing ECAs.

1) Start

Executed at the start of the game, the start event handles the initialization of variables, and showing and hiding of assets. It has an action or series of actions attached to it. AH models such as the Concept Adaptation Model (CAM) [29] and Layers of Adaptation Granularity (LAG) [30] model (via the Initialization part) have similar start states.

2) Standard

Triggered from within the game, when the user clicks on the appropriate object, and comes with both an action, and an item. This item, identified by name, indicates which item triggered the action. In AH the events are usually page clicks or accesses. Actions specified based on a particular page access are possible in LAG, CAM and the AHA! Graph editor [36]. One of their strengths is the ability to generalize and respond to page access for particular types.

B. Actions

1) Container

A grouping and selection mechanism for actions closely resembling programming constructs. The following containers can be used. Containers can also be combined.

- DoAllNow: Do all connected actions in parallel.
- DoAllSequentially: Perform the connected three actions in sequential order.
- DoLoop: Repeat the connected actions in a loop.
- DoOneByOne: Perform the connected actions one at a time, without specified order.
- DoRandomly: Perform the actions in random order.
- DoWhile: Repeat the connected actions in an infinite loop, so long as the connected condition is satisfied.
- IfThenElse: Two (sets of) actions can be attached and a condition determines which one will be performed.

AH models contain the possibility for conditional execution and loops, either using programming language constructs or formal specification languages. Conditional loops are also possible. Finally explicit control of execution order is not always possible in many models directly. LAG, the AHA! Graph editor and CAM make no distinction between the available pages. They can be made available in different order, but the user will only notice this if that is done step by step, rather than in one step.

2) Standard

The standard actions contain actions for explicitly assigning vlues to variables (ChangeBoolValue, ChangeFloatValue, ChangeIntValue, ChangePointValue), an Empty action, Aborting the game, Tracing a certain action and waiting for a specified amount time.

Assigning values is well defined in AH models, time delays are often not explicitly modeled but it would be technically possible to embed an external object that tracks time. End states for most models are implicit.

3) Specific

Some specific choices have an equivalent in AH. Choice exists both implicitly, via navigating to a specific page, as well as in (multiple choice) tests. Then hideInstance and showInstance are very similar to showing and hiding of pages and links, one of the most used adaptation features in AH. The following specific actions are available in mEditor:

- ChangeScene: Change the current game scene.
- Choice: Allow the user to pick from a list of options.
- Dialog: Display an interaction dialogue.

- DoAnim: Play an animation of a particular character.
- HideInstance: Hide the game asses from view.
- Infos: Shows textual information about something, it has a target location.
- MoveNpc: Move the non-player character.
- ShowInstance: Review the (hidden) game asset.
- CreateNPC: Create a non player character at a position.

4) Engine

The engine actions currently predefined are playing a sound, enabling or disabling the mouse and moving ('teleporting') non player characters. In AH models, as the delivery is usually achieved via a web browser, there is no possibility to explicitly disable the mouse, though this is possible via embedded objects or JavaScripts. Sounds and videos can be embedded as regular hypermedia objects.

C. Variables

Variables of the following basic types: boolean, floating point, integer, string, point (an x,y location) can be used in and updated by functions and can either be global, i.e. available through the game scenario or temporary, i.e. available only for one container. Variables are basic building blocks of programming languages and indeed prevalent in all AH authoring models. I.e. LAG is a domain specific programming language and allows user defined variables, although a type definition is not required. CAM uses a formal specification language called GAL [37] and this uses variables of different types, just like the AHA! Graph Editor.

D. Functions

A function can access global variables and those linked to its container. Functions are available for each types of variable split into two groups: functions, working on a number of variables and operators working on only one variable. Available are predefined conversion functions (e.g. valueToBool) and conditional functions (e.g. conditional float with connected values and a condition determining which value to select).

Functions are handled by the different AH models in different ways. LAG does not support functions but allows procedural programming constructs, achieving achieves the same effect. CAM was built around the idea of packaging adaptation patterns, for use as complex functions. GAL and the AHA! Graph editor rely upon defining functions.

IV. ARCHITECTURE

Authoring adaptive serious games can be achieved in various ways. Adaptation with regards to selecting when to present the game can be done entirely in existing AH systems by generating a number of alternative games at authoring time. This would be very time consuming and be limited to the alternative game configurations that were compiled by the author. A tighter integration could be relatively easily achieved. Instead of creating a number of alternative games, the author would use variables and conditions inside the game scenario that refer to the learner profile. This would then result in a personalized scenario, generated at run time by the adaptive delivery engine, just before the system presents the game to the learner [19]. This approach would require a slightly closer integration and careful consideration of cold start issues.

However it is possible to go even further. In this case the game engine would need to read and write the user profile. This could be achieved in different ways, such as directly communicating with a database, or via the use of an intermediary communication mechanism such as a web-service. This is an attractive approach especially as flash-based game engines like Succubus' engine and some popular 3D engines like Unity 3D already support web services.

