KNOWLEDGE CENTRE FOR EDUCATION

INFORMATION AND COMMUNICATIONS TECHNOLOGY AND LEARNING

State of the Field Review

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In this State of the Field study our goal was to conduct an objective and comprehensive review of the field of ICT in Education in order to summarise the field, identify the primary research themes that have emerged, understand why they have emerged, summarise the principal activities and findings from those research themes, and finally identify future strategic research actions that would strengthen not only each theme but also the entire field of ICT in Education

CONTENTS

EXECUTIVE SUMMARY

In this State of the Field study our goal was to conduct an objective and comprehensive review of the field of ICT in Education in order to summarise the field, identify the primary research themes that have emerged, understand why they have emerged, summarise the principal activities and findings from those research themes, and finally identify future strategic research actions that would strengthen not only each theme but also the entire field of ICT in Education.

For our main corpus the most influential works published since 2000 in peer reviewed scientific journals were selected. To identify the National perspective, all completed Norwegian Doctoral Dissertations since 2000 were collected, and to provide some perspective on international research themes all IST projects reported on the European Union's ISTweb repository were included.

In order to minimise the subjectivity usually associated with a literature review we used two independent sources and influence ranking mechanisms, Web of Knowledge and Google Scholar, when searching for the most influential works. Furthermore, searches used to create our main corpus were carried out using independently created lists of domain terms that were obtained from the TEL Meta-project, a legacy of the Kaleidoscope and STELLAR Networks of Excellence in Europe. The digital reference management system Zotero was used to store, organise, and analyse the material from the different sources. Our material comprises a main corpus of 680 articles, a top 10% corpus of 67 articles, 60 books, 60 Norwegian Ph.D theses, and 149 EU projects.

A summary of the ICT and learning field was carried out in three ways. First, Paper Machines, an open-source data visualisation extension for Zotero, was used to generate analyses and advanced visualisations of our corpora including word clouds, topic models, phrase nets, and n-grams. Second, an analysis of the tags used on the main corpus was carried out using terms from the TEL Thesaurus, part of the TEL Meta-project. Third, a thematic analysis of recurring authors in the main corpus was undertaken.

Three primary research themes emerged from the analyses: Learning Design, Collaborative Systems, and Intelligent Systems. In order to understand why these three themes have emerged we carried out a background and historical analysis of the themes, identifying key texts that show the historical development. We summarised the principal activities and findings from the three themes producing systematic reviews of the three primary themes. In addition to the historical picture for each of the areas we have suggested target research actions and we have identified future strategic research actions not only for each theme, but also for the entire field of ICT and Learning.

Our conclusions are both methodological and thematic. Methodologically we raise questions about monopoly of sources, author awareness of tagging, and access to completed projects, including both EU projects and Norwegian doctoral dissertations.

The theme ICT and Learning is a vast and complex domain of enquiry. It is subject to rapid change as it seeks to reflect advances in the capabilities of the underlying technology. Studies are often driven by exploration of the technology as opposed to fundamental research questions related to pedagogical design or learning, and little evidence of real world impact was visible within our corpus.

The last decades of the 20th century saw the development of increasingly powerful information and communication technologies (ICT) (Berleur & Galand, 2005), with an impact so far reaching that it would have been impossible to predict. In the Norwegian Stortingsmelding nr. 17, *An Information Society for All,* it is written that "Information and communication technology (ICT) has helped to change the world, not just once, but many times … ICT is the technology area over the past 30 years that has contributed to major changes in our everyday lives" (Stortingsmelding, 2006). Thus, it is only logical that these advances in technology would be applied to the field of education, as it was also applied to other areas of society. In fact, the application of ICT for learning has been around since the earliest days of computing.

From the first operational instructional program, developed in 1963 at Stanford to teach elementary mathematical logic (Suppes, 1971), to current learning applications that can be run (e.g., Norwegian developed Dragonbox ++[1]) or accessed (e.g., Khan Academy[2]) on your Smartphone or iPad, emerging technologies have been embraced, and have impacted practices within formal learning (e.g., in schools, higher education, Professions) and informal learning (e.g., in museums) settings, and in the workplace (eg., KnowledgeForum[3]).

Initially educational applications of ICT were crude attempts to provide rudimentary rote learning practice (Hunt, 1987) but, as the capabilities of the technology advanced, the educational applications became increasingly complex and invasive into all aspects of educational practice (Leach & Moon, 2002). In this complex field, we find ICT involved in the administration of student enrolment and attendance (e.g., LMS systems), and performance (e.g., e-assessment), through to the use of rich interactive digital media (e.g., simulations) to provide students with compelling learning experiences that closely matched advances in recreational gaming (e.g., SERIOUS games), mobile devices (e.g., location-based learning applications), and social media (e.g., Twitter in the classroom), and in the development of 21C competences (e.g., digital, creativity, collaborative, etc.). That is, all aspects of education have the potential to be transformed. One cannot, however, discuss ICT and learning without being cognisant of the dichotomy between the digital everyday lives of students (Tapscott, 1998; Prensky, 2003, 2007) and traditional schooling systems that are resistant to change where "pedagogical practices have largely remained traditional even though the adoption of ICT in classroom practices has increased" (Law, Yuen & Fox, 2011).

Figure 1 presents a historical overview of the development of ICT and learning environments since the late 1960s (Wasson, 2013) from Computer-Aided Instruction (CAI) and Computer-Based Learning (CBL), to microworlds, Construction environments, and Intelligent Tutoring Systems, through Computer Support for Collaborative Learning, Telelearning (or Online learning environments) to Mobile Learning and Participatory environments (or Social Learning environments). Most of these environments emerged from research fields that are still active today, many with dedicated journals and conferences. Imposed over the development axis are the major theories of learning (or emerging theories) that have had an impact on the field. Under the axis are theories of teaching (Olsson, 1991, augmented by Wasson (2013), that can be said to have had an impact on our understanding of the role of the pedagogical practices operationalised in the learning environments. Such a historical overview provides only a starting place for understanding this complex field of ICT and Learning.

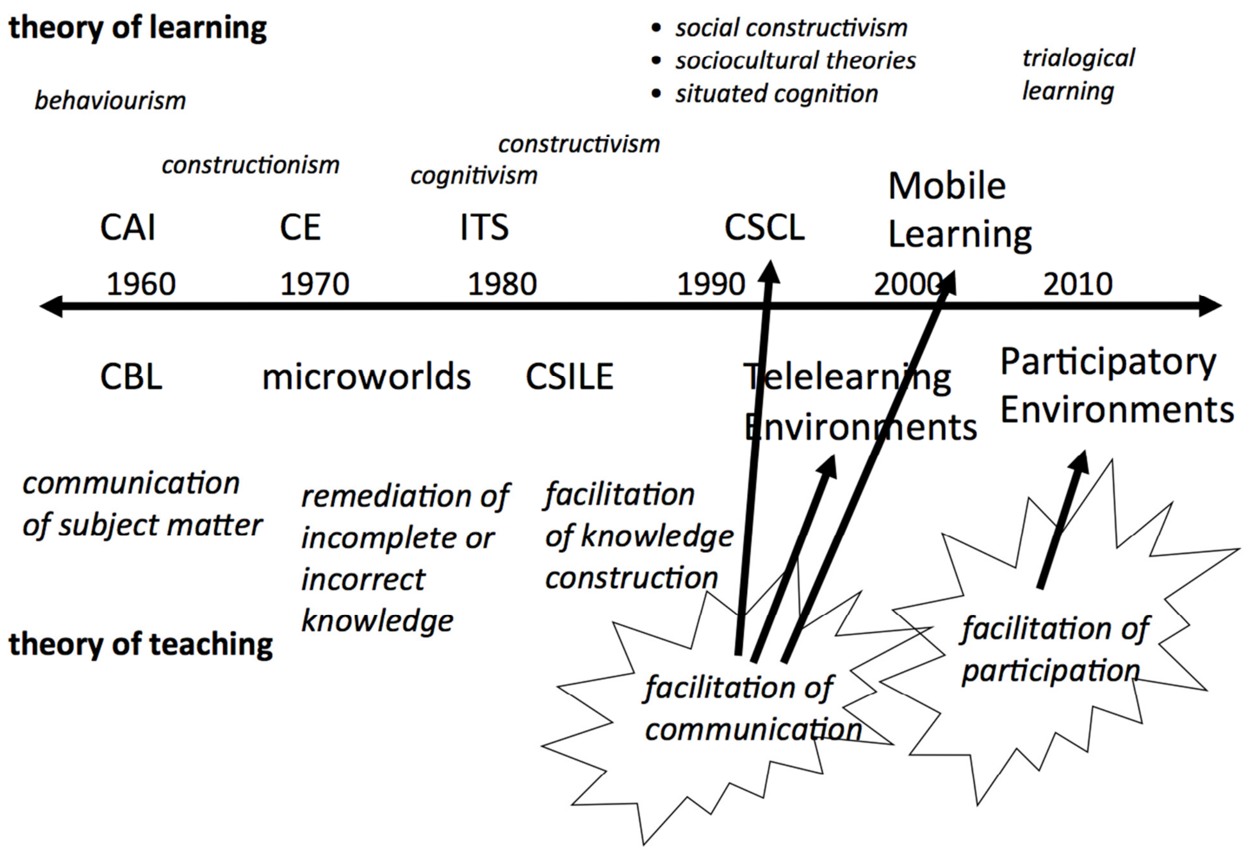

Figure 1: Historical Perspective on ICT and Learning (Wasson, 2013)

Legend: CAI (Computer Aided Instruction), CE (Construction Environments), ITS (Intelligent Tutoring Systems), CSCL (Computer Support for Collaborative Learning)

By the end of the first decade of the 21st century the field of ICT and learning covered all aspects of the modern learning experience for students (e.g., Clark, Logan, Luckin, Mee & Oliver, 2009; MIT2012), all aspects of the pedagogical process for educators (e.g., Wake & Wasson, 2011), and all aspects of the administrative processes for educational institutions (e.g., Laurillard, Oliver, Wasson & Hoppe, (2009)). One interesting observation is that this process of reforming the learning environment into a digital form has been largely driven by advances in technology (e.g., Horizon reports, http://www.nmc.org/horizon-project) and very little of the development has been driven by informed theory or empirically derived design decisions (Ross, Morrison & Lowther, 2010). This means that although learning and pedagogical practice have been transformed (e.g., see latest report on innovating pedagogy (Sharples et al., 2013)), it has not always been an informed process as research has tended to follow changes in the capabilities of technology and not directly influenced the design or implementation of such new technological capabilities. Advocates of design based research approaches (Brown,1992; Barab & Squire, 2004), however, try to remedy this general situation (e.g., Barab et al., 2007; Richey & Klein (2008)).

The pervasive nature of ICT has transformed the ways we work, shop, communicate, play, and socialise. It has also transformed the economies of developed nations of the G20 group from economic models based on industrial production to rapidly evolving economic models based on knowledge transformation and creation within digital forms (Drucker, 2004). Increasingly this knowledge manipulation and creation is being represented in rich multimedia formats that transcend traditional geographical and temporal boundaries, and which interact autonomously with semi intelligent mobile devices in real time. These systems share information and knowledge at speeds, which transcend human perceptual and cognitive limits. With such transformations in the capabilities of ICTs there is an expectation that such knowledge and communication will be available everywhere instantly. Consumers, communicators, learners, and citizens have an expectation that their requirements for rich digital forms of knowledge will be instantaneously available on demand and independent of traditional constraints of time and space. Furthermore, this is necessary so that Nations are able to maintain a competitive advantage with respect to the skills of their citizens in a global knowledge economy.

Such fundamental changes in the economic models of developed nations demand equally fundamental changes in the expectations of, and the performance of, the educational delivery modalities, learning outcomes, pedagogical techniques and the administrative systems employed by schools and postsecondary institutions (Kozma, 2005, 2008; Law et al., 2011). Other issues at stake are the growing digital divide (both access and skills (see Digital Agenda for Europe (EU2020), and digitaldivide.org), the gap between learner's life in and out of formal learning institutions (e.g., digital experiences from informal settings do not directly convert to learning strategies (Egeberg et al., 2012; Pedro, 2012; Søby, 2013)), lifelong learning (Sharples, 2000; and more recently personal learning environments (Attwell, 2007)) and the fundamental discussion (both political and academic) around how and what students need to learn (e.g., Rochelle et al., 2000; Brinkley et al., 2012).

CHALLENGE FOR STAKEHOLDERS

The challenges for strategic stakeholders seeking to advance Regional and National interests in science, technology and education are therefore complex. With such radical change taking place it is problematic to know where to invest limited state resources to gain the results necessary to ensure that a nation's human capital remains optimally skilled for the knowledge economy.

In Europe, two flagship initiatives under the over-arching policy EU2020 are *Digital Agenda for Europe* (DAE) and *Youth on the Move*. DAE's objective is to promote Internet access and take-up by all European citizens through actions in support of digital literacy and accessibility, with a special focus on the digital divide and those who are socially excluded or at risk for social exclusion. *Youth on the Move* outlines policies to reduce youth unemployment rates and promotes approaches such as apprenticeships and in addition the acquisition of digital and media skills to improve attractiveness for the workforce. The use of ICT and learning is central in these initiatives.

In Europe regional efforts have focused on funding Technology Enhanced Learning (TEL) research on "...how information and communication technologies can be used to support learning and teaching, and competence development throughout life." (TeLearn: CORDIS Web site, 2013). However, such broad regional research actions can leave it unclear to National research bodies where they should encourage their own National research focus, as the possible populations to be studied are extremely broad and the variables that could be investigated in any one research project are wide ranging. With so many possible elements to investigate it is easy to focus studies on existing learning situations and ignore factors that could play critical roles in the future. For example, age and multicultural users are seldom considered in current research within the field and yet both could have major implications (Berends & Penaloza, 2010).

NEED FOR A SYSTEMATIC SYNTHESIS OF THE FIELD

With our future competitiveness at stake it is clear that there is an urgent need for developing a knowledge base to support evidence-based policy making, management, dissemination, practice, and debate around the role of ICT and learning for all levels of education.

A major step in this process is the provision of a definitive review of the most influential research work that has been completed within the field of ICT and learning, with the goal of identifying the methodologies that have been applied, the theoretical perspectives that have proven successful, the findings that have proven to be relevant enough to transform real world practice, and an understanding of how those findings interact with other studies.

Such a comprehensive, systematic synthesis of our understanding of this complex field can provide strategic stakeholders with a clear roadmap of what is known, how it complements other work, and most importantly where the gaps exist in our understanding of this complex and evolving field.

DEFINING THE PROBLEM SPACE

The field of ICT and learning is an evolving multifaceted and multidisciplinary collaboration between the scientific specialisations of computer science, psychology, learning sciences (*cognitive science, educational psychology, anthropology, linguistics, design of curricula, learning environments, instructional methods, and policy innovations*), educational sciences (*pedagogy, didactics*) and sociology. Five main areas of research underpin the field (Balacheff, Ludvigsen, de Jong, Barnes and Lazonder, 2009):

- *The design area*: with a focus on the design and co-evolution of new learning activities.
- *The computational area:* with focus on what technology makes possible.
- *The cognitive area:* with focus on what the individual can learn under certain conditions in different types of context
- *The social and cultural area:* with focus on meaning-making, participation, and changes in activities in schools, universities, workplaces and informal settings, and
- *The epistemological area:* with focus on how the specificities of the domain impact the design and use of technologies.

As such it demands a specialised multidisciplinary expertise to be able to fully understand the literature and synthesise its methods, theories and findings into a coherent whole that can clearly show what is known: the unit of analysis *(individual development, group process, interaction through technology, institutional, etc.*), how it was discovered (*what methodologies were applied: experimental, case studies, design research, action research, etc.*), how the findings were understood (*the theories underlying the work: cognitive, constructivism, socio-cultural, socio-technological, etc.*), their impact on practice, and most importantly what is uncertain or remains to be discovered.

This report is an attempt to provide such a synthesis. Beginning with the development of a corpus of literature published since 2000, we have analysed the literature from several perspectives, traced the roots of the emergent themes, and taken a look forward to where the research is headed.

NARROWING THE FOCUS

The target learning domains that could be studied are also very broad and include both formal (pre-school, Primary, Lower and Higher Secondary, Higher Education, and Professional and Workplace settings) and emerging informal educational mechanisms (e.g., You Tube, informal online academies, and massive open online courses (MOOCs)). Within these learning domains there are numerous operational variations, see figure 2, that could be legitimately investigated, including how the learning space is configured physically, technologically and virtually; support for and tolerance of temporal and geographical independence of learners and learning; pedagogical approaches (what is taught/learned; how it is taught/learned; and why it is taught/learned); learning activities (simulations, face to face, collaborative); models of learning being employed; and finally which competences are being inculcated (creativity, digital skills, participation, inquiry, collaboration).