An example of such integration is the approach taken within the ALICE project [19], integrating a LMS and a serious game to create a solution which can respond to input from LMS and adapt the game dynamically, an architecture is implemented which allows direct method invocation from LMS in-game and vice versa using XML log files. This allows assessment engines to use input from the game, and communicate feedback to the player, e.g. through a virtual companion's dialogue. Such methods provide a means for rich data capture on player interactions, and support blending and dynamic in game-based learning resources.

V. CONCLUSIONS AND FUTURE WORK

As we have seen in this paper, integrating serious games into a personalized learning environment has the potential educational benefits of combining a personalized delivery with increased learner motivation. The paper has shown how an integration of authoring tools and a serious game editing tool could concretely be achieved and can lead to an authoring environment for AH that include adaptive games and goes beyond the current state of the art in integration of AH and serious games. A logical next step is to build and test the proposed authoring environment. However, at this point another question is raised: what are the exact elements in the game that can be adapted and how might these impact different types of learners? For AH a comprehensive taxonomy exists [5] and there is a clear need for such taxonomy for adaptive games and an overview of how different techniques impact different learners.

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Designing a Hybrid Breadth-first CS1 Course

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Abstract **– With the cost of education rising, more no-traditional students returning to school and employers looking for students with experience beyond the classroom, institutions are evaluating how to best deliver the educational experience to today's student. The Babson Survey Group reported that in 2011, there were more than 6 million students enrolled in online courses. The report also stated that approximately one-third of all higher education students now take at least one online course with this number projected to grow. However, in higher education there still remains a debate on the merits of online courses versus the traditional face-to-face classroom experience. In response to this debate, many institutions now offer three modes of instruction which include traditional face-to-face, online and hybrid. Hybrid courses can be described as a blended method of face-to-face and online. However, there are challenges to designing a hybrid course, especially in the science, technology, engineering, and mathematics (STEM) areas. The aim of this paper is to present the design for a hybrid course in an introduction to computer science course taught a two-year institution. The course is a breadth-first course taken by majors, as well as students who need a course to substitute for a mathematics course, required as part of the common core curriculum. The uniqueness of the work is tri-fold: 1) the environment in which the course is offered; 2) the student population enrolled in the course; and, 3) the nature of the delivery mode. The paper presents the design of the course which includes course content and learning outcomes; the teaching pedagogy; course organization and how the course will be evaluated.**

Keywords – Hybrid learning; collaborative learning; learning content management system; undergraduate computer science

I. INTRODUCTION

The United States Department of Commerce, Economics and Statistics Administration in its July 2011 report stated that science, technology, engineering, and mathematics (STEM) occupations are projected to grow by 17.0 percent between 2008 and 2018, compared to 9.8 percent growth for non-STEM occupations [1]. Additionally, STEM workers command higher wages, earning 26 percent more than their non-STEM counterparts and for women who hold STEM jobs; they earn 33 percent more than women in other occupations. Moreover, STEM degree holders enjoy higher salaries, regardless of whether they are working in STEM or not [1]. These statistics provide an impetus for more students to choose STEM areas as fields of study. However, the number of students choosing STEM disciplines, inclusive of computer science is not growing at the rate necessary to keep up with job demand.

According to The New York Times' Christopher Drew, studies note that approximately 40 percent of students who choose to pursue a STEM area either switch their major in college or do not graduate at all [2]. This statistic, as stated by Drew, is twice the combined attrition rate of all other majors [2]. A great deal of research has been conducted on the reasons as to why students choose not to study STEM. It has been suggested that societal stereotypes, environmental and cultural factors, a lack of visible role models, different interests and experiences, and academic un-preparedness are some of the reasons [3]-[6]. However, while these reasons are substantive and well-documented, more research is now being conducted on what happens to students during the first two years of college which deters them from pursuing their goals of becoming a scientist, engineer, mathematician or computer scientist.

One article posits that there has been a dramatic shift in the way in which students learn [7]. It suggests that most high school classes are small. A teacher works with about 30 students at a time rather than the 200 students a college professor teaches during each session. Consequently, many professors cannot offer individual attention to all students enrolled in the course, sometimes leaving some students to teach themselves, which they have not learned how to do [8]. Therefore, a continuously studied issue in higher education is teaching pedagogy and how to best offer course content to a larger population of students who has different learning styles and needs, especially found in the STEM areas.

In the report entitled Distance Education at Degree Granting Postsecondary Institutions 2000-2001, from the National Center on Education Statistics, it was noted that during the 2000-2001 academic year, 56 percent (2,320) of all 2-year and 4-year Title IV-eligible, degree-granting institutions offered distance education courses. Moreover, there were an estimated 3,077,000 enrollments in all distance education courses offered by 2-year and 4-year institutions during the 2000-2001 academic year [9]. Since that report, it has been noted that online course enrollment in the United States hit an all-time high in 2010 with more than 6.1 million students and according to the report from the Babson Survey Group, this number surpassed itself in 2011 and will only increase [10]. The report also stated that approximately thirty-one percent of higher education

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students now take at least one course online and that academic leaders believe that students are satisfied with this type of content delivery method [10].