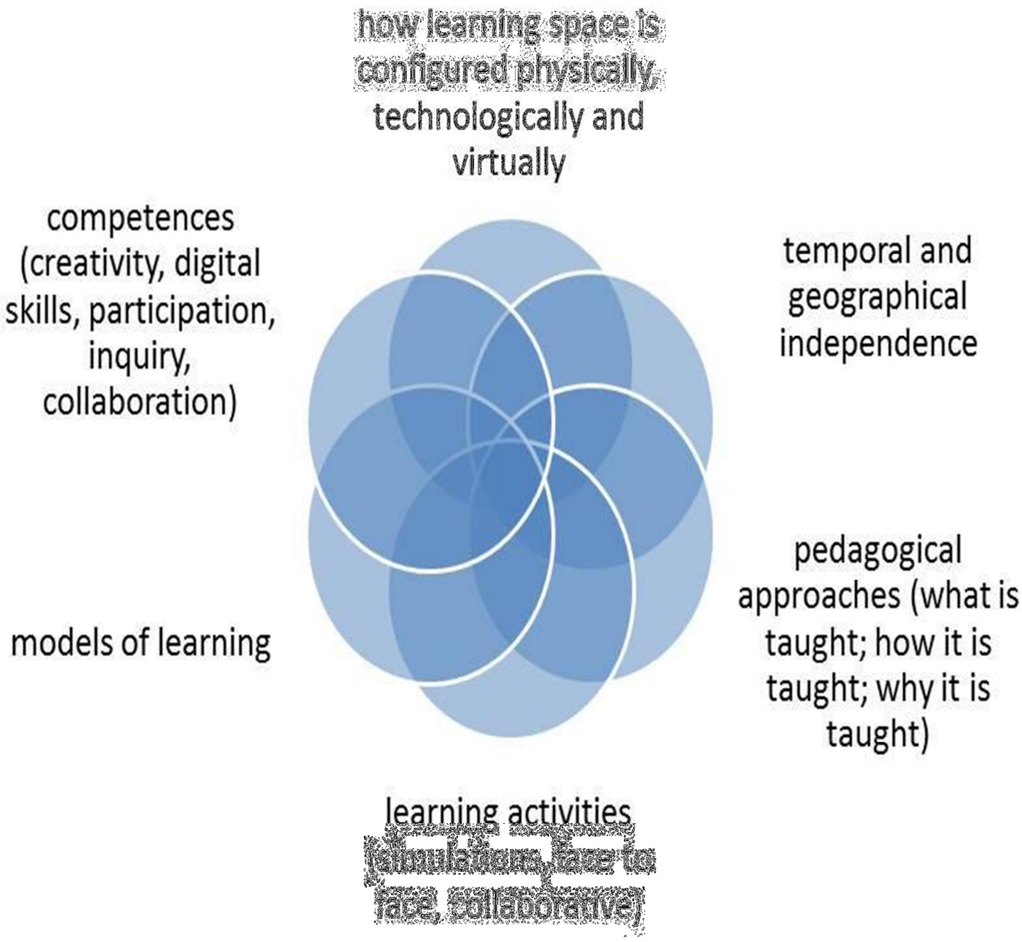

Figure 2: Operational variations in Learning Domains

Section 2 on Methodology addresses how we have focused the study.

ORGANISATION OF THE REPORT

The report is organised to reflect how we have conducted the state-of-the-field review. First, the methodology that we used to create our corpus of literature is described. Second, we present our analysis of the corpus. Third, we present the results of the analysis through a number of strategic reviews. Fourth, we conclude and discuss future directions of the field of ICT and learning.

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[1] http://dragonboxapp.com

[2] http://www.khanacademy.org

[3] http://www.knowledgeforum.com/

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METHODOLOGY CHAPTER

Our goal while designing this study was to conduct an objective and comprehensive review of the field of ICT in Education in order to summarise the field, identify the primary research themes that have emerged, understand why they have emerged, summarise the principal activities and findings from those research themes and finally identify future strategic research actions that would strengthen not only each theme but also the entire field of ICT in Education.

In designing the study to achieve these goals we had 5 primary methodological considerations.

- How to select which materials we would reference
- How to search for the materials
- How to store, organise and reference the materials
- How to analyse the materials
- How to identify and understand the primary research themes that emerged from the analysis

We will discuss each of these considerations in turn to provide a complete overview of the process that we followed in completing this work.

SELECTING THE SOURCE MATERIALS TO REFLECT DEFINITIVE WORK

Most literature reviews have a methodological flaw in terms of the subjective selection of the primary sources that are included within the review and the subjective exclusion of other primary sources that will not be included within the review process.

The systematic review methodologies that have emerged out of the field of evidence based medicine in the last decade have tried to address some of the subjectivity by introducing requirements (such as PRISMA and the Cochrane Handbook for Systematic Reviews) that literature sources are identified along with clear statements of the number of records downloaded, how they are selected, excluded and analysed (Savoie, Helmer, Green & Kazanjian, 2003; Pawson, Greenhalgh, Harvey & Walshe, 2005). However, even within these rigorous quality constraints there remains levels of subjective bias in selecting search terms, the literature sources that will be consulted and how the basic research question selected for the systematic review is interpreted (Petticrew & Roberts, 2006; Higgins & Green, 2011).

We wanted to minimise these possible methodological flaws within our own work.

In selecting which studies would form the basis of our review of the field we attempted to restrict ourselves to the most influential works published since 2000 in peer reviewed scientific journals, books and, in order to identify the National perspective, Norwegian Doctoral Dissertations. We also wanted to provide some perspective on the international research themes so we included all IST projects reported on the European Union's ISTweb repository (see separate appendices that describe our methodologies for selecting and importing the Norwegian PhDs and the European Projects).

CHALLENGES WHEN DEFINING THE MOST INFLUENTIAL WORK

Within science the traditional method used to determine influence is the count of how many times a work has been cited by other researchers or the impact of the journal in which it was published. However citation and impact factors are not the only methods that can be used to determine the value of a publication (for a list of the top 100 journals in the field see final appendix "Full List of Ranked Journals").

We are fully aware of the many reservations (Joint Committee on Quantitative Assessment of Research, 2008; EASE Statement on Inappropriate Use of Impact Factors, 2007; Lozano, Larivière & Gingras, 2012; Wilhite & Fong, 2012) that have been raised regarding the limitations of the traditional Thomson Reuters Journal Citation Index (JCI) impact factor as the sole factor in determining the quality of journals and papers.

We therefore planned to use three alternative measures of scientific influence to select our source literature, namely the traditional Thomson Reuters citation count provided within their literature repository Web of Science (WoS), the independent citation system Eigenfactor, (*an academic research repository project at the University of Washington that uses recent advances in network analysis and information theory to develop novel methods for evaluating the influence of scholarly work (Bergstrom, 2007*) and finally the methods identified by Harzing & Wal, R. (2008) in the development of the Google Scholar "H factor" citation ranking for publications.

ATTEMPTING DATA TRIANGULATION OF LITERATURE SOURCES FOR RELIABILITY AND VALIDITY

Having identified three target literature repositories, each with their own citation or influence ranking (Thomson Reuters Web of Knowledge (WoS), Google Scholar and Eigenfactor respectively), we anticipated considerable duplication and redundancy in our final combined data set. However, we also hoped that in having three independent sources and impact measures we would achieve some degree of data triangulation and increased confidence that we had a representative sample of the most influential works published between 2000 and 2013.

However closer examination of the design of the Eigenfactor system revealed that although they used alternative ranking and citation methods they still utilised the Thomson Reuters WoS as the original source of their scientific literature. This common source made Eigenfactor no longer suitable as one of the sources as it replicated the same papers as Thomson Reuters WoS.

While examining Eigenfactor we also evaluated the linked resource Microsoft Academic Search but determined that the list of references was highly restricted to specific journals and authors.

In searching for a third scientific literature resource we also evaluated JSTOR

http://www.jstor.org/

and this was for some time considered as an alternative source for data triangulation but further work revealed that JSTOR was indexed and referenced in Google Scholar searches. It was therefore redundant, in the same manner as Eigenfactor, since Google Scholar searches returned JSTOR search results.

This problem of the pervasive nature of Google Scholar referencing alternative sources within its own searches caused a challenge for true data triangulation for this phase of the project.

In the end, after considerable investigation of various scientific literature sources, we determined that Thomson Reuters and Google had between them developed a near monopoly on digital resources of scientific literature. There have been attempts to create open source, open content rivals, such as GetCITED but these have been largely superseded by Google Scholar.

It was therefore concluded that we would use these two independent sources WoS and Google Scholar as our sources and impact methods. This provides some degree of reassurance for validity and reliability for our final combined data set.

DETERMINING THE BEST METHODS TO SEARCH FOR THE MATERIALS

Having identified the sources that will be searched for the literature we next had to decide what search terms would provide us with an objective and representative data set of the most influential literature.

As we have already discussed when describing the process of systematic review (see above) traditionally academics use quite subjective methods to determine the search terms that they will use when querying a scientific literature database.

We wished to avoid this potential bias so in selecting the exact terms for our searches on the WoS and Google Scholar systems we decided to perform searches on every term defined in the TEL Dictionary produced by the Kaleidoscope Network of Excellence.

http://www.tel-thesaurus.net/wiki/index.php/TEL_Dictionary_entries

The TEL Dictionary was one of two key deliverables from the European Union funded Technology Enhanced Learning (TEL) meta-project, see http://www.tel-thesaurus.net/, built on a legacy of the Kaleidoscope FP6 European Network of Excellence (NoE). It has developed within the context of the Stellar FP7 NoE with the collaboration of the associations TELEARC and EATEL. This meta-project was intended to create an intellectual platform to support the conceptual and theoretical integration in the TEL research area.

Two tools resulted: a TEL Thesaurus and a TEL Dictionary. Both tools are fully interdisciplinary, multilingual and took into account the multicultural and epistemological roots of research on learning.

The TEL Thesaurus established a list of the key terms currently used across TEL research (based on the corpus provided by journals and conferences). Currently there are 471 terms.

The TEL dictionary provides definitions of all key terms in the field with key references exploiting open access resources, and in particular the TEL open archive. Currently there are 111 dictionary entries.

IDENTIFYING THE BEST REFERENCE MANAGEMENT SYSTEM TO STORE, ORGANISE AND MANIPULATE THE MATERIALS

We considered a number of possible database systems for storing our literature searches.

http://www.techsupportalert.com/content/best-free-bibliographic-database-software-stub-only.htm

We conducted brief evaluations of

JabRef and Mendeley

http://jabref.sourceforge.net/

http://www.mendeley.com/

JabRef lacked the ability to automatically input search results from WoS and Google Scholar.

Mendeley did provide this functionality so we selected it for some initial testing.

We did searches in WoS and Google Scholar for the terms "Educational Technology Learning"

In the process of these trial runs we encountered problems with Mendeley failing to input all the records from a search into the database.   Further controlled test runs determined that Mendeley did not perform in a deterministic manner when repeating identical actions on identical data sets.

We had to therefore reject Mendeley as a tool for our project and instead adopted Zotero.

https://www.zotero.org/

Zotero is a research tool that helps collect, organize, and analyze research and share it in a variety of ways. Zotero includes the ability to store author, title, and publication fields and to export that information as formatted references.

Zotero is a project of the Roy Rosenzweig Center for History and New Media at George Mason University, and was initially funded by the Andrew W. Mellon Foundation, the Institute of Museum and Library Services, and the Alfred P. Sloan Foundation.

Tests on Zotero proved that it was both deterministic and reliable, it also provided good tagging features and some advanced data visualisation tools for analysing the corpus.

SELECTING THE BEST METHODS TO ANALYSE THE MATERIALS

With the advent of digital literature management systems researchers have faced the challenge of understanding the themes and concepts that exist within very large data sets. This challenge has resulted in the development of advanced automated tools to permit visualisations of highly complex data analysis and synthesis. The Zotero community of developers have provided a set of such advanced data visualisation tools called Paper Machines.

Paper Machines is an open-source extension for the Zotero bibliographic management software. Its purpose is to allow individual researchers to generate analyses and visualizations of user-provided corpora, without requiring extensive computational resources or technical knowledge.

This project is a collaboration between historian Jo Guldi and digital ethnomusicologist Chris Johnson-Roberson, graciously supported by Google Summer of Code, the William F. Milton Fund, and metaLAB @ Harvard.

https://github.com/chrisjr/papermachines

Although Paper Machines provides a number of advanced tools and resources for understanding the concepts, themes and even geographical trends within large repositories for the purposes of our TEL literature we utilised only a subset of resources.

WORD CLOUDS

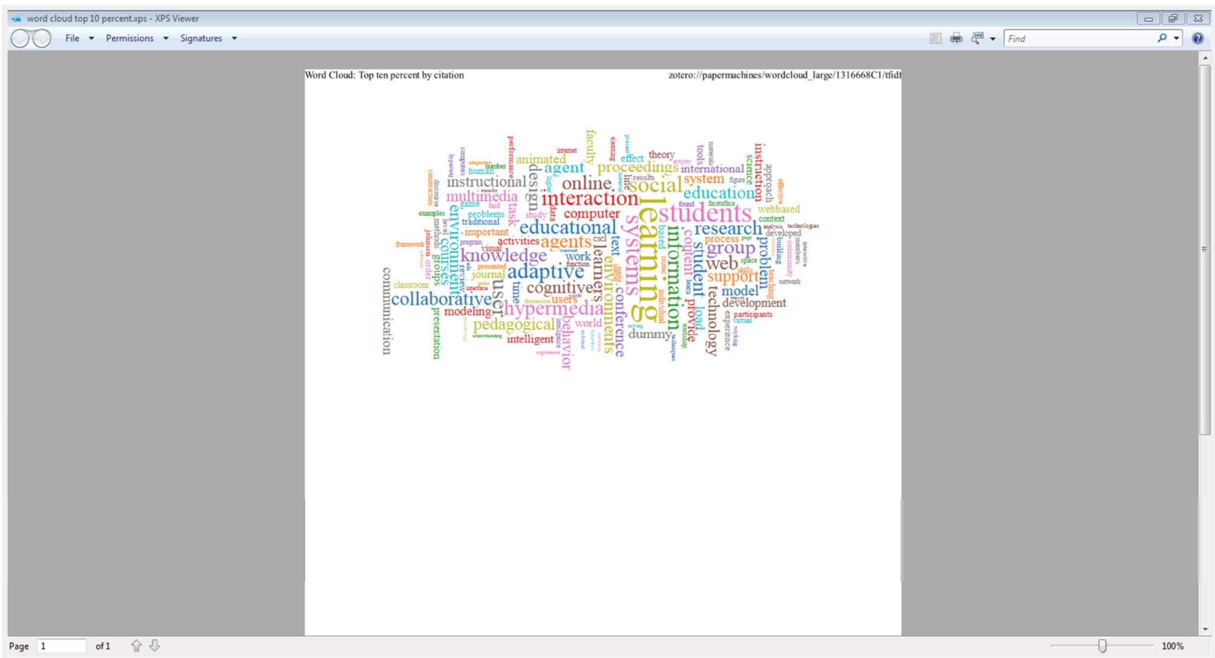

FIGURE 1 EXAMPLE WORD CLOUD

Word Clouds or Tag Clouds are a data visualisation technique that originated from cartography keys showing the relative populations of cities. In the early 1990s the technique began to be used to show frequency of words in documents and was rapidly adopted within the web 2.0 technologies in the early 2000. Within Paper

Machines the word cloud data visualisation shows the frequency of specific words within the corpus where more frequency of occurrence is represented by the relative size of individual words.

TOPIC MODELS

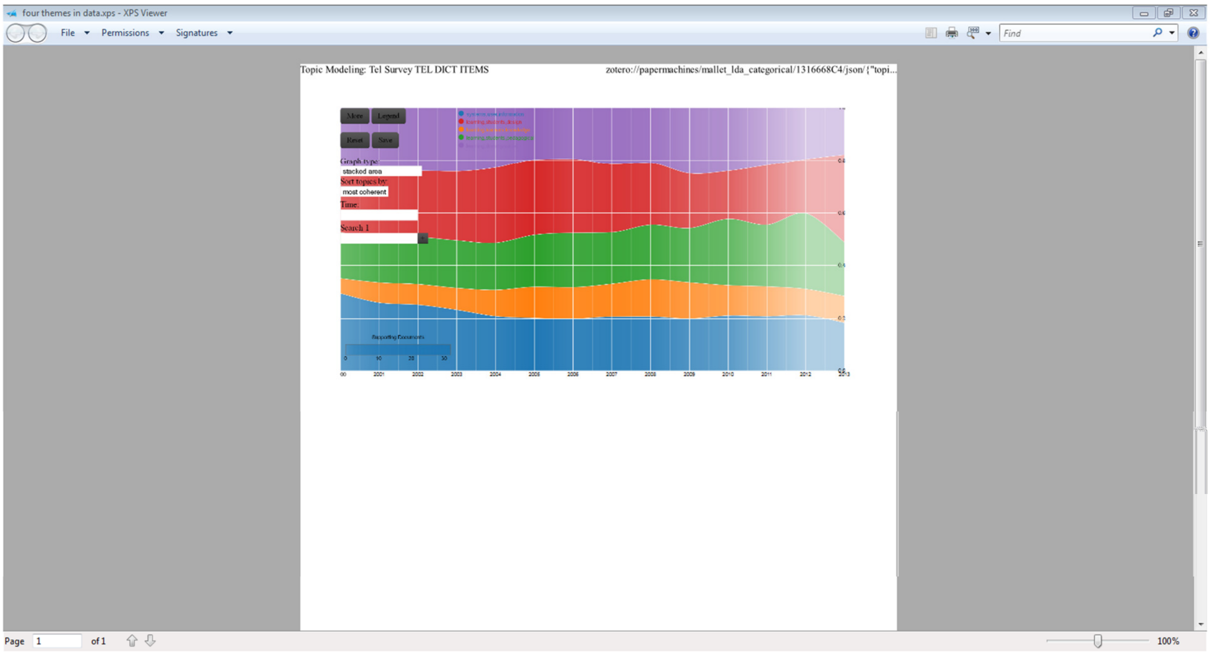

FIGURE 2 EXAMPLE TOPIC MODEL

In machine learning and natural language processing, a topic model is a type of statistical model for discovering the "topics", themes or ideas that occur in a collection of documents. A topic model captures the main ideas within a set of documents in a mathematical framework, allowing researchers to examine large sets of documents and discover the main concepts within those documents.