However, there remains a question concerning online instruction and its effectiveness as compared to face-to-face instruction. Researchers have found that while some online courses have reported significant improvements in student performance over their face-to-face counterparts, other courses found no significant improvement and sometimes students performed worse [11]. Researchers also reported that the reason some online courses are unsuccessful in improving student performance is because they lack the face-to-face interaction that students desire with their instructor and classmates [12], [13]. Consequently, an alternative to online instruction is blended teaching or hybrid courses.

Hybrid courses are often seen as a third alternative in instruction delivery because they offer a mix between online courses and traditional face-to-face instruction. Some researchers describe hybrid courses as a course where 24% to 75% of the course content is delivered online and the other is face-to-face; or the use of a system that relies on computer-mediated instruction; or even a combination of web-based learning delivered using a Learning Management System, face-to-face meetings and chats or blogs [14],[15]. However, no matter what definition is used, hybrid teaching is becoming increasingly popular with many educators because not only do they view it as an effective method for reaching students whose way of learning has shifted away from more traditional techniques but also as a way to promote more active learning among a large student base.

The following section begins by providing an introduction to the environment in which the hybrid course will be offered. The next section introduces the face-to-face course which provides the foundation for the hybrid course. The subsequent section presents the hybrid course. The way that the course will be evaluated is also presented and future work is offered in the last section.

II. COURSE ENVIRONMENT

The hybrid course is designed to be offered at Georgia Perimeter College (GPC), a state college part of the University System of Georgia (USG). The University System is composed of 35 higher education institutions including 4 research universities, 2 regional universities, 13 comprehensive universities, 14 state colleges, 2 two-year colleges and the Skidaway Institute of Oceanography. GPC, a 2-year institution, offers Associate degrees in Arts, Sciences, and Applied Sciences [16]. GPC typically hosts the largest freshman and sophomore enrollments in Georgia, making it the top producer of transfer students to 4-year institutions within the state of Georgia. It has five campus locations throughout the Atlanta-metro area and services approximately 22,000 students. The number of students choosing one of the STEM disciplines is roughly 10% [17].

A. *Instructional Methods of Delivery*

GPC offers courses through several modes of delivery which include face-to-face, online and hybrid. While the number of online course offerings and students enrolled in online courses has grown significantly, there still remains a need for hybrid course offerings in certain areas. The STEM areas typically have less hybrid courses than their humanities counterparts, yet all students are required to take at least College Algebra with a large population required to take Chemistry I and one computer science course. A survey of the 95 hybrid classes offered during the 2011-2012 academic year found that there were approximately eight hybrid classes offered in science and mathematics and none offered in computer science or engineering. Furthermore, of the eight science and mathematics hybrid classes offered, only the statistics course offered is accepted as credit toward a STEM degree; the other courses offered are general science courses. An additional survey of hybrid courses was conducted for the fall 2012 semester. The results again revealed that basic science and mathematics courses were offered, one upper-level division computer science course offered and again no hybrid course offered in engineering.

B. *Hybrid Courses at GPC*

Hybrid courses are offered in five instructional delivery modes at GPC. These modes include:

1) *Type A* - face-to-face meeting once per week
2) *Type B*- face-to-face meeting on alternate weeks
3) *Type C* - face-to-face meeting on alternate Saturdays
4) *Type D* – fact-to-face meeting on four Saturdays in which classes meet for a double class period
5) *Type E* – face-to-face meeting on Super Saturdays, in which classes meet for a triple class period for two or three Saturdays.

The other instruction is offered online. It should be noted that students are informed that hybrid courses do not offer a reduced workload, but offer the flexibility of online learning with personal contact with the instructor and classmates. All hybrid course students complete the same amount of course work with the same learning goals and outcomes as their traditional face-to-face or online course counterparts [18]. The classes are held during a 16 week semester.

The author has taught traditional face-to-face courses at the undergraduate level within the computer science curriculum for many years. Prior to the design of the hybrid course, the author taught *CSCI 1300 – Introduction to Computer Science* using the traditional face-to-face method of delivery. At GPC, *CSCI 1300* is a course that is part of the common core and therefore it is a commonly taught course. The next section describes the course; the student population enrolled; and, includes the methodology the author used to teach the course. This material is used as the basis for the design of the hybrid course which is presented in the subsequent section.

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III. Introduction to Computer Science

A. Course Description

CSCI 1300 – Introduction to Computer Science is designed to provide students with an overview of selected major areas of current computing technology, organization and use. Topics surveyed include the history of computing, data representation and storage, hardware and software organization, communication technologies, ethical and social issues, and fundamental problem solving and programming skills [19].

Prerequisites are exit or exemption from all Learning Support, English as a Second Language (ESL) requirement and successful completion of College Algebra [19]. For computer science majors, the course is a prerequisite for successive courses within the program of study. For non-math based majors, the course meets the requirements of the common core in the area of science, mathematics and technology from which students must choose.

B. Topics Covered

Since the course is a commonly taught course, all students regardless of delivery mode are presented with the following topics [19]:

- The history and vocabulary of computers
- Problem-solving, algorithms and algorithm efficiency
- Data representation and storage
- Computer hardware and software concepts
- Computer networks
- Information security
- Programming concepts and problem-solving
- Social and ethical issues

C. Learning Outcomes

The learning outcomes are designed by the course curriculum committee. It was decided that by the end of the course, a student should be able to [19]:

- Discuss the history of computing.
- State the methods by which data is represented and stored in a computer's memory.
- Recognize and understand the fundamental hardware components of a computer system.
- Recognize and understand the fundamental software components.
- Understand the concepts of current communication technologies.
- Understand basic networking and information security.
- Recognize and understand social and ethical issues involved in computer use.
- Analyze a basic real world problem and solve it with a computer program.
- Understand and write algorithms using fundamental computing concepts.

D. Student Population

The course is designed for and utilized by students who have chosen one of the STEM areas as a major. Non-STEM majors are encouraged to enroll in another course, with similar content but designed specifically for students not pursuing one of the STEM areas as a major. However, since *CSCI 1300* can also be used by non-STEM majors to satisfy a math requirement, the student population is often varied. On average, course enrollment is between 20 and 30 students, with the percentage of STEM to non-STEM majors fluctuating.

The next part of this section describes popular teaching styles and introduces collaborative learning. Also presented is the rationale for the utilization of the stated teaching style.

E. Teaching Methodology

According to Grasha, there are four approaches to teaching [20]:

- Formal authority, an instructor-centered approach where the instructor provides the flow of content
- Demonstrator/personal model, an instructor-centered approach where the instructor demonstrates the skills
- Facilitator, a student-centered approach where the instructor acts as a facilitator and the responsibility is placed on the student to achieve results
- Delegator, a student-centered approach where the instructor delegates and places the responsibility for learning on students and/or groups of students

The instructor decided that based on the student population enrolled in the course, that formal authority would be used as the teaching style. It is noted that this teaching approach has its challenges, with one being the lack of personal engagement between teacher and student; and student and student. Consequently, the instructor also incorporated collaborative learning into the course.

F. Collaborative Learning

In educational environments, student study groups are often formed to gain better insight on course topics through collaborative efforts. Collaborative learning is defined as the grouping and/or pairing of students for the purpose of achieving an academic goal [21]. Davis reported that regardless of the subject matter, students working in small groups tend to learn more of what is taught and retain it longer, than when the same content is presented in other more traditional instructional formats [22].

Supporters of collaborative learning suggest that the shared learning environment allows students to engage in discussion, take responsibility for their own learning, hence becoming critical thinkers [21]. Research has shown that collaborative learning encourages the use of high-level cognitive strategies, critical thinking, and positive attitudes

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toward learning [23]. Further, it has been suggested that collaborative learning has a positive influence on student academic performance [24].

G. *Content Delivery*

The class time was divided into three segments. The first half of the class time was spent providing students with the theoretical concepts, while the second part of the class period students spent solving problems independently or in groups. Toward the end of the class period, students shared the results of the work and concepts were summarized and reinforced. The instructor found that this method worked well for both STEM majors, who needed both the theoretical foundation and the application; and, for the non-STEM majors who enjoyed the application of the course content. Consequently, the instructor decided to use this model as the premise for the development of the hybrid course.

IV. Hybrid Course Design

As previously stated, a survey of courses found that during the academic year 2011-2012, no hybrid courses were offered in computer science. A survey of the fall 2012 classes, found that once hybrid computer science course was offered, but it was for computer science majors only and is typically taken by second year students who are on the verge of transferring to a 4-year institution the next semester. Therefore, the uniqueness of this design is for a course offered at the freshman level which will impact a larger student population with a wide variety of technical backgrounds.

A. *Course Content and Learning Outcomes*

Since the course is a common course, the learning outcomes and the course content remains the same. However, it was decided that during the first face-to-face meeting an overview of the Colleges' Learning Management System, iCollege/Desire2Learn, would be done to ensure that students know how to properly use the system since the course would rely heavily on its use.

B. *Teaching Pedagogy*

It was decided that the facilitator teaching style would be utilized. The facilitator teaching method, unlike formal authority, is a more student-centered approach which shifts the focus of activity from the teacher to the learners. This method includes active learning, collaborative learning and inductive teaching and learning [20]. The facilitator teaching style has been stated to work best for students who are comfortable with independent learning and who can actively participate and collaborate with other students [25]. In particular, this approach was chosen because in education literature, the method has been shown to increase students' motivation to learn, to lead to a greater retention of knowledge, and to positively impact attitudes toward the subject material being taught [24], [26], [27]. Moreover, the method places a strong emphasis on collaborative learning. Additionally, the author had previously used this method in similar courses and has had good results [28].

C. *Content Delivery*

As previously stated, researchers note that there has been a dramatic shift in the way in which students learn [7]. Technology supported learning provides students with an opportunity to view online situations and examples that help to aid the learning process. Additionally, technology supported learning has been shown to be beneficial to students who are visual learners rather than auditory learning [29]. It has been noted that students process visual information 600,000 times faster than text, and visual aids can improve learning by 400% [30]. However, from a delivery perspective, technology supported learning provides a semi-permanent resource which allows students to re-visit the clips, thereby having the potential to develop greater understanding of the material.