PHRASE NETS (X AND Y; X OR Y CHARTS)

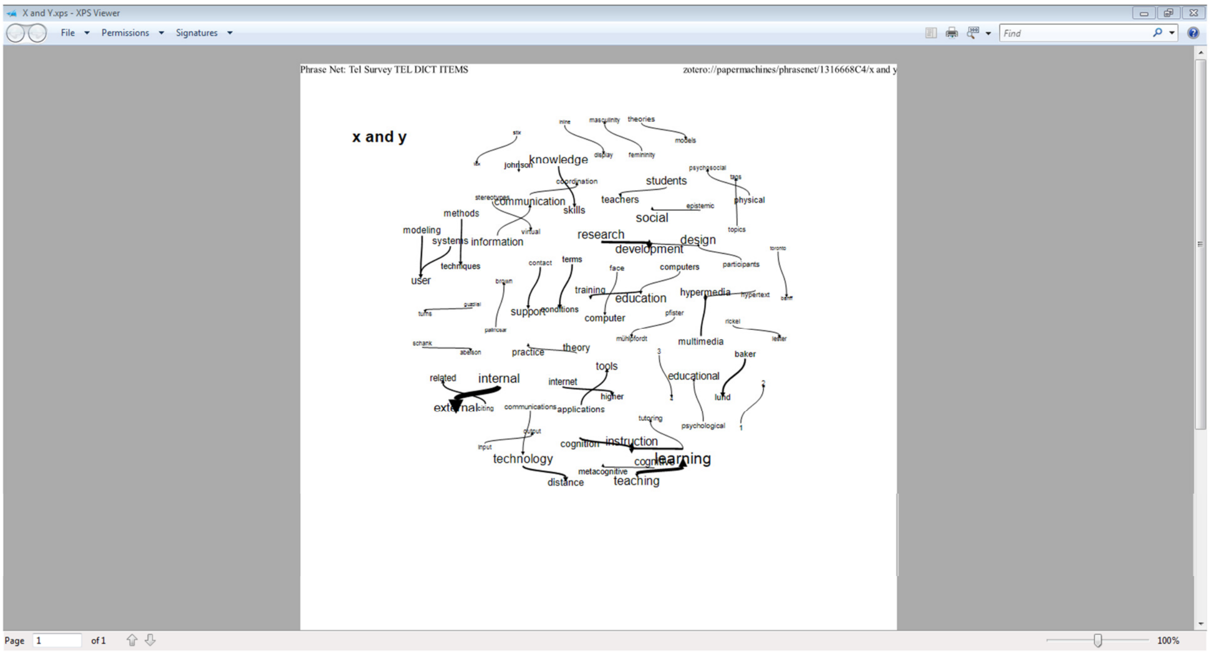

FIGURE 3 EXAMPLE PHRASE NET

IBM research labs developed this new data visualisation technique which is designed to provide a view of the major inter word relationships within large data sets

N-GRAMS

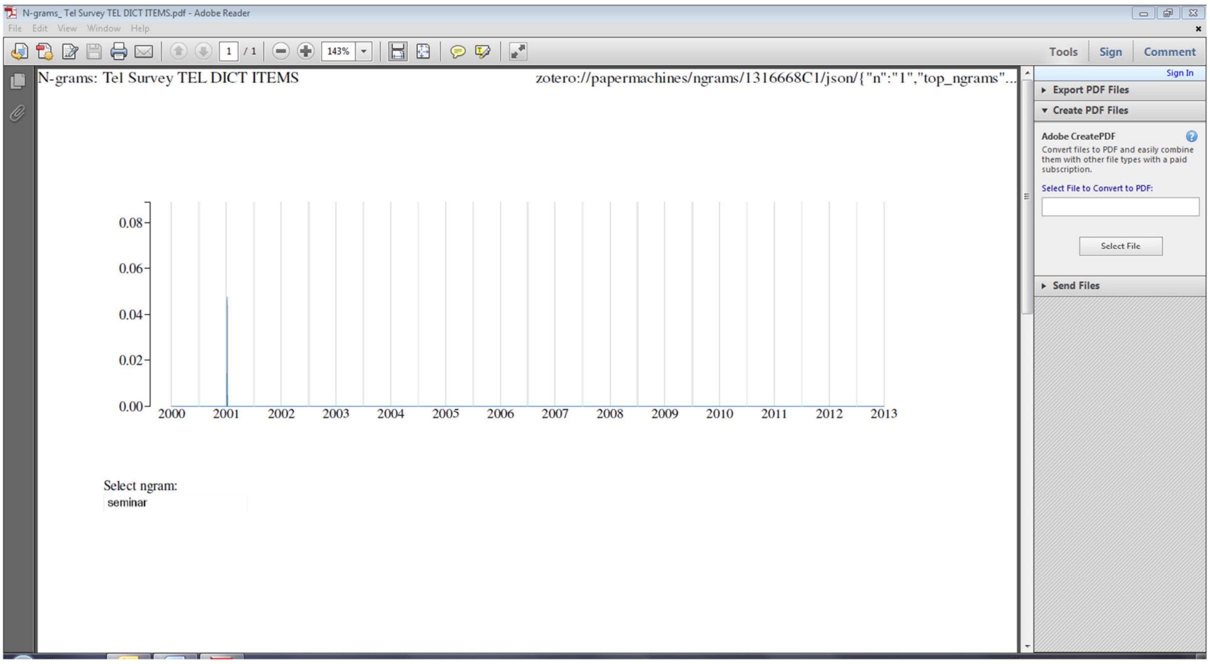

FIGURE 4 EXAMPLE N-GRAM

Paper Machines provides a basic data visualisation tool called "N-Grams" that is conceptually similar to the phrase-usage graphing tool "Google Ngram Viewer" developed by Jon Orwant and Will Brockman of Google in 2009. It shows an interactive graph where sets of N-grams (*sequence of letters of any length, which could be a word, a misspelling, a phrase or gibberish*) that have been identified as repeating within the corpus and which can be manipulated to show the relative frequency of their occurrences over time.

This tool was only used on the main corpus to identify if there were any thematic trends associated with our selected time period 2000-2013.

TAGGING FOR THEMATIC IDENTIFICATION

Items automatically added to a Zotero collection bring with them associated tags (or keywords) that have been assigned by either the author or the journal in which the item has been published (or publisher for book chapters or books). In addition, it is possible to add your own tags, both as articles are being automatically added or after, or after manually adding an item to a collection. In addition to adding the search term as a tag, we added either WoS (Web of Science) or Google Scholar to each entry to indicate the origin of the article. In many cases the authors had used the search term as a tag, so the articles were double tagged with that term.

The tag selector of the standalone version of Zotero lists all tags used in the collection. The Figure below shows a picture of all the tags that appear on the main corpus. While it is not possible to read all the tags in the figure, it does give an impression of the plethora of tags that have been used for the 680 journal articles that comprise the main corpus.

Figure 5: Picture of the Tag sector of the Main Corpus in Zotero

Within Zotero each tag is clickable, and clicking on one tag results in only articles tagged with that tag to be shown in the item window, see figure 6 which shows the selection of tag "computer supported collaborative learning" and the 13 articles from the main corpus that are tagged with this tag. As can be seen in figure x, once one selects a tag in the tag selector (highlighted in blue), the only tags visible (of the ones shown in figure x above), are those tags associated with the articles tagged with this tag; in this case those tags visible in figure x are all the tags associated with the 13 articles tagged with "computer supported collaborative learning". In this way, one can study the collection via the tags.

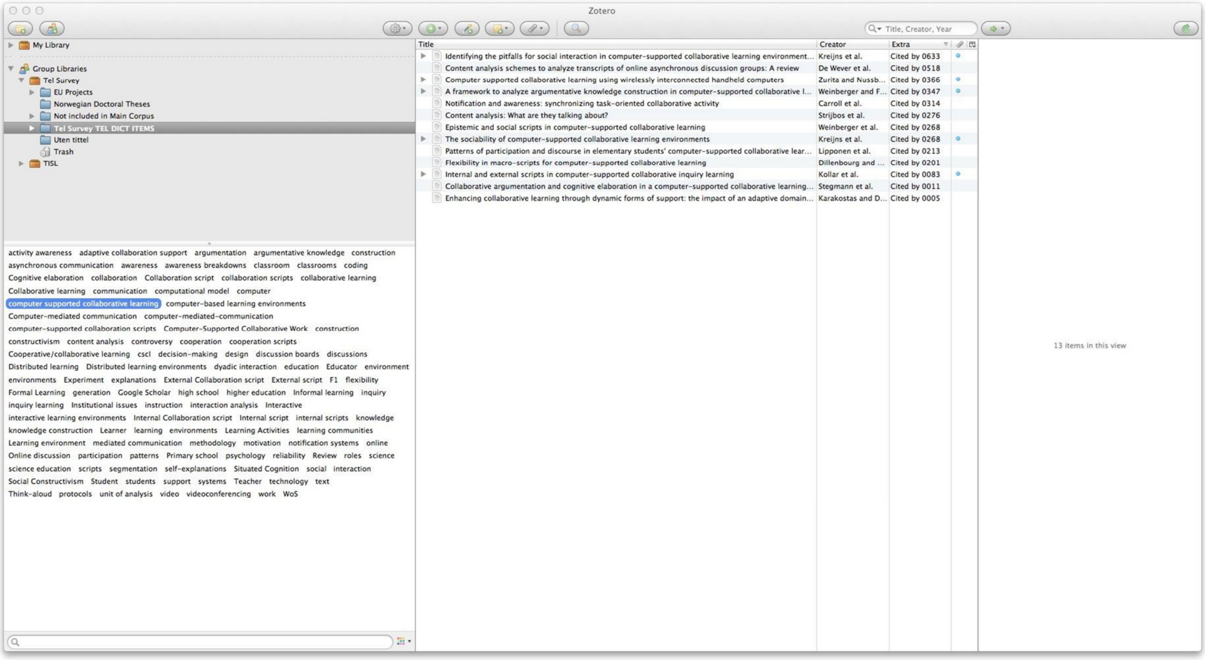

Figure 6: Picture of the Tag sector of the Main Corpus in Zotero

THE SEARCH PROCESS

We searched both the WoS and Google Scholar using all the TEL Dictionary terms and tagging each of the results from the respective searches with the search term while importing the first 10 items ranked by citation or influence using the automated importation feature of Zotero. This process resulted in 1680 search results (see appendix "Full Search Results"). That is 112 search terms x 10 results per page for WOS and separately 112 search terms x 10 results per page for Google Scholar. Some searches did not provide 10 results on a page and some resulted in zero results.

We then removed those results that were either irrelevant (based on a joint evaluation independently by both researchers) or were clearly not peer reviewed journal publications (again based on a joint evaluation independently by both researchers) (see appendix "Non Relevant Results").

- For example: Ahmed, F., & Discher, D. E. (2004). Self-porating polymersomes of PEG-PLA and PEG-PCL: hydrolysis-triggered controlled release vesicles. Journal of Controlled Release, 96(1), 37–53. doi:10.1016/j.jconrel.2003.12.021

And finally we removed entries that were duplicated using the duplicates function in Zotero (see appendix "Duplicated items").

This left us with a database of 691 items (see appendix "Reduced Data Set"). This set was defined as a sub collection within Zotero called "Tel Survey TEL DICT ITEMS"

To further refine the data set we used a Zotero script that defined the citation count for each individual item within our corpus of 691 items and then extracted a sub collection of the top 10% of the 691 items based on citation, regardless of the topic contained within the individual paper.

This resulted in a Zotero sub collection called "Top Ten Percent by citation" which contained 69 items.

Subsequently, while working on the analysis stages of the work, we discovered 4 items had been mis-categorised by the Zotero importing process as journal papers when they were in fact conference papers, manuscripts or books. These misdiagnosed items were removed from the "Top Ten Percent by citation" folder and placed in a separate sub folder called "Not Journals". We also discovered 7 duplicate entries that had not been identified by Zotero and which were removed to a sub collection called "Duplicates".

After these minor changes the number of records in the "Tel Survey TEL DICT ITEMS" main corpus stood at 680 and the number of records in the "Top Ten Percent by citation" stood at 67 records.

In addition to these two main collections we also created other subcollections in the process of the data analysis. We will briefly describe them here but they will also be mentioned in greater detail in the analysis section of the report.

In collecting all the European Union funded IST projects related to Technology Enhanced Learning (see appendix that describes the process) we created a folder called "EU Projects from all calls and frameworks combined" which contained 149 items.

In collecting all the Norwegian PhD dissertations (see appendix that describes the process) we created a subcollection called "Norwegian Doctoral Theses". This contained 60 items.

We also examined those 730 items that had been excluded from the main corpus "Tel Survey TEL DICT ITEMS" because they were not peer reviewed journals and created a sub collection of books, manuscripts and conference publications related to Technology Enhanced Learning called "Books and texts that are not journals but are theme related". This contained 54 items.

As part of the data analysis we examined the literature that had been cited by works within our main corpus "Tel Survey TEL DICT ITEMS" and created a sub collection of those works called "Key Texts referenced by Corpus". This contained 17 items. As a further analysis we examined those works that had in turn been cited by these sources and created a further sub collection called "Works cited by Key Texts". This contained 5 items.

Finally as part of the analysis work conducted on the EU Projects we identified the works that had been frequently cited within the EU Projects and created a sub collection called "Texts Cited by EU Projects". This contained 6 items.

METHODOLOGY APPENDIX: OBTAINING IST EU PROJECTS

As an adjunct to the main literature review performed in the study we have also uploaded the listing of EU projects from the Cordis (Community Research and Development Information Service, whose job it is to provide information on all EU supported research and development activities) website categorised under the fifth, sixth and seventh frameworks respectively.

http://cordis.europa.eu/ist/telearn/projects_all.htm

http://cordis.europa.eu/fp7/ict/telearn-digicult/telearn-projects-fp6_en.html

http://cordis.europa.eu/fp7/ict/telearn-digicult/telearn-projects-fp7_en.html

These project details were individually uploaded into our Zotero database (with as much detail as was still available either on the EU site or the project web site listed in the database).

These details, for 149 projects covering a period from the late 1990's through to 2013, show a wide range of different initiatives by the European research council.

However it has to be observed, while we commend the work of Cordis in listing details of all of the funded research projects and networks over the period, we note that the scientific value of the research that is being performed is to some extent negated by the lack of continuing support for the documentation of projects after their funding period has ceased. Whereas several hundred million euros of state funding has been utilised in the numerous framework calls it is regrettable that a large proportion of the projects websites no longer exist after the project has terminated. This is especially noticeable for projects more than three years old. There is also a lack of linkages between the various projects so it is virtually impossible for a researcher to do any kind of scaffolding for the findings produced by these initiatives over a decade and a half of time.

Clearly this is extremely wasteful and one can only speculate at the knowledge that is being lost through any lack of cumulative analysis between the different projects, and any attempts at retrospectively understanding the projects is rendered impractical by the lack of documentation once the project websites cease to exist. Researchers are left with a large listing of projects and only, in some cases, a single paragraph to describe an initiative with a budget in excess of a million euros. Clearly it is a recommendation of our work that future research initiatives by national or international funding bodies include some provision for the long term support for documenting said projects and for ensuring that there is a clear scaffolding of cumulative knowledge generation that is documented in the repository that should be supported by the research councils. It is further recommended that phd stipends and other significant project work that is likely to contribute to advancing new knowledge or understanding is also systematically included within such a repository coordinated by the research councils that are funding such work. Such a repository would be of enormous benefit to the scientific community of each respective jurisdiction and also to the research councils to better enable themselves to see the direct outputs and cumulative knowledge generation that results from their investments in R&D at national and international levels.

METHODOLOGY APPENDIX: NORWEGIAN DOCTORAL THESES

A Zotero folder was created for Norwegian Doctoral theses, since 2000, related to the field of Technology Enhanced Learning. The result was a collection of 60 dissertations.

SOURCES FOR THE NORWEGIAN DOCTORAL THESES

- NORA is the Norwegian Open Research Archives, which gives access to all of the institutional open repositories (BORA, DUO, MUNIN, DIVA, BRAGE) at the higher educational institutions and the research institutions in Norway. The repositories comprise Masters and Doctoral theses, articles and other Open Access works.
- List of Norwegian Researchers working in the field of Technology Enhanced Learning, provided by the Knowledge Centre.
- Our knowledge of the research groups and researchers working in the field in Norway.

SEARCHING

Searches were carried out through both keyword searches (e-learning, education, training) of Doctoral dissertations and manually through browsing the titles of Doctoral dissertations in the individual institution's open repositories (BORA, DUO, MUNIN, DIVA, BRAGE).

From 2000-2013 (October) there are 4387 Doctoral dissertations accessible through NORA.

NON-AUTOMATED DATA GATHERING

As we knew that the dissertations that were found through NORA were not the complete set (not all institutions require the Doctoral dissertations to be uploaded to their Open Archive) we resorted to a manual search of the web pages of the relevant Institutions, Research Groups, and individual researchers.

Email was sent to contacts at University of Oslo (UiO) as the UiO dissertations were the most difficult to get access to; unfortunately there is no routine at the Faculty of Education to either request the individual researchers to upload their dissertations to DUO (the UiO Open Archive), nor to keep a copy at the faculty. We were directed to a site which announces all the Doctoral defences at the faculty, thus if we did not manage to obtain a copy of the dissertation, we at least used the abstract posted on this announcement site in the abstract descriptor field of the Zotero record.

Email was also sent to individual researchers asking for a copy of their dissertation. This resulted in an addition 4 dissertations being added to our Zotero database.

ISSUES RELATED TO DISSEMINATION OF NORWEGIAN DOCTORAL WORK

One issue that was highlighted in an email from one of the researchers was that many of the dissertations contain published articles that may have copyright restrictions on publishing in an open archive. This is addressed in the Open Archives by separating the articles from the "kappa" (introductory chapters), uploading the "kappa" and listing the articles separately with a copy of the paper if the copyright allows it (e.g., https://bora.uib.no/handle/1956/7376).

LANGUAGE

Abstracts written in Norwegian were translated to English to facilitate the automatic analysis by Paper Machines. This included both those records for which we had only an abstract, and for those where the included dissertation was written in Norwegian.

METHODOLOGY APPENDIX: DEFINITIONS AND CLARIFICATIONS

SOURCES OF LITERATURE

We used two independent sources of scientific literature, Thompson Reuters Web of Knowledge and Google's Google Scholar respectively.

KEYWORDS AND TAGGING OF PAPERS: TEL DICTIONARY

The TEL Dictionary was one of two key deliverables from the European Union funded Technology Enhanced Learning (TEL) meta-project built on a legacy of the Kaleidoscope FP6 European network of excellence (NoE). It has developed within the context of the Stellar FP7 NoE with the collaboration of the associations TELEARC and EATEL. This meta-project was intended to create an intellectual platform to support the conceptual and theoretical integration in the TEL research area.