Consequently, it was decided that the PowerPoint slides that the author typically uses in face-to-face classes, would be revised to include an enhanced learning experience for students. The slides would be revised using Camtasia Studio. Camtasia is a screen recording and video editing tool that allows educators to edit and share high-quality screen video on the Web, YouTube, DVD, CD, portable media players and the iPod [31]. The slides would be posted in iCollege. iCollege also has chat, blogs, video and email features.

D. *Course Organization*

The instructional delivery format that the *CSCI 1300* hybrid course will utilize is Type A, which means that the face-to face class period will meet once per week for 1 hour and 15 minutes and all other meetings will take place online.

Prior to the class meeting, students will be strongly encouraged to view the enhanced PowerPoint lecture slides available in iCollege/Desire2Learn. At the end of each lecture, end-of-lecture questions will be asked to which students will receive immediate feedback. The instructor will also have access to student responses and performance. This information will be used to determine the content and the time frame needed for review of material during the face-to-face class period.

The face-to-face class period will be spent as an interactive lab environment coupled with collaborative learning, much like those seen in flipped classroom models [32],[33]. For the first 15 minutes of the course, the instructor will answer questions and review key concepts from the online lectures. The next 45 minutes will be spent by students engaged in hands-on laboratory work using the computer. The last 15 minutes will be used to summarize the concepts presented and to briefly introduce the next concepts to be discussed. Figure 1 presents the design for the face-to-face class meeting.

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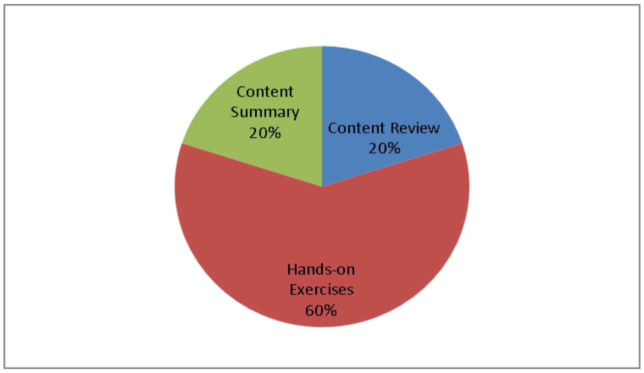

Figure 1. Hybrid Course Design

To teach hardware and operating system concepts, computer simulators will be used like those from teach-sim educational simulators and Cisco Binary Game [34], [35]. To teach problem-solving, algorithm writing and efficiency, students will utilize the algorithmic simulators that accompany the required laboratory textbook. Visual Studio is used as the development environment and students will use this to program small-scaled projects in C++. Lastly, to engage students in the concepts of social and ethical issues, it was decided to use case studies and debates. Students will be divided into teams and given an issue in which they must debate the pros and cons of the argument. Table 1 provides an overview of how topics will be covered during the 16 week semester.

TABLE I. CONTENT DELIVERY

Week	Topic	Activity
1	Introduction to Course and History of Computing	iCollege review
2	Representing Algorithms	Algorithmic simulators
3	Attributes of Algorithms	
4	Binary Numbering System	Cisco Binary Game and binary numbering simulators
5	*In class exam*	
6	Boolean logic and gates	Logic gate simulators
7	Components of a computer system	Computer simulators
8		
9	Basic networking	Network software simulator
10	Software security	Research on threats and encryption software simulators
11	*In class exam*	
12	Introduction to C++	Introduction to and using Visual Studio
14	Ethical issues	In class debates
15		
16	Prepare for final exam	

V. ASSESSMENT

A. Student Assessment

Students will be assessed in the following manner:

- *End-of-lecture questions* – these questions are basically designed for student use and will be used by the instructor not as a tool for grading but to determine concepts on which the instructor needs to spend more time reviewing during the class period.
- *Assignments* – the common course outline requires that there be a minimum of eight projects completed during the semester
- *Exams* – there will be two in-class exams
- *Final exam* – one final examination will be given at the designated time at the end of the semester

B. Course Assessment

Two types of assessments will be utilized to determine the effectiveness of the course. The first assessment will be a student survey which will include measures on students' attitudes and self-efficacy as it relates to course material and content delivery. The second evaluation will be student performance.

VI. CONCLUDING THOUGHTS

The aim of this paper was to present the design for a hybrid breadth-first introductory course in computer science taught at a 2-year institution. The course content, learning outcomes, teaching pedagogy, course organization and how the course will be evaluated were presented. Future work includes the redesign of the traditional PowerPoint slides to include an enhanced learning experience for utilization in the hybrid course.

The course is unique in that it provides an opportunity for a large number of students whose technical skill set is often varied to engage in and actively learn foundation principals in computer science. The delivery of the content through hybrid learning provides a blended mix of the traditional face-to-face interaction students often desire with the flexibility of online learning, which many 2-year institution students need. However, the author acknowledges that the redesign is not without its challenges. The author anticipates concerns in the areas of student perception and performance. Moreover, the author has some concerns on creating the videos to ensure that the theoretical concepts are correctly captured for the skill set of the audience.