Two tools resulted: a TEL Thesaurus and a TEL Dictionary. Both tools are fully interdisciplinary, multilingual and took into account the multicultural and epistemological roots of research on learning.

The TEL Thesaurus established a list of the key terms currently used across TEL research (based on the corpus provided by journals and conferences). Currently there are 471 terms.

The TEL dictionary provides definitions of all key terms in the field with key references exploiting open access resources, and in particular the TEL open archive. Currently there are 111 dictionary entries.

SEARCH PROCESSES (WEB OF KNOWLEDGE)

The Web of Knowledge Service provides a single route of access to the Thomson Reuters products subscribed to by an individual institution. It includes Web of Science; Journal Citation Reports; Current Contents Connect; Derwent Innovations Index and many others. This platform provides a unique way of searching, including the ability to perform an 'All Database' search on the content of multiple searchable products.

Thomson Reuters claims to be "the world's leading source of intelligent information for businesses and professionals" with significant market share in scientific literature, financial markets, legal legislation changes, current affairs, news and media.

SEARCH PROCESSES (GOOGLE SCHOLAR)

Google Scholar provides a simple way to broadly search for scholarly literature. From one place, you can search across many disciplines and sources: articles, theses, books, abstracts and law court opinions, from academic publishers, professional societies, online repositories, universities and other web sites. Google Scholar helps you find relevant work across the world of scholarly research.

Google Scholar aims to rank documents the way researchers do, weighing the full text of each document, where it was published, who it was written by, as well as how often and how recently it has been cited in other scholarly literature

DATA STORAGE AND MANIPULATION: MENDELEY

Mendeley is a reference manager and academic social network that organizes research materials, supports group collaboration with social media support. It generates bibliographies, imports papers from other research software, and suggests relevant papers based on what you're reading.

Mendeley claims it "***is used at, and endorsed by, some of the world's leading research institutions***".

DATA STORAGE AND MANIPULATION : ZOTERO

Zotero is a research tool that helps collect, organize, and analyze research and share it in a variety of ways. Zotero includes the ability to store author, title, and publication fields and to export that information as formatted references.

Zotero is a project of the Roy Rosenzweig Center for History and New Media at George Mason University, and was initially funded by the Andrew W. Mellon Foundation, the Institute of Museum and Library Services, and the Alfred P. Sloan Foundation.

DATA ANALYSIS: PAPER MACHINES

Paper Machines is an open-source extension for the Zotero bibliographic management software. Its purpose is to allow individual researchers to generate analyses and visualizations of user-provided corpora, without requiring extensive computational resources or technical knowledge.

This project is a collaboration between historian Jo Guldi and digital ethnomusicologist Chris Johnson-Roberson, graciously supported by Google Summer of Code, the William F. Milton Fund, and metaLAB @ Harvard.

WORD CLOUDS

Word Clouds or Tag Clouds are a data visualisation technique that originated from cartography keys showing the relative populations of cities. In the early 1990s the technique began to be used to show frequency of words in documents and was rapidly adopted within the web 2.0 technologies in the early 2000. Within Paper Machines the word cloud data visualisation shows the frequency of specific words within the corpus where more frequency of occurrence is represented by the relative size of individual words.

REFERENCES

Gilles Deleuze, Felix Guattari (1992). Tausend Plateaus. Kapitalismus und Schizophrenie. ISBN 3-88396-094-2.

TOPIC MODELS

In machine learning and natural language processing, a topic model is a type of statistical model for discovering the "topics", themes or ideas that occur in a collection of documents. A topic model captures the main ideas within a set of documents in a mathematical framework, allowing researchers to examine large sets of documents and discover the main concepts within those documents.

REFERENCES

Papadimitriou, Christos; Raghavan, Prabhakar; Tamaki, Hisao; Vempala, Santosh (1998). "Latent Semantic Indexing: A probabilistic analysis" (Postscript). Proceedings of ACM PODS.

Hofmann, Thomas (1999). "Probabilistic Latent Semantic Indexing" (PDF). Proceedings of the Twenty-Second Annual International SIGIR Conference on Research and Development in Information Retrieval.

Blei, David M.; Ng, Andrew Y.; Jordan, Michael I; Lafferty, John (January 2003). "Latent Dirichlet allocation". Journal of Machine Learning Research 3: 993–1022. doi:10.1162/jmlr.2003.3.4-5.993.

Blei, David M. (April 2012). "Introduction to Probabilistic Topic Models" . Comm. ACM 55 (4): 77–84. doi:10.1145/2133806.2133826.

PHRASE NETS (X AND Y CHARTS)

IBM research labs developed this new data visualisation technique which is designed to provide a view of the major inter word relationships within large data sets

REFERENCES

Van Ham, Wattenberg & Viégas (2009) "Mapping Text with Phrase Nets " IEEE Transactions on Visualisations and Computer Graphics, Vol. 15, No. 6, November/December 2009

ACCESSING OLDER LITERATURE VIA DIGITAL TOOLS

When conducting the final reviews of the themes that emerged from our analysis of the corpus we found that existing digital research resources emphasize specific periods of time (strongly favouring recently published material) and there is a selection bias in which papers and literature are more easily accessible.

METHODOLOGY APPENDIX: REFERENCES FOR METHODOLOGY SECTION

DATA VISUALISATION AND ANALYSIS

Word Clouds

Gilles Deleuze, Felix Guattari (1992). Tausend Plateaus. Kapitalismus und Schizophrenie. ISBN 3-88396-094-2.

Topic Models

Papadimitriou, Christos; Raghavan, Prabhakar; Tamaki, Hisao; Vempala, Santosh (1998). "Latent Semantic Indexing: A probabilistic analysis" (Postscript). Proceedings of ACM PODS.

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Blei, David M.; Ng, Andrew Y.; Jordan, Michael I; Lafferty, John (January 2003). "Latent Dirichlet allocation". Journal of Machine Learning Research 3: 993–1022. doi:10.1162/jmlr.2003.3.4-5.993.

Blei, David M. (April 2012). "Introduction to Probabilistic Topic Models" . Comm. ACM 55 (4): 77–84. doi:10.1145/2133806.2133826.

Phrase Nets (X and Y Charts)

Van Ham, Wattenberg & Viégas (2009) "Mapping Text with Phrase Nets " IEEE Transactions on Visualisations and Computer Graphics, Vol. 15, No. 6, November/December 2009

SYSTEMATIC REVIEWS

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Shojania, K. ; Sampson, M. ; Ansari, M..; Ji, J.; Doucette, S.; Moher, D. (2007). "How Quickly Do Systematic Reviews Go Out of Date? A Survival Analysis". *Annals of Internal Medicine* **147** (4): 224–33.

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CITATIONS AND IMPACT FACTORS

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The European Association of Science Editors (EASE) Statement on Inappropriate Use of Impact Factors (November 2007)

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Harzing, A.W.; Wal, R. van der (2008) 'Google Scholar as a new source for citation analysis?'. Ethics in Science and Environmental Politics, vol. 8, no. 1, pp. 62-71.

Harzing, A.W.; Wal, R. van der (2008) 'A Google Scholar H-Index for Journals: A Better Metric to Measure Journal Impact in Economics & Business?'. paper presented at the 2008 Academy of Management Annual Meeting, August 8-13, 2008 - Anaheim, California.

Joint Committee on Quantitative Assessment of Research (12 June 2008). 'Citation Statistics'. International Mathematical Union.

Lozano, George A.; Larivière, Vincent; Gingras, Yves (2012). 'The weakening relationship between the impact factor and papers' citations in the digital age'. Journal of the American Society for Information Science and Technology 63 (11): 2140.

Wilhite, A. W.; Fong, E. A. (2012). 'Coercive Citation in Academic Publishing'. Science 335(6068): 542–3.

ELECTRONIC RESOURCES

Eigenfactor.org®. an academic research project co-founded by Jevin West and Carl Bergstrom and sponsored by the Bergstrom Lab in the Department of Biology at the University of Washington. We aim to use recent advances in network analysis and information theory to develop novel methods for evaluating the influence of scholarly periodicals and for mapping the structure of academic research.

http://www.eigenfactor.org/about.php

Google Scholar. Provides a search of scholarly literature across many disciplines and sources

http://scholar.google.co.uk/ Referenced 4th May 2013

Harzing, A.W. (2007) Publish or Perish

http://www.harzing.com/pop.htm Referenced 4th May 2013

Thomson Reuters Journal Citation Index (JCI)

http://thomsonreuters.com/products_services/science/science_products/a-z/journal_citation_reports/
Referenced 4th May 2013

PAPER MACHINES DATA VISUALISATION

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BASIC WORD CLOUD

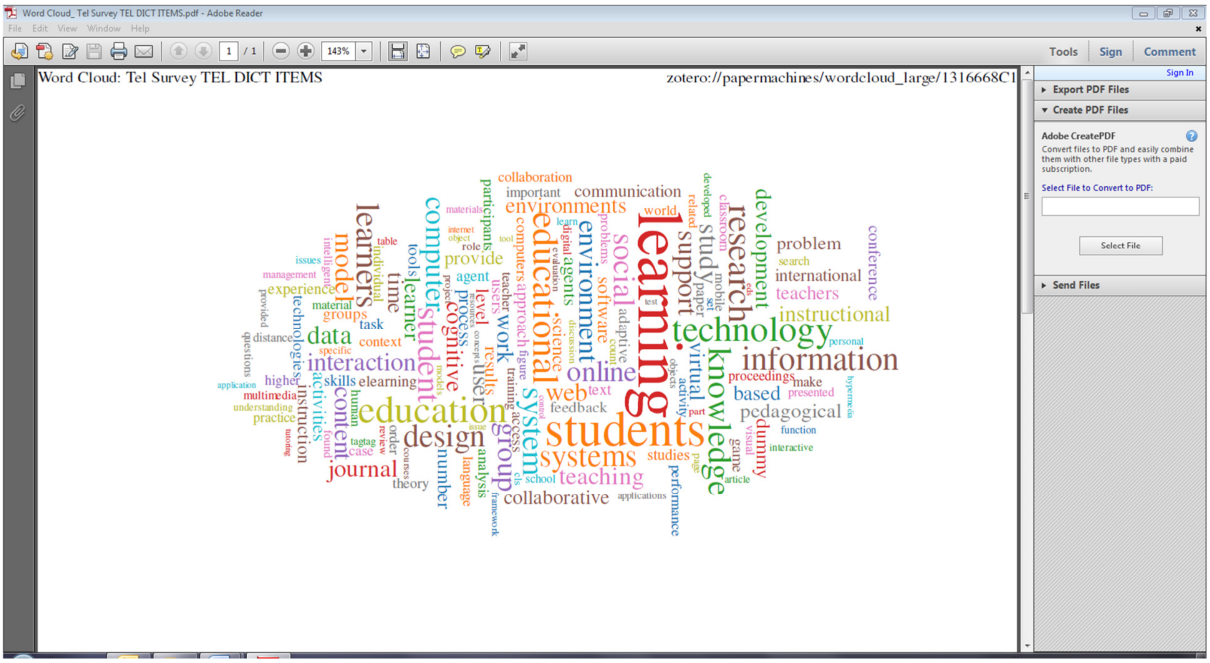

FIGURE 5 MAIN CORPUS WORD CLOUD

There are approximately 52 words in the cloud. The primary word is *learning*, followed by *students, learners* and then you have another subset which *includes research, education, collaboration, collaborative, pedagogical, educational, knowledge and design*. The third layer of groups cover a much broader perspective and *include information, social, computer, system, development, instructional, content, process, agent, science, activities, interaction, instruction, time*. There are no great surprises but the Word Cloud does appear to show structure and a coherent listing of themes that would be expected within this context and literature domain.

It is interesting to note what is missing from the Word Cloud. That is a theoretical perspective – although we have the words *collaboration, cognitive, collaborative, pedagogical and model* – there is nothing to suggest an underlying coherent theoretical framework and neither do we see evidence of empirical progression towards practical outcomes that could be applied. Instead the basic word cloud is more reflective of a research literature that is descriptive in terms of its evolution alongside developments of technology.

MULTIPLE WORD CLOUDS (TIME BASED, MANN WHITTNEY, 365 DAY INTERVALS)

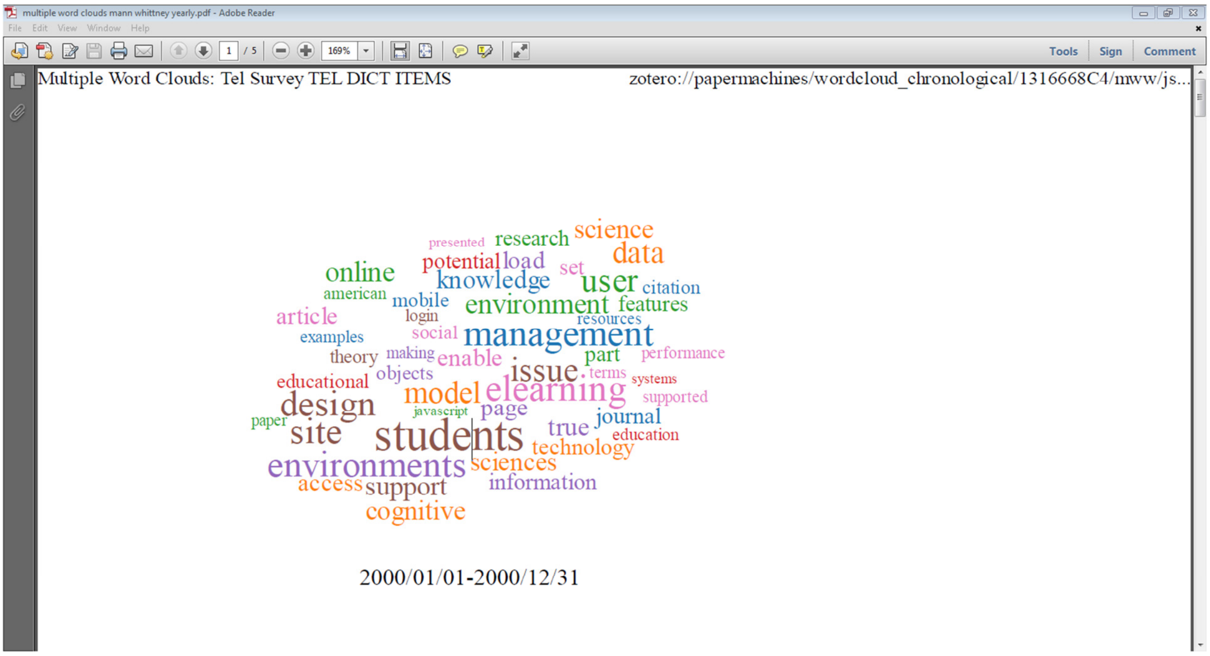

FIGURE 6 2000

2000

The largest word that comes out is *students*, followed by *management*, *elearning*, *environments*, *design*, *cognitive*, *environment*, *potential*, *examples*, *education*, *educational*, *American* and *javascript*. This Word Cloud shows a tendency towards the use of elearning for the management of education and the use of words such as *potential*, *performance*, *examples*, *objects*, *citation*, suggest a domain in its emerging stages. The inclusion of the words *cognitive*, *theory*, *model* and *load* suggest a bias towards more cognitive theories and a belief in the potential of the technology to enable and improve student knowledge. It is remarkable that the word *learning* does not make a significant presence in the word cloud.

FIGURE 7 2001

2001

Whereas in the previous word cloud *learning* had very little presence in 2001 it became the most significant word and it is notable that we also see the emergence of the words *collaborative and computersupported* as terms along with *social, writing, English* and *context.* Gaming is clearly an emerging theme as the terms *games and game* make a strong presence. We should also make note that within this cloud is mention of *twitter, facebook, publishing, beliefs* and *discourse.*

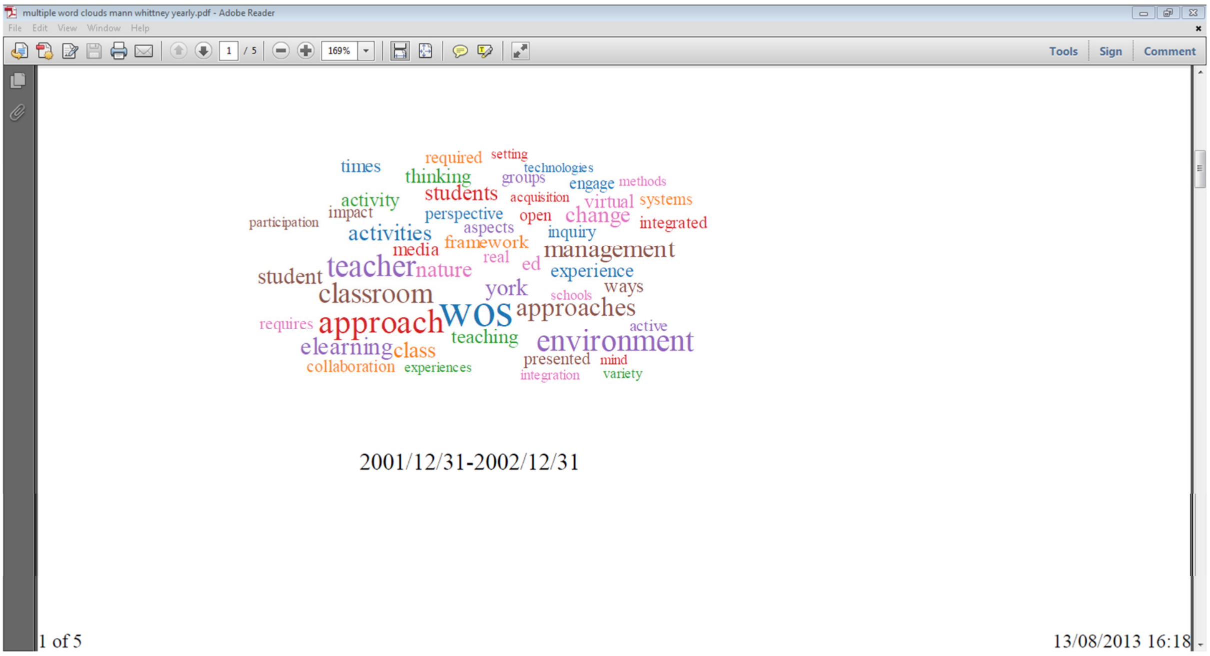

FIGURE 8 2002

2002

The primary words from this period are *environment, approach, teacher and WOS* (Web of Science). This may indicate that the majority of consistency for this year is coming from Web of Science records. The word cloud includes *collaboration, participation, setting, frameworks* and *integration* which may suggest a more socio-cultural theme for this year. However we do also have mention of *mind* and *experience* so this cannot be seen as conclusive support for a stronger socio- cultural focus for this period.