It is projected that the U.S. will see over 1.2 million STEM job positions open up by 2018. As the workplace and the way in which students learn change, the way in which to best meet the needs of these constituency groups must change as well. As educators it is our job to ensure that our students are ready for these and other opportunities and to provide them with an educational experience that will increase their chance for success.

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Simulating Forces

Learning Through Touch, Virtual Laboratories

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***Abstract*— With the expansion of e-learning course curricula and the affordability of haptic devices, at-home virtual laboratories are emerging as an increasingly viable option for e-learners. We outline three novel haptic simulations for the introductory physics concepts of friction, the Coriolis Effect, and Precession. These simulations provide force feedback through one or more Novint Falcon devices, allowing students to "feel" the forces at work in a controlled learning environment. This multimodal approach to education (beyond the audiovisual) may lead to increased interest and immersion for e-learners and appeal to the kinesthetic learners who may struggle in a traditional e-learning course setting.**

Keywords-Haptic simulations; e-Learning

I. Introduction

E-Learning has exploded in popularity in recent years, and for good reason. Both online and brick-and-mortar institutions offer an increasing variety of courses on the web to students from around the world. While the convenience of an e-learning course is difficult to beat, instructors may struggle to retain students, keep them engaged, or know whether their students are fully grasping the material. Furthermore, many courses do not always translate effectively into existing Edtech (Education Technology) platforms [1, 2].

As virtual classrooms proliferate, the tools of trade continue to develop in tandem. Multimodal interactions are especially important, and these novel and multidimensional approaches have been proven to increase user engagement, interaction, and mastery of concept [3–6]. While these virtual classrooms do not replace traditional face-to-face teaching models, they can augment these models and may prove invaluable to e-learning course curricula.

Haptics in computing refers to the addition of force feedback to the user through commercially available hardware. Through this technology, users may engage their senses beyond their visual perceptions alone, allowing for a more intuitive understanding of complex or abstract concepts. Haptics in virtual laboratories are particularly effective when touch is required for the correct comprehension of physical phenomena, variation of frequencies, medical procedures, engineering, virtual museums, etc. [4].

We provide an overview of three haptic-based virtual simulators that can be merged into existing Edtech systems like Vista or MOODLE. These simulators take advantage of the open source H3D API, creating three dimensional audiovisuals coupled with a tactile (haptic), interface. The three simulations outlined in Section 2 augment the teaching of Introductory Physics Concepts of: friction, the Coriolis Effect, and torque-induced precession [7].

II. Background and Related Work

A. *E-Learning and Virtual Laboratories*

While the majority of e-learning programs are merely video, chat, and discussion board based, it is easy to see the prudence of elevating to a standard that may nurture and stimulate students' curiosity and aptitudes. Creating an authentic learning experience has long been a concern of e-learning course providers, and many experts agree that such an environment requires community, "experimentation and action" [8].

Haptic, or kinesthetic, learners are those who prefer a more active approach to course materials [9]. Vincent and Ross estimate that these kinesthetic learners make up approximately 17% of the population [10]. The integration of virtual laboratories into online Edtech platforms creates environments where e-learners may both self-teach and collaborate with others to maximize their learning potential [5].

Brown, et al [11], argue that how a person perceives an activity is dependent on their environments and tools. Thus the implementation of haptics in e-learning may improve experiments where the representation of material properties and experimentally relevant forces are of the utmost importance [4]. Dudulean et al found that haptic feedback, through a low cost and relatively small device, increased the effectiveness of an interaction, resulting in students spending more time exploring the virtual objects, and increased motivation, interest, critical thinking development, and problem solving [12]. While most haptic simulations were designed to augment traditional classrooms, Schaf, et al [6] went one step further to integrate their deriveSERVER (providing remote access to a virtual reality environment and also a real experiment) with

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a collaborative MOODLE interface for their engineering workspaces.

The ideal collaborative learning environment for engineering education, according to Pereira et al [5], includes: a shared workspace for educational media and a theoretical material module (common to virtual learning environments), an immersive 3D social interface (like SecondLife), content adaptation to user feedback, integration of virtual labs or experiments, intelligent tutoring systems, teamwork and collaboration support, augmented sense immersion (beyond just sight, hearing, and touch), and serious game concepts – the use of game-like solutions that capture attention and educate as they entertain [5]. While no such system yet exists, the continued incorporation of haptic technology into existing e-learning courseware may be a great step toward providing distance learners an education more on par to that of students at traditional brick-and-mortar institutions.

B. *Haptics APIs: H3D*

SenseGraphics' H3D API is an open source, cross platform development toolkit for creating visuo-haptic scene graphs [13]. It is released under the GNU GPL license with commercial licensing options. The high level interfaces of the API are X3D (another open source format) and Python. While X3D provides the 3D graphics vocabulary, Python describes the application's user interface behavior [14]. Most importantly, H3D allows for rapid prototyping and supports a wide range of haptic devices.

III. CASE STUDIES

The three physics demos outlined herein were developed with the intention of augmenting the introductory (calculus-based) physics curricula at Armstrong Atlantic State University in Savannah, Georgia. While the simulations have not yet been implemented into an online e-learning system, expansion into that realm would be an immediate future extension.

Each of the case studies below employed one or more Novint Falcon devices. This device, classified as a game controller, was chosen because of its robustness, relatively small working volume, commercial availability, and increasing affordability. Currently, one can purchase one such device (with the standard features) on the Novint website for the same price as a HD web cam [15].

A. *Concept: Friction*

The Friction demo, detailed in [7], provides a carefully controlled environment where students can perceive the effects of static friction, kinetic friction, slope inclination (and gravity by extension), mass, and user-generated forces on the movement of a block on an inclined plane. While the virtual environment is 3D, the block movement on the inclined plane is restricted to one dimension to facilitate user control. The three dimensionality of the simulation ultimately comes into play through manipulation of the

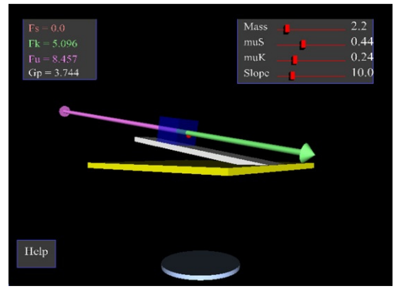

Figure 1. Friction Simulation: Screen shot of simulation.

rotating disk at the bottom, center (Figure 1) that allows the user to rotate the scene to view it at different angles.

Students were given instructions on how to interact with a block on an inclined plane. A static frictional force acted on the block to impede its movement, while a kinetic frictional force acted on the block as it moved. Users attempted to move the block via the haptic pointer. In addition to the haptic force feedback from the Novint Falcon hardware, resulting force directions and magnitudes were displayed visually through three dimensional arrows while a heads-up display stated the explicit magnitude values, as illustrated in Figure 2.

An evaluative pre-test of the 86 participants showed that most students had only a rudimentary knowledge of static and kinetic friction, with the average score being 36.7% (random chance would yield a score of 19.7%). After the pre-test, the students attended a 50-minute conventional lecture about static and kinetic friction. The lecture was followed by a post-test, and students were split into two groups with equivalent post-test results.

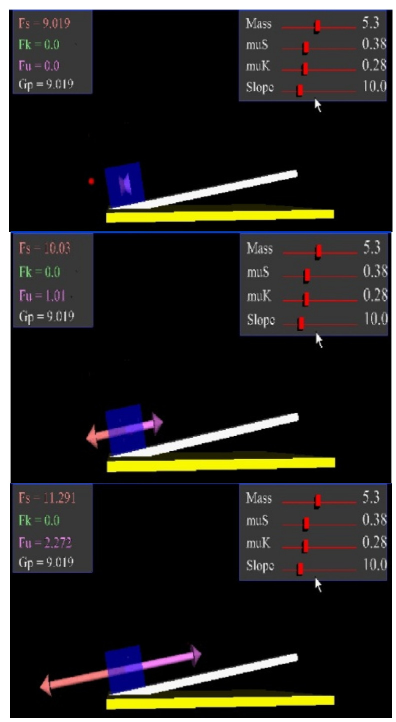

Figure 2. Friction Simulation: Force magnitudes represented as arrows, as the user pushes the block up. The dot on the topmost image near the block represents the position of the haptic pointer.

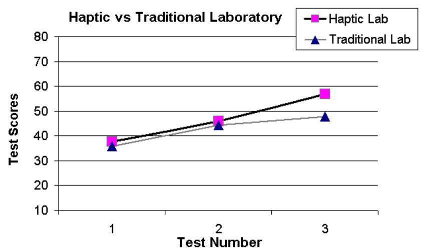

Figure 3. Average Test Scores For Haptic vs. Traditional Lab Groups [7]

After the division into groups, group A performed lab experiments using the visuo-haptic simulator while students in group B performed similar experiments in a traditional laboratory setup. Afterward a final test was administered, test score normalized gains were calculated as

$$(\text{Test } 3 - \text{Test } 2) / (100 - \text{Test } 2). \qquad (1)$$

Figure 3 illustrates the efficacy of the haptic simulation over traditional teaching methods regarding frictional force concepts. The normalized gain of group A was 0.182, while the gain was slightly negative for group B at -0.011. Not only were average test scores higher among the student users of the simulation, but overall student curiosity and attention measured in an attitude survey were superior to those who had not used the setup.

B. *Concept: The Coriolis Effect*

The Coriolis effect is one of the more complex concepts to convey to introductory students. It is a phantom force that appears to alter the path of an object in juxtaposition of another spinning frame of reference. A plane flying south from the North Pole would appear to be deflected to the right (or westward) because of the Coriolis effect.