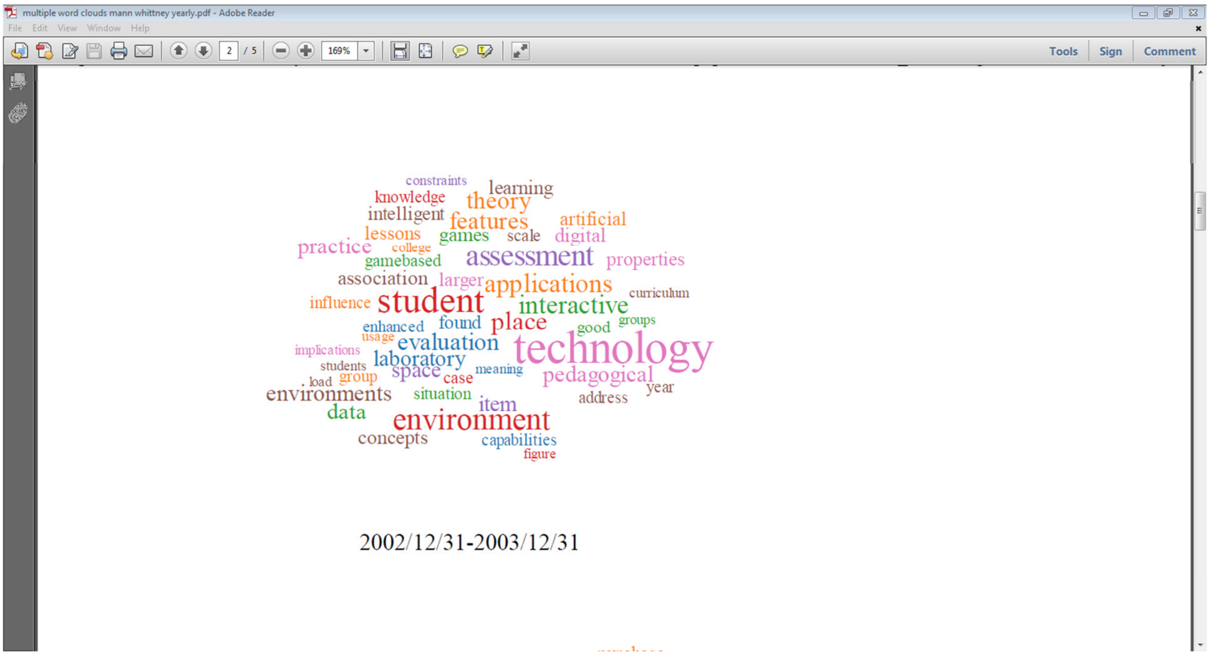

FIGURE 9 2003

2003

In this Word Cloud *technology, student, environment* and *assessment* are the strongest themes followed by *gamebased, groups, laboratory* and, for the first time the word *theory*, although there is no clear evidence as to what focus that theory might have.

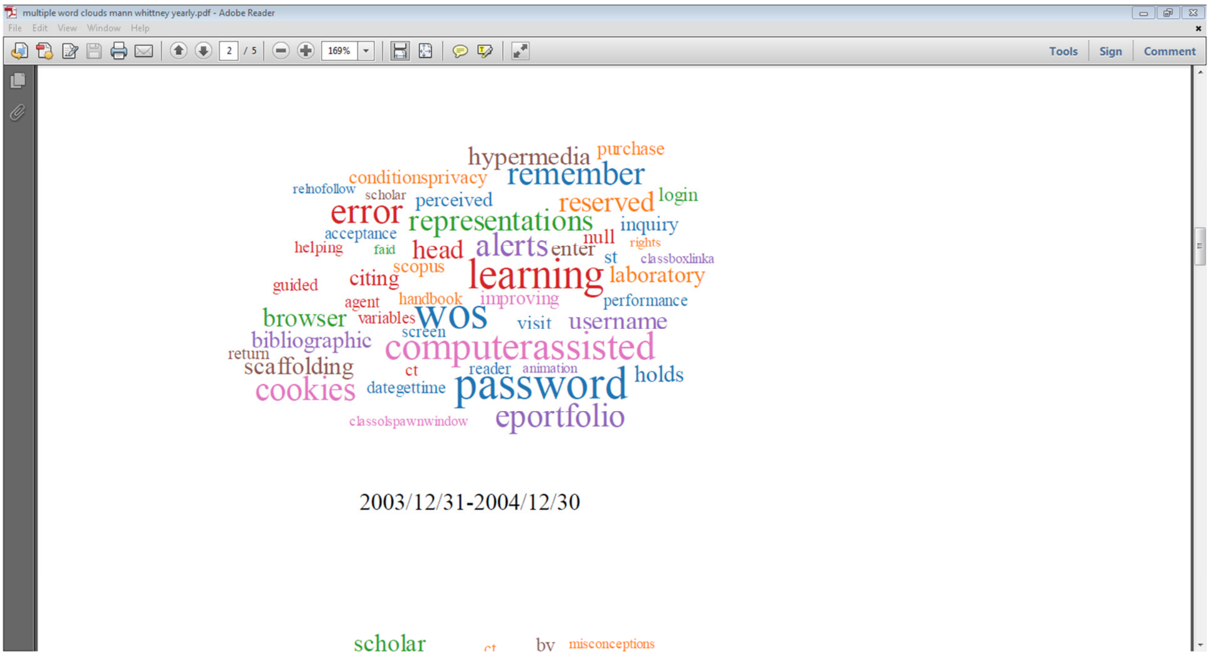

FIGURE 10 2004

2004

This Word Cloud shows some evidence of a concern about privacy as *password* is one of the larger along with *username, conditions, privacy, login, rights*, and *cookies*. We also see the word *faid* appearing along with *WOS, browser, bibliographic, hypermedia, representations, head* and *agent*. There is no clear evidence of theoretical perspectives or experimental work and most of the terms could quite easily be reflective of many implementation studies where we see *reader, dategettime, classolspawnwindow, classboxlinks*. It is probable that we are seeing a lot of papers describing the in depth implementation of elearning systems.

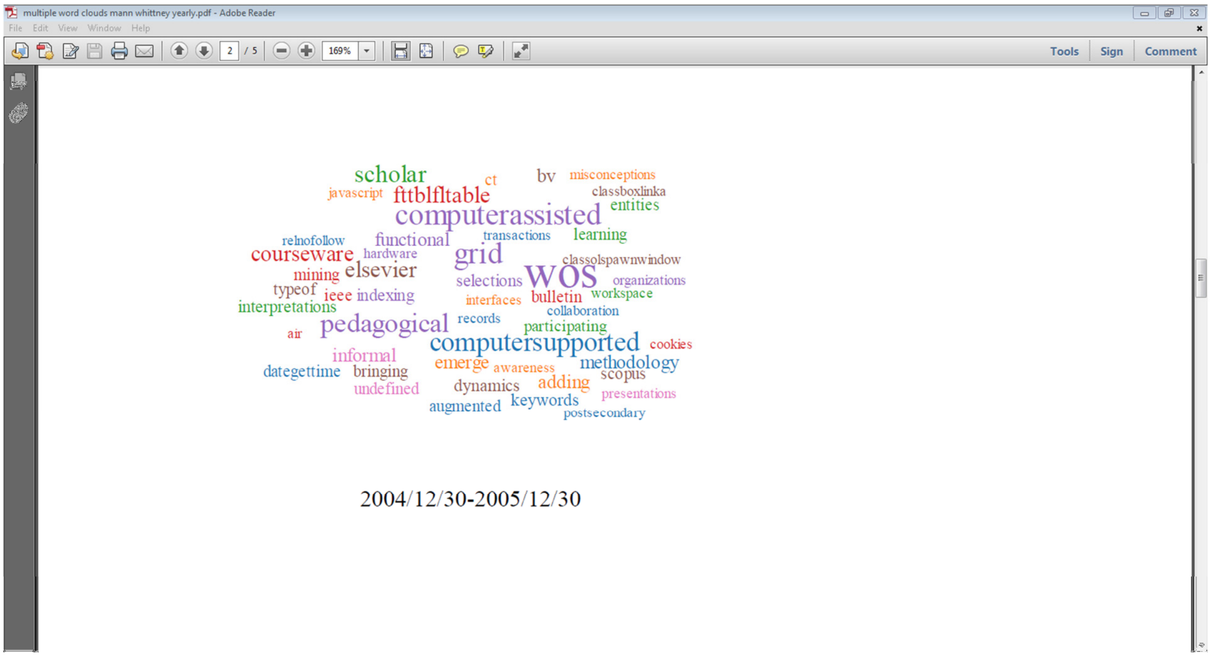

FIGURE 11 2005

2005

Again the main item is *WOS*, which would seem to suggest a consistency throughout the Word Clouds of higher quality data coming from WOS items. In this Word Cloud *computerassisted, computersupported, pedagogical, collaboration, participation, augmented* and *workspace* all give some suggestion for computer supported collaborative work, although we also see evidence of papers related to implementation with *dategettime* and *classboxlinks* appearing again.

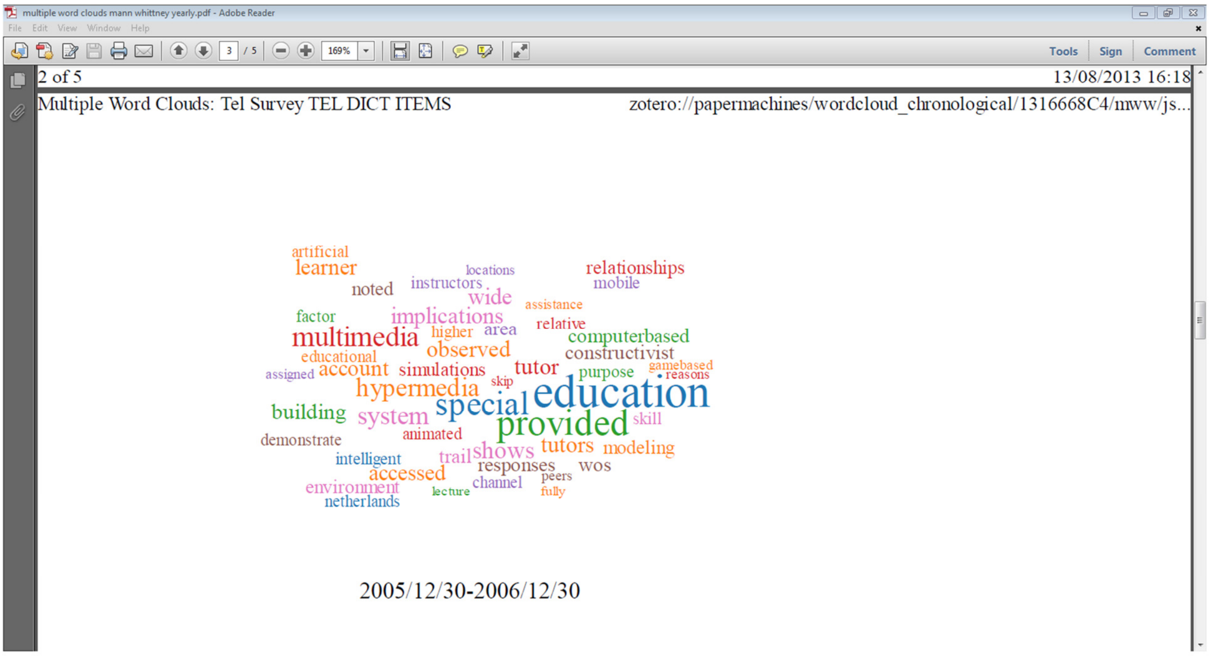

FIGURE 12 2006

2006

Shows the words *education, special* and *provided* as being the strongest themes. We also note the terms *hypermedia, constructivist, observed, simulations, modelling, environment* and *mobile* which strongly suggest that special education may have been an important theme emerging within the field at this time and that simulation based learning and modelling also became more significant along with the emergence of mobile systems. We will also note that *WOS* has less influence in this Word Cloud and that the word *Netherlands* appears which may indicate significant work in a Dutch context.

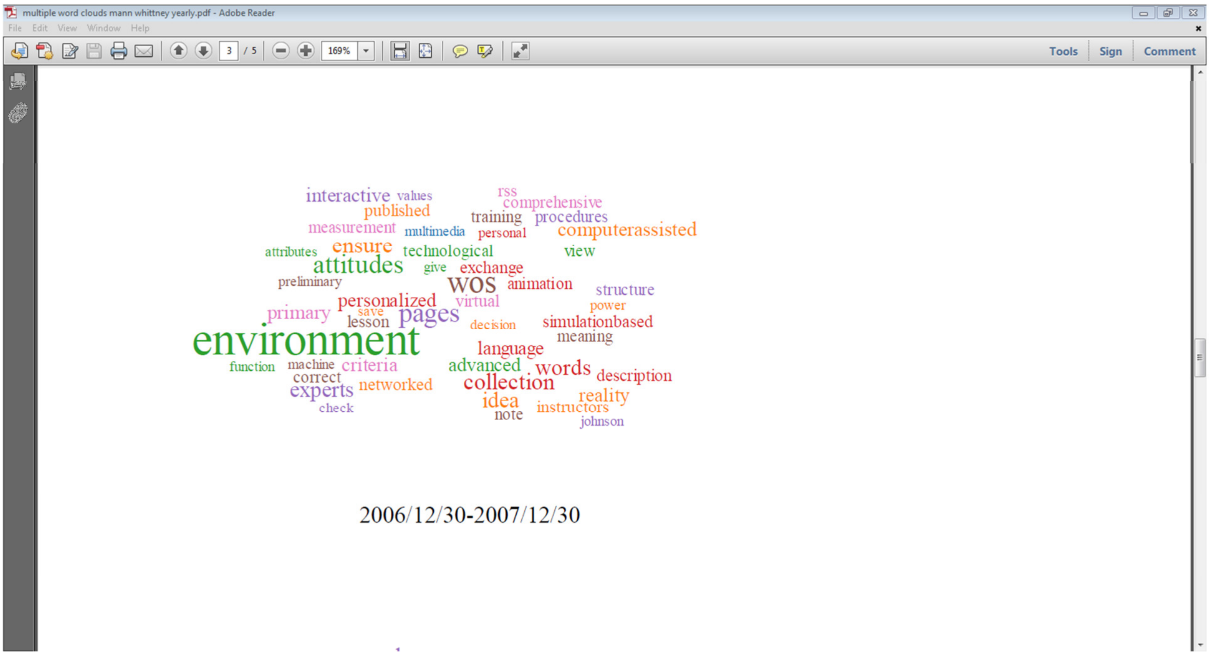

FIGURE 13 2007

2007

Environment is clearly the largest influence in this Word Cloud since it is significantly larger than any of the other associated words. We see a reoccurrence of *simulationbased, multimedia*, and *computerassisted*, but there is less evidence of theoretical work. And we see for the first time a name which could be an author, *Johnson.*

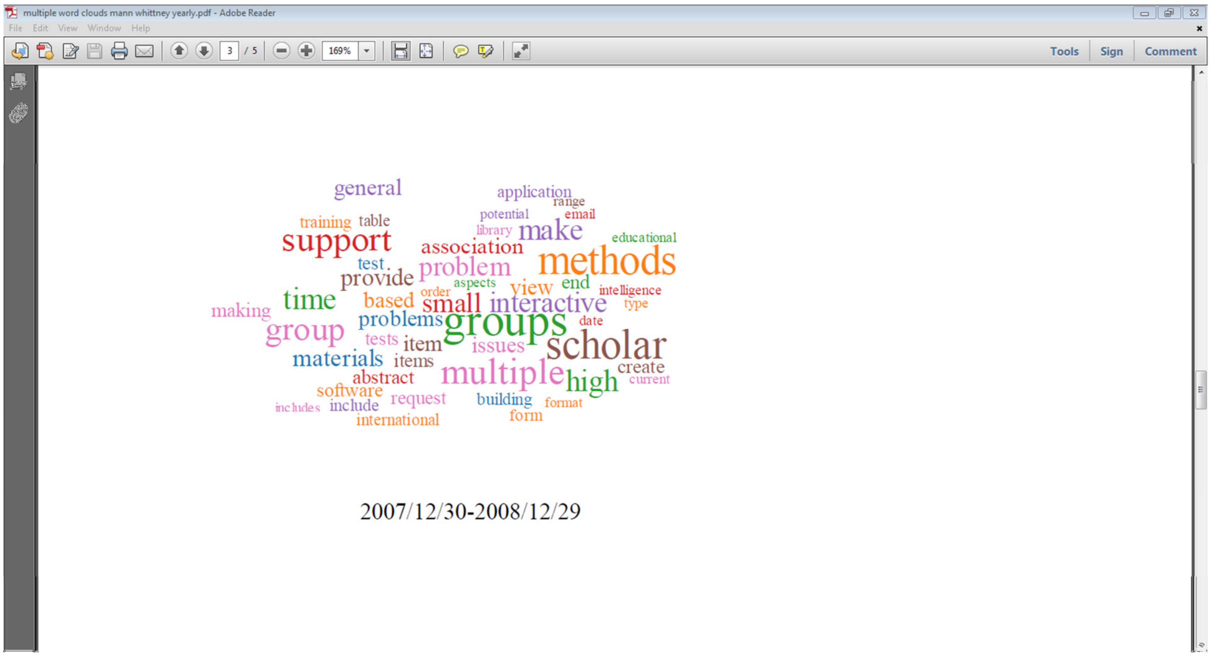

FIGURE 14 2008

2008

This Word Cloud shows *groups, group, support, scholar, multiple*, and *methods* as being the primary influences of this period. We also note *interactive, materials, time, tests*, and *building* and for the first time the use of the word *international.* It is assumed that these words indicate a greater focus on sociocultural and group or team based activities for learning.

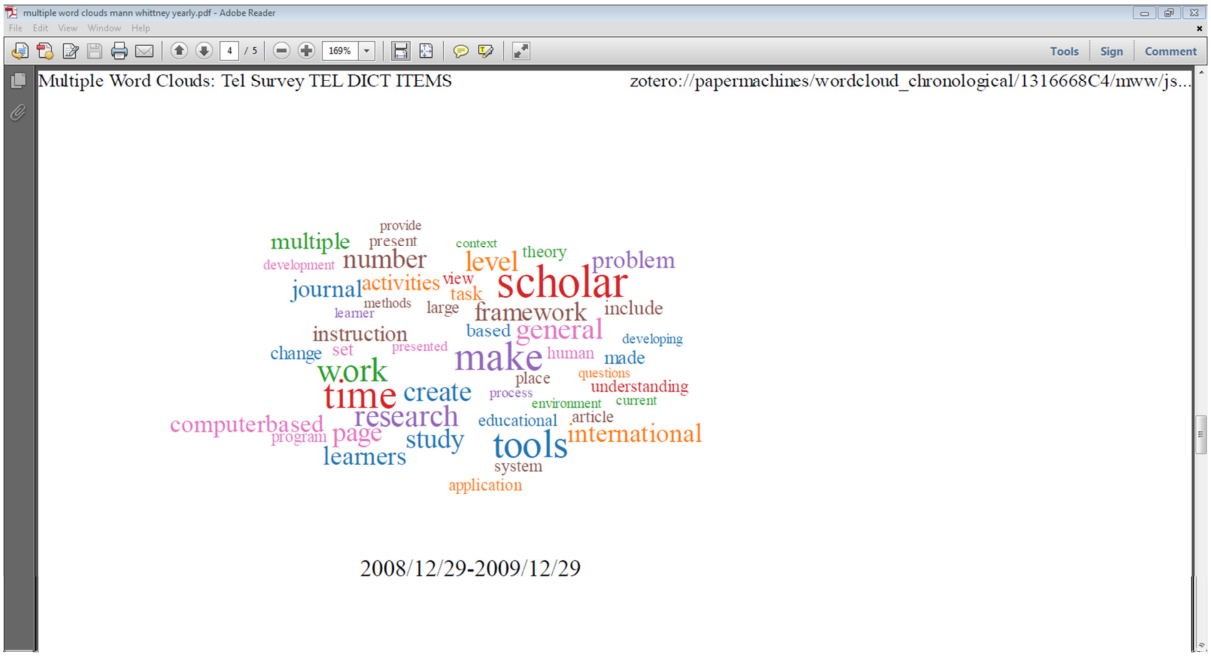

FIGURE 15 2009

2009

The main terms in this Word Cloud are *scholar*, *make*, *time,* and *tools* followed by *research*, *multiple*, *number*, *problem*, *framework*, *international*, *computerbased*, *learners*. We do have the words *theory* and *context* along with *understanding* and *view* which suggests that, within this time period, there may be some literature or movement toward a theory or theoretical based understanding of the field.

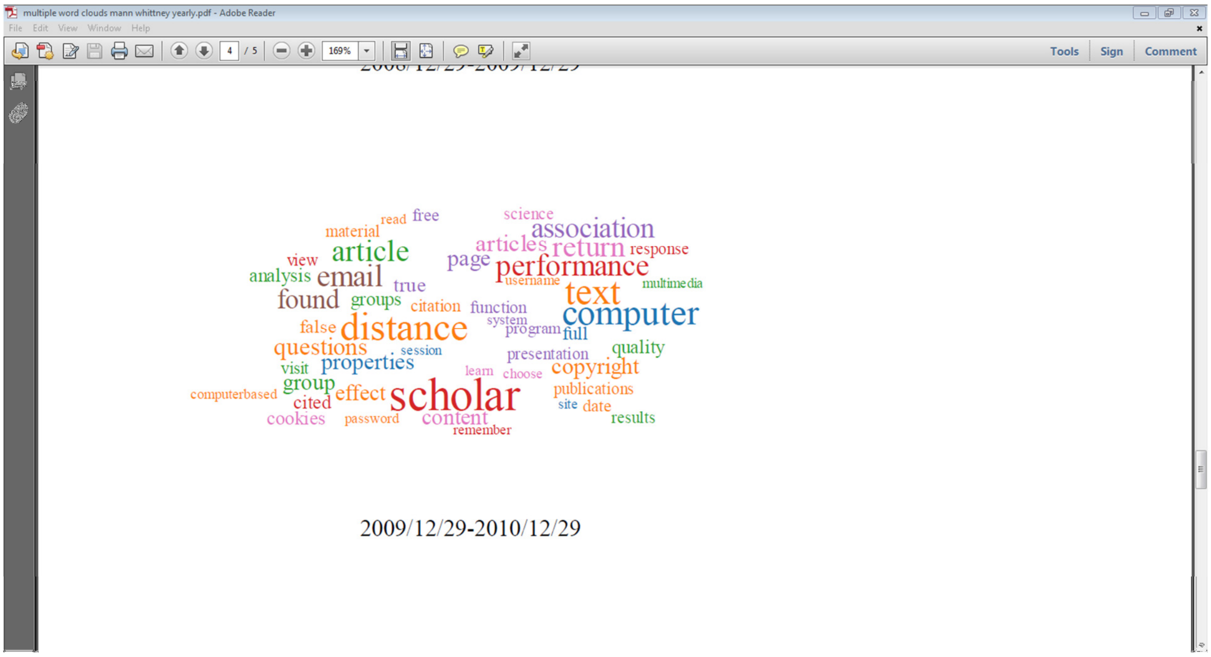

FIGURE 16 2010

2010

2010 repeats the pre-eminence of the word *scholar*, along with *computer*, *distance* and *performance*. We note terms such as *copyright*, *publications, cited,* and *cookies* along with *association, username,* and *function* which may indicate that this period is associated with either publications or the construction of bibliographic findings.

FIGURE 17 2011

2011

The main themes for this period are *computer*, *research*, *information*, *journal*, *design*, *instruction, teaching* and *scholar.* At a lower level there are also terms such as *language*, *authors, author, text, study, users, article* and *review* which suggest a continuation of the focus on bibliographic systems or of how findings are being published or cited. We note the terms *cognitive* and *model* are included but they are the smallest text so may not be significant.

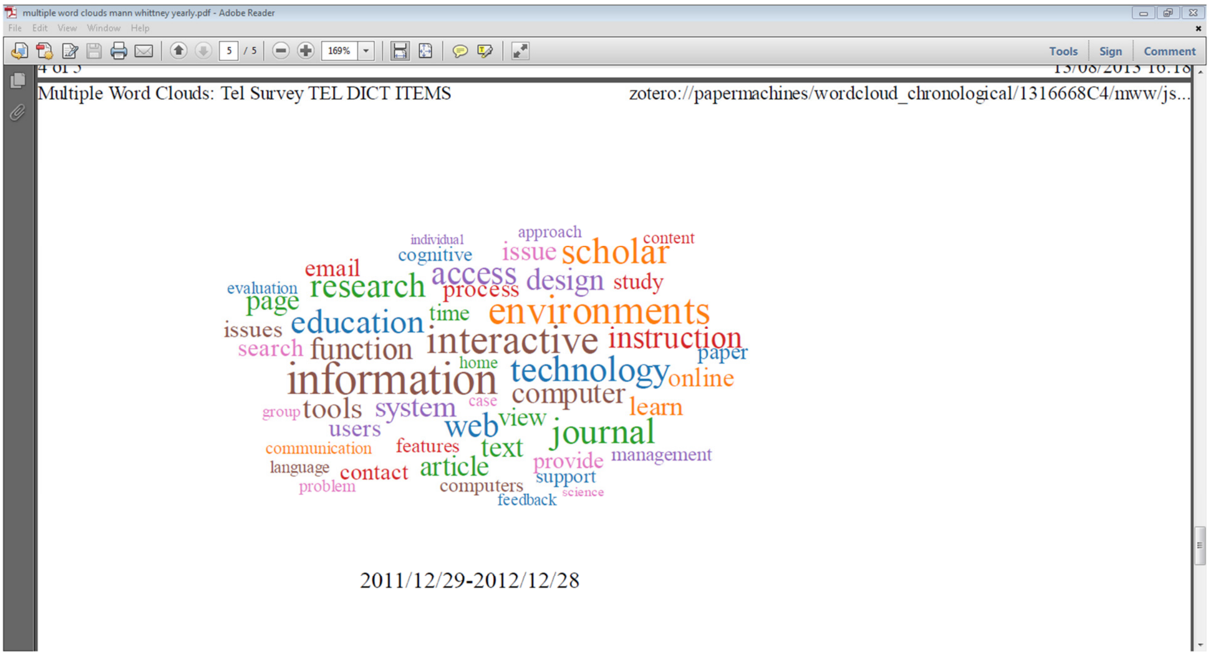

FIGURE 18 2012

2012

2012 shows a much more uniform size of the words in the Word Cloud having *interactive, environments, information, education, research* and *journal* all at similar levels. We have a continuation of the theme of bibliographic systems or publications with the words *article, journal, paper, content*, *issue* and *page* which again suggest some focus on either how the literature on the field is being stored, referenced or published. As in the last Word Cloud we see the word *cognitive* and the word *learn* but these are quite small and may not be indicating a theoretical work.

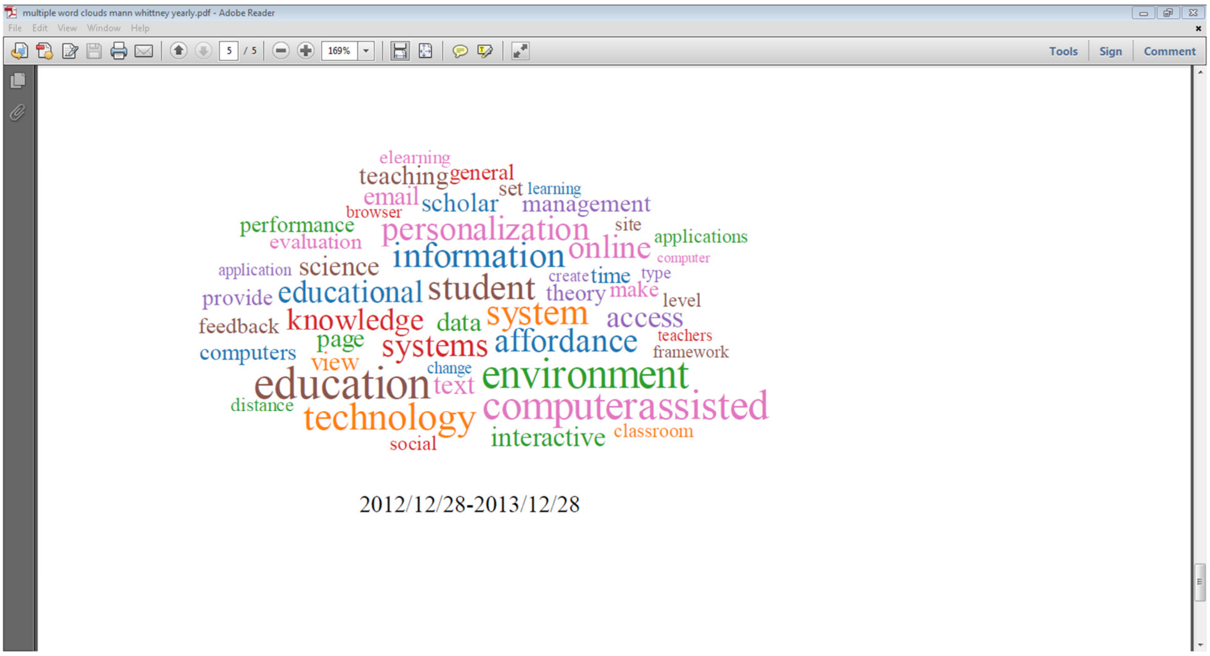

FIGURE 19 2013

2013

The most significant terms within this Word Cloud are *computerassisted, education, environment, technology, educational, knowledge, personalisation, information* and *affordance*. These would seem to indicate a move towards psychological perspectives in the design of systems but there does not seem to be a theoretical perspective reflected within this final Word Cloud.

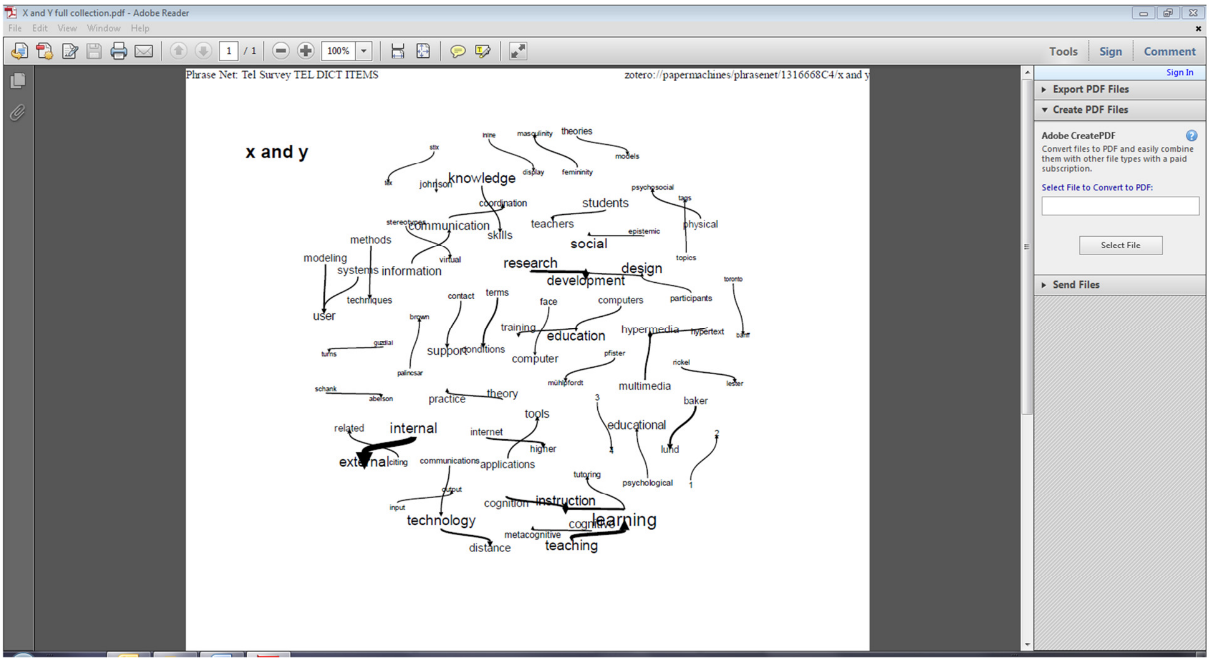

FIGURE 20 X AND Y

The x and y visualisation when applied to the entire data set provides confirmation in terms of word linkages and logical relationships that strongly suggest the data is both reliable and valid, for example, *theory and practice, hypermedia and hypertext and multimedia, physical and psycho-social, students and teachers, femininity and masculinity, theories and models*. All of these strongly suggest that we are looking at a reliable and valid visual representation of the data. In terms of structured relationships we see an interesting linkage in the area between *information, communication, coordination* and *skills* with *knowledge* which would be expected. We also see linkages between *computers, training* and *education* and between *research, development, design* and *participants*. The aforementioned linkages strongly imply socio-cultural theories and methods as being deeply embedded in the research literature as does the linkage between epistemic and social.

There is also an intriguing relationship shown between *cognition, instruction, tutoring, cognitive, metacognitive* and *learning* and *teaching* which again implies some deep relationship in the data related to the use of cognition as a factor in instruction, teaching and learning.

Aside from these thematic linkages there are also author names that are clearly revealed in the data, for example *Baker* and *Lund, Rickel* and *Lester, Pfister* and *Muhlpfort, Schank* and *Abelson, Brown* and *Palinscar*, and *Guzdlal* and *Turns*. Which we discuss later in this report under the heading "Investigation into possible author names appearing in main corpus".