The Coriolis application attempts to illustrate the concepts of this perceived force through a simple simulation where the user attempts to push a ball into a goal (using the Novint Falcon haptic device) within a spinning frame of reference. While the background of the simulation spins, users feel a deflecting force (representing the Coriolis effect) parallel to the direction of rotation. Users are forced to compensate for this force to score a goal (as illustrated in Figure 4).

In contrast, users may appreciate the change in “feel” without the Coriolis effect - second simulation. The second simulation implements a glider (instead of a ball) that is not affected by the surface friction of the ground, thus mimicking a static (non-rotating) frame of reference.

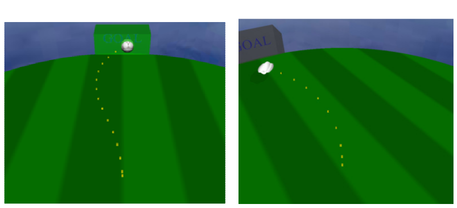

Figure 4**.** Coriolis Simulation: Ball and Glider Simulations

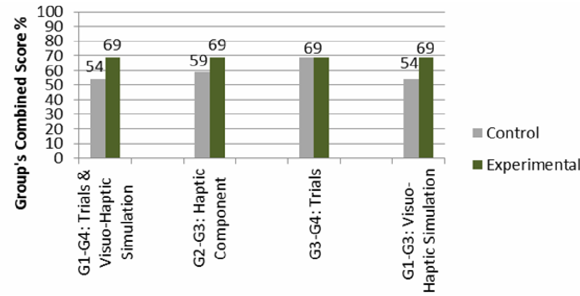

Figure 5. Coriolis Quiz Score Comparisons

24 undergraduate students taking Principles of Physics I at Armstrong Atlantic State University were divided into four groups of six students. GPAs between groups were similar. All groups were given supplemental reading material and a video on the Coriolis effect. Group 2 participated in a visual simulation with no haptic feedback. Group 3 participated in a visuo-haptic simulation involving force feedback. Group 4 was given a tutorial on the use of the haptic devices, then participated in a visuo-haptic simulation with force feedback. All groups were quizzed and given subjective assessment questionnaires at the end.

As shown in Figure 5, the groups that participated in the visuo-haptic simulation showed a 15% advantage in quiz scores over the groups only given reading material and a video. The group that participated in a simulation without haptic feedback only showed a 10% increase in quiz scores. A tutorial on the haptic hardware prior to the simulations did not affect quiz scores, proving either the tutorial ineffective or unnecessary. Both test scores and students' subjective assessments reflected the positive benefits of the simulation, including increased student engagement and grasp of abstract concepts [16].

C. *Concept: Precession*

Torque-induced precession refers to the wobble that occurs when a spinning object’s axis of rotation shifts in orientation because of an applied torque, or rotational force. Precession is often observed in spinning tops and gyroscopes. Precession, and its relationship to angular velocity and angular momentum, is an important abstract concept that is not always immediately understood, especially by kinesthetic learners. The Gyroscope application provides force feedback through an interactive gyroscope that tilts as it spins (Figure 6,7).

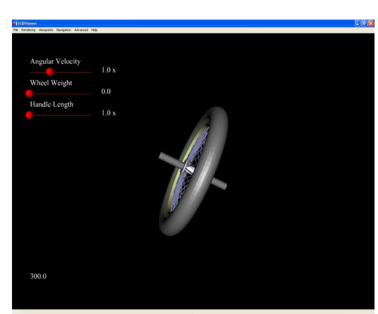

Figure 6. Gyroscope Simulation: Screen Shot


Figure 7. Gyroscope Simulation: Device Setup

This simulation utilizes two Novint Falcon devices, one for each of the user's hands, pointed toward each other. The devices are engaged simultaneously, allowing the user to feel the tilt of the gyroscope handles as the wheel spins. Users can adjust angular velocity, wheel weight, and handle length to experience the resulting precession changes.

The application is currently under assessment and if successful, it may become an integral part of our introductory physics Touchable Virtual Laboratories.

IV. Conclusion and Future Work

In the early days of e-learning, costs and lack of sophistication in online courses were prohibitive. The lowering of hardware prices, dramatic improvement of internet bandwidth and reliability, and increased savviness of online educators in their course designs suggest that the popularity of e-learning programs can only grow. While conventional institutions of higher education are not expected to fall by the wayside, they must improve content and knowledge delivery to keep up with the new demands in the informational age. As much as many e-learning instructors are "motivated by a strong conviction that the work they are doing is important to students who need flexible access to education", they are still "clearly meeting a need" [17]. For e-learning courseware to truly compete with the traditional brick-and-mortar programs, measures must be taken by institutions to impart a more immersive, engaging experience on their students.

Just as the pedagogy of physics was advanced dramatically by the introduction of computers as visual learning devices, the tactile activities envisioned in a haptic-enabled laboratory promises similar benefits, especially for kinesthetic learners and for students with disabilities [18]. The three applications outlined in this paper are just examples of the plethora of content a virtual haptic enhanced laboratory can provide. These virtual labs stimulate multiple user senses, and may prove invaluable additions to existing e-learning systems, improving their information distribution capacity, user engagement, and users' learning efficiency.

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