X OR Y PHRASE NET

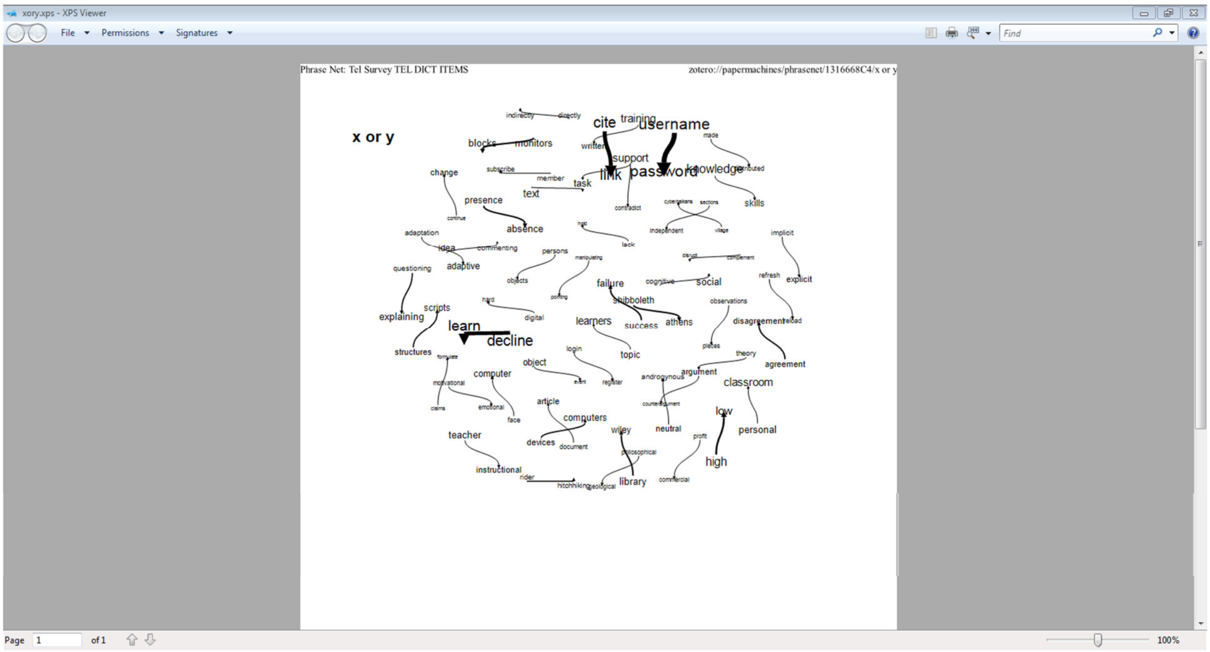

FIGURE 21 X OR Y

The diagram shows several relationships which suggest the reliability and validity of the data and the processing for the visualisation, for example, *implicit or explicit, refresh or reload, directly or indirectly, presence or absence, questioning or explaining, success or failure, profit or commercial, high or low, agreement or disagreement, complement or disrupt, persons or objects, teacher or instructional, personal or classroom*. However, there are also some more puzzling relationships, such as *rider or hitchhiking*, and *philosophical or geological*.

The strongest relationship shown in the x or y diagram is between *decline or learn* (if we ignore the more obvious *username or password*, and *cite or link*, which are not high level theoretical concepts but rather practical elements of computer use that are shared amongst many studies). Other puzzling relationships are between *cognitive or social, shibboleth or Athens*, *observations or pieces*, and *village or cyber-Balkans*, so that it is apparent that there are a number of relationships which must be represented in the data but which do not provide us with any clear picture of a developing body of knowledge.

N-GRAMS FROM 2000 TO 2013 SHOWING TEMPORAL OCCURRENCES OF SIGNIFICANT THREE WORD PHRASES

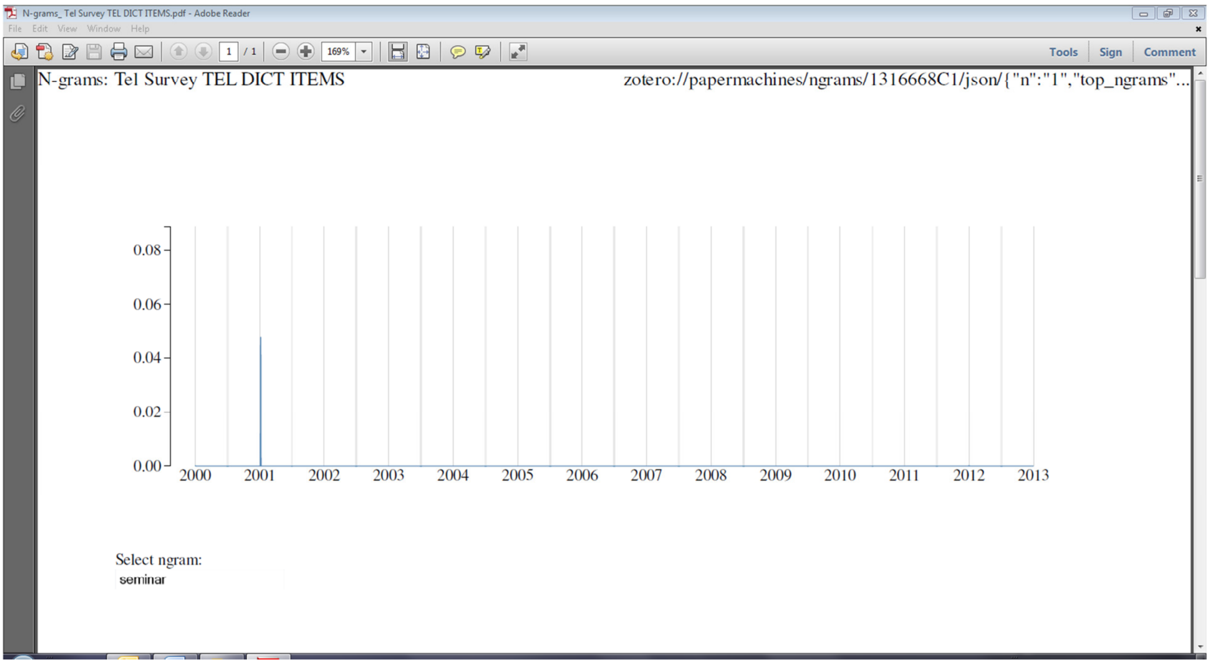

FIGURE 22 N GRAM

As would be expected many of the three word phrases are not specifically related to the literature domain, for example *user acceptance WOS*, *screen reader users*, *related articles related*, *SDM undefined typeof*. We will therefore ignore these non-theme related phrases.

Personal learning environment – this shows use across the entire time period with growing significance from 2008 to 2012 where the periods 2010 to 2012 show exponential growth in the use of the term.

computersupported collaborative learning – this shows use across the entire range of the time period but with notable peaks in 2003, 2006, 2007 and then reduced activity with smaller peaks in 2011 and 2012.

Intelligent tutoring system – this shows activity in 2000, 2003, 2005, and 2008 but note this is low level activity.

Data mining educational – this shows peaks of activity in 2011, 2012 and 2013.

Distance education elearning – this shows a single peak in 2013.

Learning management systems – this shows activity in 2006, 2008 and 2009, reduced activity in 2010 and a large peak in 2013.

Improving classroom teaching - shows a single large peak in 2013.

Simulationbased learning environment – this shows activity growing in 2010 and 2011, no activity in 2012 and then a higher peak in 2013.

Argumentative knowledge construction – this shows a peak in 2006 and 2007 and no activity elsewhere.

Learning environment students – shows activity in 2011 and a larger peak in 2013.

Animated pedagogical agents – shows a peak in 2000, lower level activity in 2002, then no activity until we see it peaking slightly in 2008, but at a lower level than it was in 2000.

Interactive white board – first noticed in 2011 then 2012 with a much larger activity in 2013 so is obviously a growth area.

Bibliographic information citing – shows small activity in 2002, 2003 and a higher level of activity in 2011.

Interactive learning environments – shows activity in 2009, 2010 and 2011 and then does not appear in 2012 or 2013.

Computer assisted learning – shows activity of a low level in 2001, 2003, 2004, 2005 and 2006 and then much lower level activity until a slight rise in 2012, but no activity in 2013.

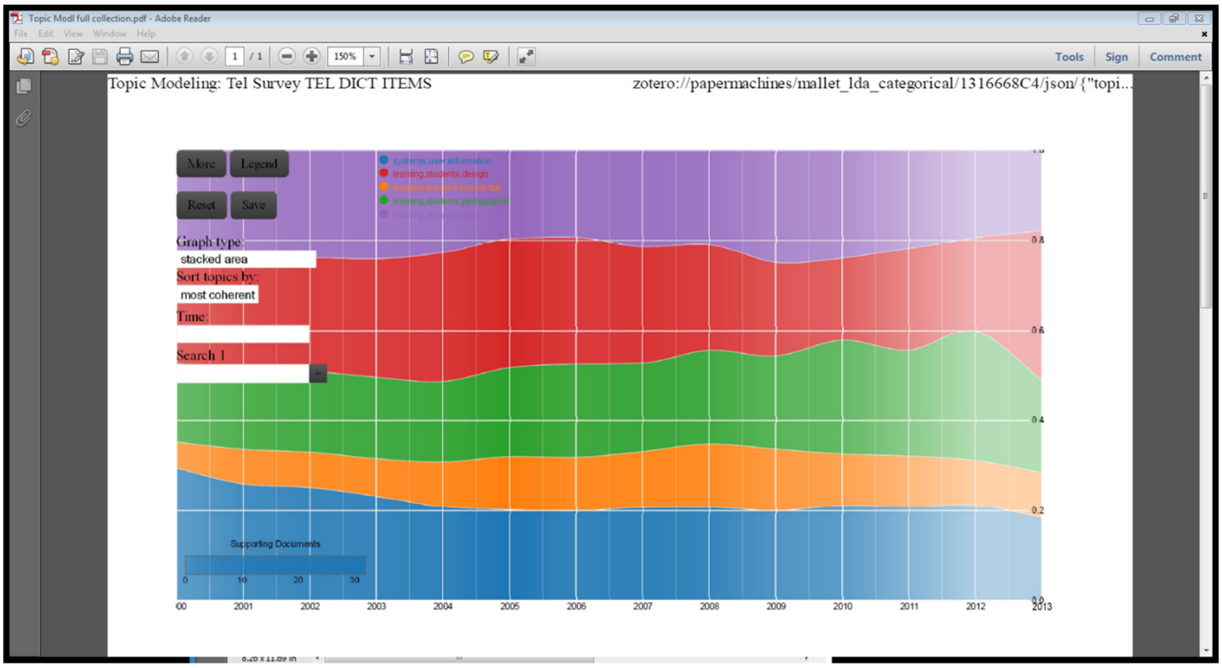

FIGURE 23 TOPIC MODELLING MAIN THEMES

Regression analysis found 5 primary themes covering all of the data. They were (in order of strongest coherence) –

systems, user, information

learning, students, design

learning, learners, knowledge

learning, students, pedagogical

learning, dummy, social

Each of these themes are reflected in the diagram, showing the percentage of their presence in the data over time, each occurrence having a minimum of 30 supporting documents. When looking at the five themes we see *social* along with *systems, user, information* (that is the first category and the last category) appearing most stable over the whole period. The other factors vary over time. The *learning, students and design* shows a reduction in area between the years 2008 and 2011 but overall the amount of area occupied out of the total for this category appears quite consistent. It is larger than the other themes indicating that more literature has been devoted to this particular domain than others.

The two remaining subdomains that have not been covered take up less area and of those two the *learning, students, pedagogical* show some increase in their area and therefore importance in the field with some growth between 2010 and 2012. In contrast the theme *learning, learners and knowledge* has shown an increase in its area from the year 2000 to 2005 and from thereon with a slight peak in 2008 it has remained fairly consistent.

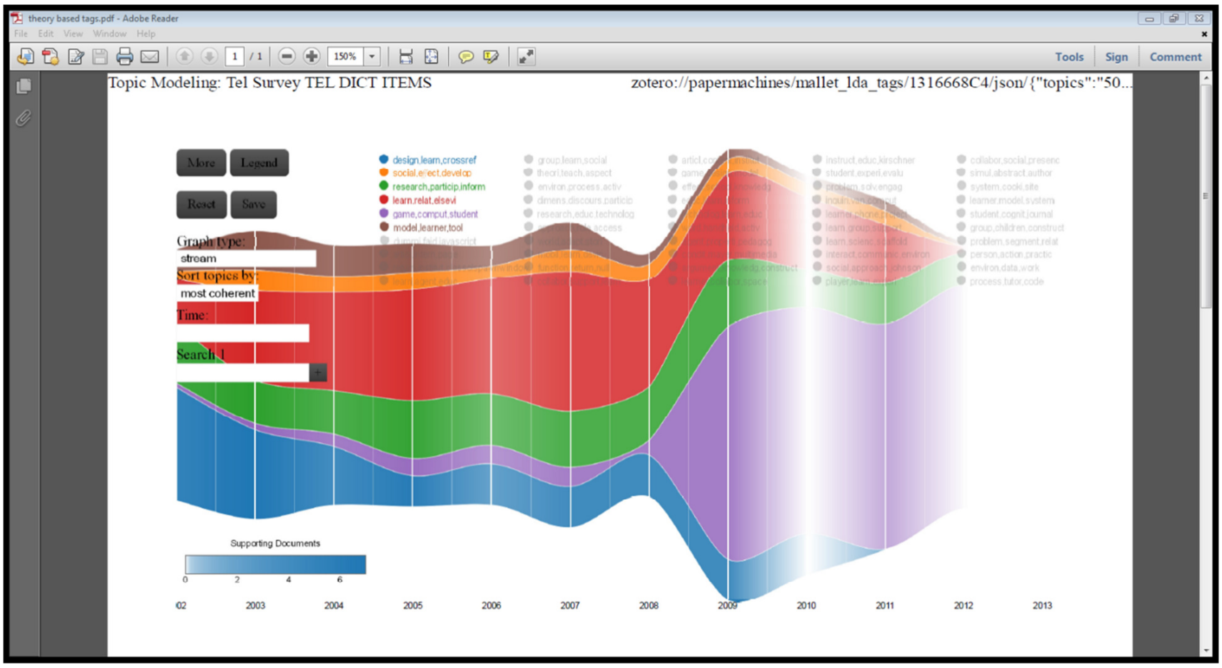

FIGURE 24 TOPIC MODELLING WITH THEORY TAGS

This diagram was produced by performing a regression on the data using the following tags, which were felt to represent theory based work which would have been performed within the literature. These tags were as follows -

Metacognition

Theory

Cognitive load

Collaborative learning

Learner model

Mobile learning

Motivation

Social presence

Cooperative/collaborative learning

Game based learning

Learner modelling

Framework

Constructivist

Collaboration

Expectation-confirmation

The regression identified 6 primary factors which were in order of coherence (having a minimum of 7 supporting documents)

Design, learn, cross-reference

Social, effect, develop

Research, particip, inform

Learn, relate, Elsevier

Game, compute, student

Model, learner, tool

When reviewing these six factors in terms of their area, we note there has been a decline in most of them except with a dramatic contrast, that of gaming, which from 2008 shows a quite dramatic increase in area which would reflect a much larger proportion of the literature from 2008 through to 2012. The other areas of literature have been impacted by this dramatic growth and all show reduced areas from 2008 onwards. The research theme*, research, particip, inform* is shown to have been the largest and therefore the most significant area for theoretical work from the years 2003 through to the years 2008-9 from which time it would appear that gaming and student based gaming have become by far a much larger area in the literature.

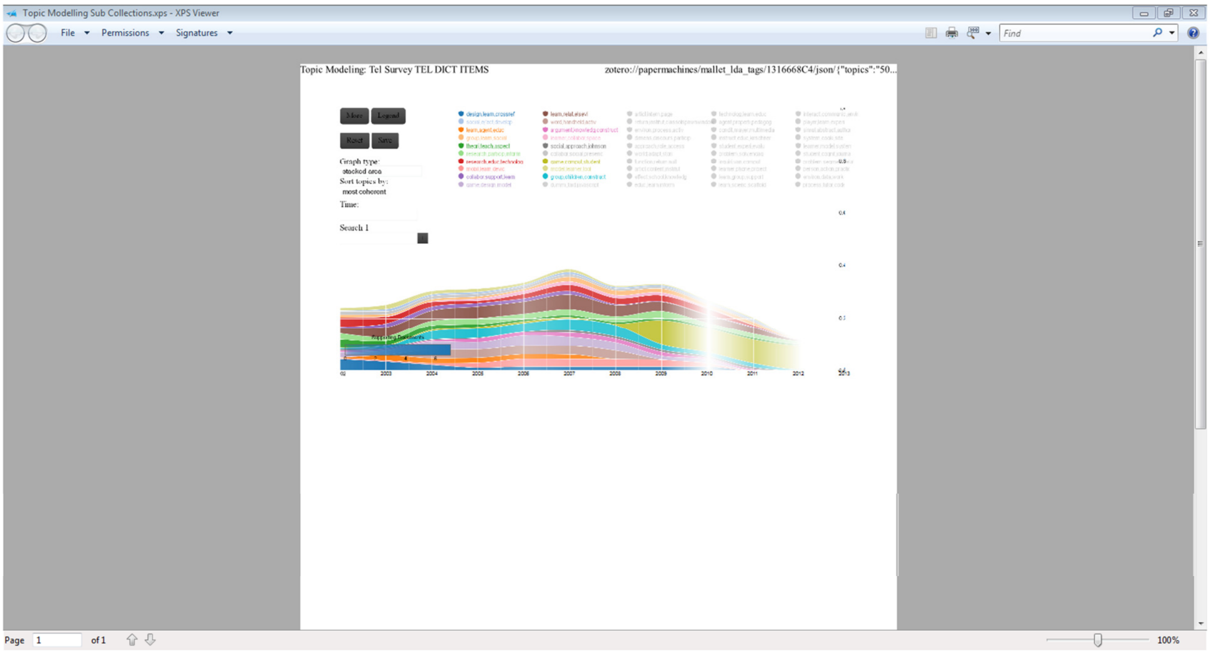

FIGURE 25 TOPIC MODELLING SUB COLLECTIONS

This is a regression based on at least 7 documents for each of the items and it has returned 19 sub-collections. They are, in order of coherence

Design,learn, cross-reference

Social, effect, develop

Learn, agent, educ

Group, learn, social

Theori, teach, aspect

Research, particip, inform

Research, educ, technolog

Mobil, learn, devic

Collabor, support, learn

Game, design, model

Learn, relat, elsevi

Word, handheld, activ

Argument, knowledg, construct

Learner, collabor, space

Social, approach, Johnson

Collabor, social, presenc

Game, compute, student

Model, learner, tool

Group, children, construct

The overall largest area in this combined data *is learn, relat, elsevi*. All of the themes look relatively consistent in terms of the amount of area space that they cover, the notable exception being *learn, agent, edu* which is active from the start right the way through to the latter end of 2007 when it disappears from our literature. There is also a reduction in surface are for *collabor, support, learn* which phases from the literature with a reduction starting in 2007 and becoming very minimal towards 2011. The factor *group, children, construct* shows growth from 2003 until 2008 where it shows from that point a decline in its surface area and therefore in its field. The field *design, learn, crossref* shows a decline in its surface area from 2002 when it is at its peak to the middle of 2010 when it ceases to appear. The other final remark we have to make is related to *game, compute, student* which shows a massive growth from 2008 in terms of its total surface area in relation to the other fields and there is a clear decline in the other field's surface area as gaming becomes one of the most predominant features in the literature.

INVESTIGATION INTO POSSIBLE AUTHOR NAMES APPEARING IN MAIN CORPUS

X and Y Phrase Net

There are a number of papers authored by Baker but none with Lund in the corpus. Baker and Lund can be found in Google Scholar having published 'Promoting reflective interactions in a CSCL environment' in the Journal of Computer Assisted Learning in 1997. Since 1997 is prior to our search date it would explain why the paper is not within our corpus.

We have Rickel and Lester listed in our literature with a paper called 'Animated pedagogical agents' which appeared in the International Journal of Artificial Intelligence in Education, 2000. It is very highly cited by 931 people.

Pfister does not appear within our corpus. There are mentions in a number of papers of a work by Pfister and Muhlpfort titled 'Supporting discourse in a synchronous learning environment: the learning protocol approach' which appears in the Proceedings for Computer Support for Collaborative Learning: Foundations for a CSCL community, 2002. But the paper does not appear directly in Google Scholar searches and that is probably the reason that it was not included in our corpus.

Schank does not appear in our corpus. Schank and Abelson do however appear in Google Scholar and wrote a number of papers together, the first of which is a book from 1975 entitled 'Scripts, Plans and Knowledge' cited 476 times. The next significant publication by them is entitled 'Knowledge and Memory the real story' published in 1995 as an essay cited by 519 people. Most recently they have published in 2013 a book titled 'Scripts, Plans, Goals and Understanding: An enquiry into human knowledge structures' cited by 10,868 people, but this is a reprint of their already quoted 1975 work, which is why it does not appear in our corpus.

Although we have authors with the surname Brown within our corpus none would appear to be linked with Palinscar. However we do find mention of the pairing in Google Scholar, where they worked extensively together in the 1980's producing such works as 'Guided, cooperative learning and individual knowledge acquisition' which appears in 'Knowing, learning and instruction, Essays in honor of Robert Glaser' 1989 which is again outside of our time frame.

Guzdlal does not appear in the corpus. According to Google Scholar Guzdlal and Turns published extensively together in the 1990's and their seminal work was entitled 'Effective discussion through a computer mediated anchored forum' published in 2000 in the Journal of Learning Sciences and has been cited 302 times. They also published a well-known work titled 'Collaborative support for learning in complex domains' which was published in the first CSCL conference in 1995.

PAPER MACHINES FOR THE SUB CORPUS “TOP TEN PERCENT BY CITATION”

The entire data set was sorted by citation and of the 691 papers 70 (the top ten percent) were extracted into a subcollection. Paper machines was then run on the subcollection with the following results (for a list of the papers that made the top ten percent see the word document ‘top ten percent by citation’).

WORD CLOUD

FIGURE 26 WORD CLOUD 10%

The largest category is the word *learning* followed *by interaction, students, educational, adaptive*, *knowledge, hypermedia, environment, pedagogical, online, agent, instructional, courses.* This series of themes show the predominance of collaborative rich media within the top ten percent of the literature. *Collaboration, adaptation, agents, interaction* and *social* are strongly represented within the word cloud. Less strongly represented are more abstract terms such as *figure, materials, elearning, adaptation, hypertext, order* and *workshop*. It is argued that this shows that the top ten percent of the literature is giving us a much more coherent picture of the field as would be expected since it is the most influential. The only proper names within the data set that are represented are *Johnson* and *faid*, which we have seen appear elsewhere in the larger data set.

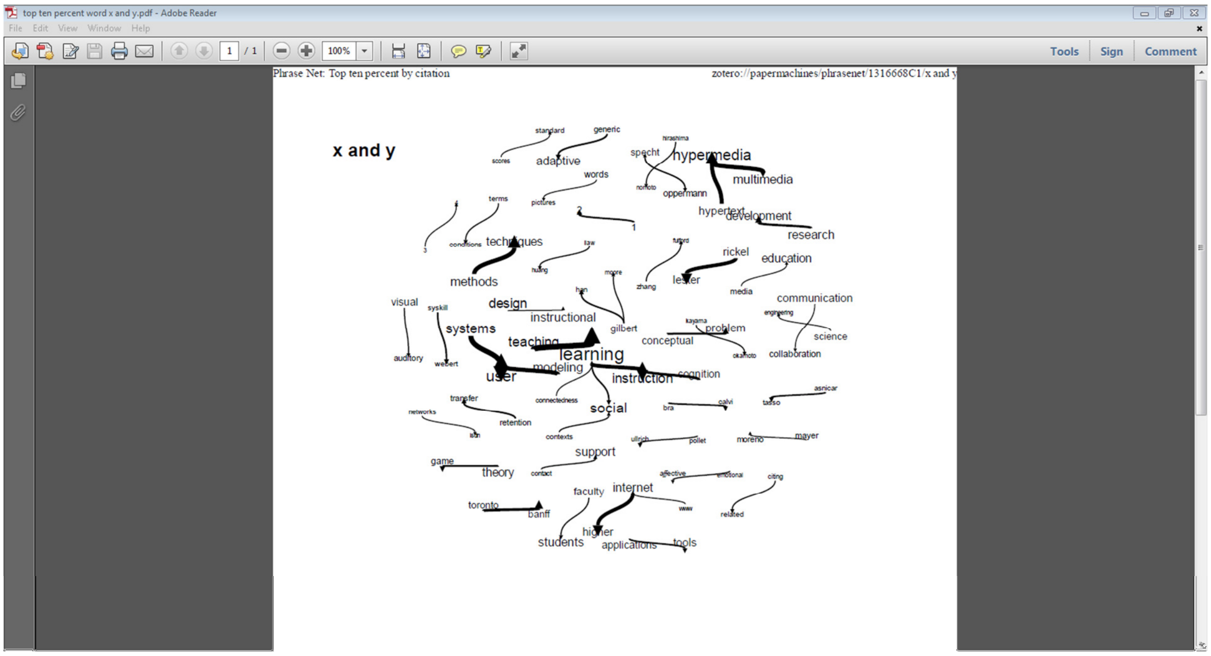

FIGURE 27 X AND Y 10%

The x and y shows a number of terms, first we will check to see if the data set looks as though it is valid and we see pairings that are indicative of reliable data:

Terms and conditions

Methods and techniques

Words and pictures

Visual and auditory

Faculty and students

Research and development

Learning and instruction

From these we have some confidence that the data shows consistent internal structure. We also see a number of references that may be indicative of relationships between studies or authors.

These are:

Specht and Oppermann

Liaw and Hung

Zhang and Fulford

Gilbert and Han

Gilbert and Moore

Rickel and Lester

Kayama and Okamoto

Asnicar and Tasso

Bra and Calvi

Mayer and Moreno

Pollet and Ullrich

Elsewhere in this report we will report on the relationships between these names as they indicate relationships between studies.

Deep relationships are shown between *learning, instruction, cognition, social, context*, *user,* and *modelling,* which implies that the thematic strength of the top ten percent of this literature is related to social and group cognition in the building of knowledge and learning.

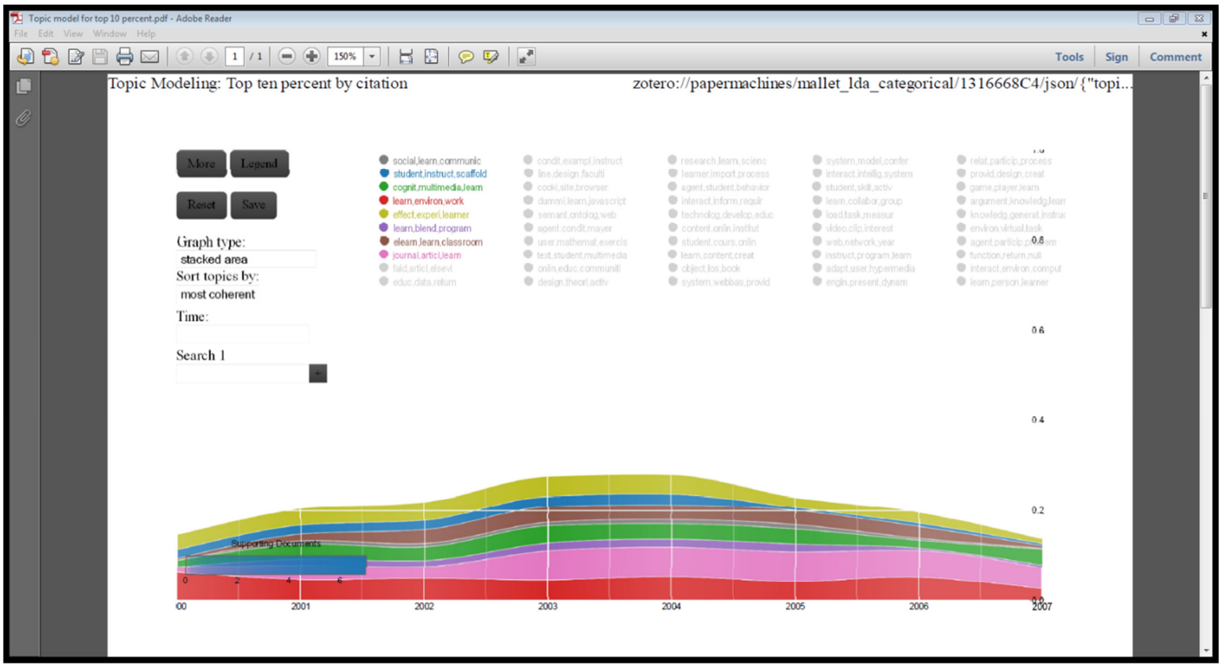

FIGURE 28 TOPIC MODELLING 10%

The topic model for the top ten percent showed a number of identified themes within the literature.

Social, learn, communic

Student, instruct, scaffold

Cognit, multimedia, learn

Learn, environ, work

Effect, experi, learner

Learn, blend, program

Elearn, learn, classroom

Journal, articl, learn

These eight topics may give us a framework with which we can understand the main thematic actions and activities within the literature, since these are the most influential papers.

INVESTIGATION INTO POSSIBLE AUTHOR NAMES APPEARING IN TOP TEN PERCENT

X AND Y PHRASE NET

There are two papers which are in the full collection authored by Marcus Specht. One of them is titled 'The 3P learning model' and the three p's proposed are personalisation, participation and knowledge pull (Oct 2012, Journal of Education Technology and Society). However this paper has not had any citations so it is unlikely to be the reference that has come out of the x and y analysis. However the second paper which is titled 'Mobile collector for field trips' is a report of the RAFT project, which is an EU project, describing how field trips can be documented by real time data collection on mobile apps. The paper was published in April 2004 in the Journal of Education Technology and Society. Oppermann has not appeared in our literature because his main work, which was related to user modelling in the 1990's in the area of intelligent tutoring systems, is outside of the time limits of our review which starts in the year 2000. We note that Oppermann and Specht wrote a paper called 'Adaptive mobile museum guide for information and learning on demand' which is cited by 38 people. We can therefore say that Specht and Oppermann are linked by association within the data. Both Reinhard Oppermann and Marcus Specht worked at GMD (German National Research Centre for Information Technology).

Although Liaw and Hung's paper does not appear within our collections we are aware that they co-published a paper titled 'Surveying instructor and learner attitudes towards elearning' which was published in Computers and Education in 2007. We must speculate that the keywords used to index this paper did not match the search terms that came from the TEL dictionary or that the paper was not amongst the most highly cited when the terms were searched through Google Scholar. Either of these explanations would explain why the paper does not appear within our bibliography but it is clearly cited by a large number of our papers.

The combination Zhang and Fulford have four main publications together, all of which are prior to the start of our period. The most influential paper that they have produced together is 'Perceptions of interaction, the critical predictor in distance education' in the American Journal of Distance Education, 1993 which has been cited by 444 people.

There is one paper that comes up with the combination of Gilbert and Han. It is called 'Arthur: a personalised instructional system' from the Journal of Computing in Higher Education, 2002. It has only been cited by 39 people so we must assume it was not amongst the most highly cited papers so for that reason it was not included in our literature base.

The first note that we encounter is that there are multiple authors that share the surnames of Gilbert and Moore. There is a prominent pairing in human genetic studies and there is a prominent paper written in 1998 which is relevant to our theme and is most likely the paper that is being frequently cited 'Building interactivity into web courses, tools for social and instructional interaction' in Educational Technology.

We have Rickel and Lester listed in our literature with a paper called 'Animated pedagogical agents' which appeared in the International Journal of Artificial Intelligence in Education, 2000. It is very highly cited by 931 people.

Kayama does not appear in our data set. Referring to Google Scholar, Kayama and Okamoto have authored a number of papers together related to knowledge navigation in hyperspace. The most highly cited being a paper titled 'Future integrated learning environments with multimedia' published in July 2008 in the Journal of Computer Assisted Learning. The paper is derived from a paper which they both presented at the 8th

International Conference of Computers in Education in 2000. We can therefore propose that the reason that this work is being highly cited is based on the work which was conducted by the two authors in 2000 and prior to the start of our review period, but we note that it has only been cited 31 times although there are 11 versions of the same work in publication. So it may be that although this work is influential any individual iteration of the work spread among the 11 versions that have been published have not individually warranted sufficient citations to be included in our search.

Asnicar does not come up within our corpus. Asnicar and Tasso produced a paper called 'ifWeb: a prototype of user model-based intelligent agent for document filtering and navigation in the World Wide Web'. This was published in the 6th International Conference on User Modelling in Sardinia 1997. It has only been cited by 138 people and is not in a peer reviewed literature and was therefore probably not included within the highly cited papers in our corpus search.

Bra and Calvi does not appear in our corpus. Bra and Calvi were actively collaborating in the 1990's in the area of adaptive hypermedia and hyper documents. Their most influential paper was titled 'AHA! An open adaptive hypermedia architecture'. Cited by 457 people it was published in the New Review of Hypermedia and Multimedia in 1998 and is therefore outside the range of our search terms.

There are a number of authors with the surname Mayer. Mayer and Moreno have published frequently together and are represented within a number of works within our corpus. The most highly cited of these is the paper 'Nine ways to reduce cognitive load in multimedia learning' published in the Educational Psychologist in 2003 and cited by 1203 people.

We have one paper in the corpus that includes Pollet and Ullrich, but also includes a number of other authors on the same paper. The title of this work is 'Active math, a generic and adaptive web based learning environment' and was published in the International Journal of Artificial Intelligence in Education' in 2001 and cited 303 times.

Having completed the data analysis on the top ten percent of journal publications, we felt that before we concluded, it would be remiss of us not to perform an analysis on a subcollection of the most highly cited books, monographs and conference papers that had been revealed in our original searches.

WORD CLOUD

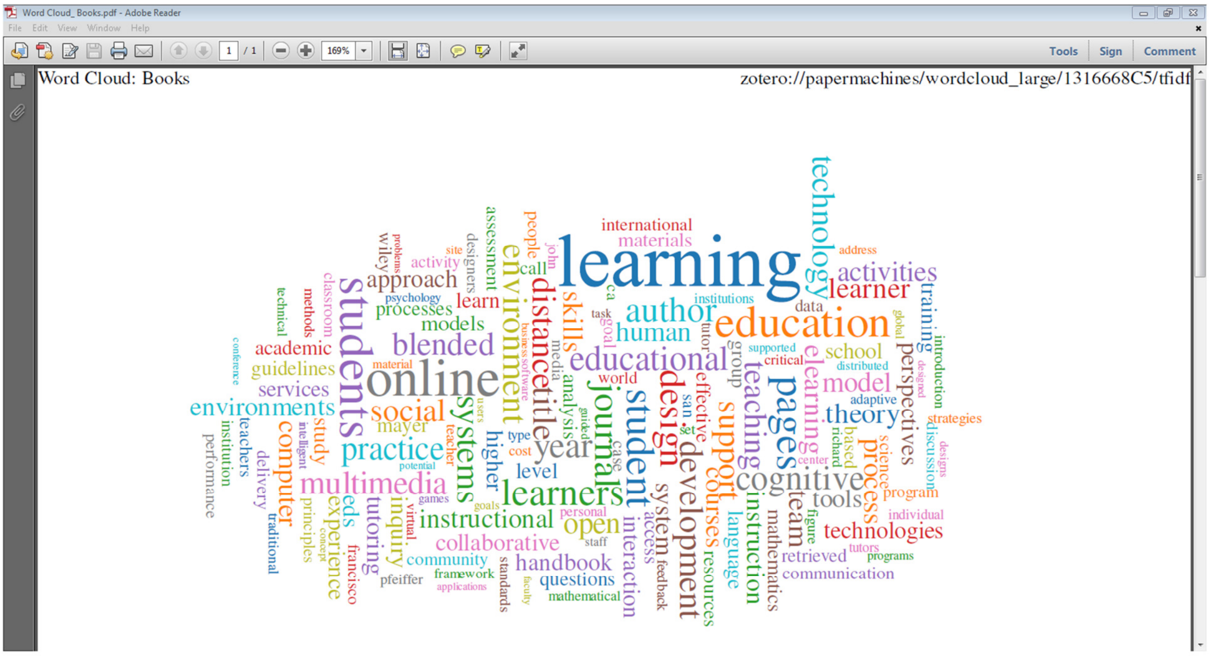

FIGURE 29 WORD CLOUD BOOKS

The main themes are *learning, education, cognitive, distance, student, skills, online, practice, learners, development, author, blended, multimedia, technology*. It is argued that these prominent words reflect the themes one would expect to find and therefore argue for a reliable and valid data set. In comparing the word cloud for the books with those for the journals, the books show a much more balanced overview of the field in terms of theories and themes that have been represented within the literature for instance,

teachers, institution, performance,

collaborative, community, framework,

people, environment, assessment,

problems, psychology, processes, models

The corpus of material reflected in the word cloud for the books shows a much more coherent grouping.

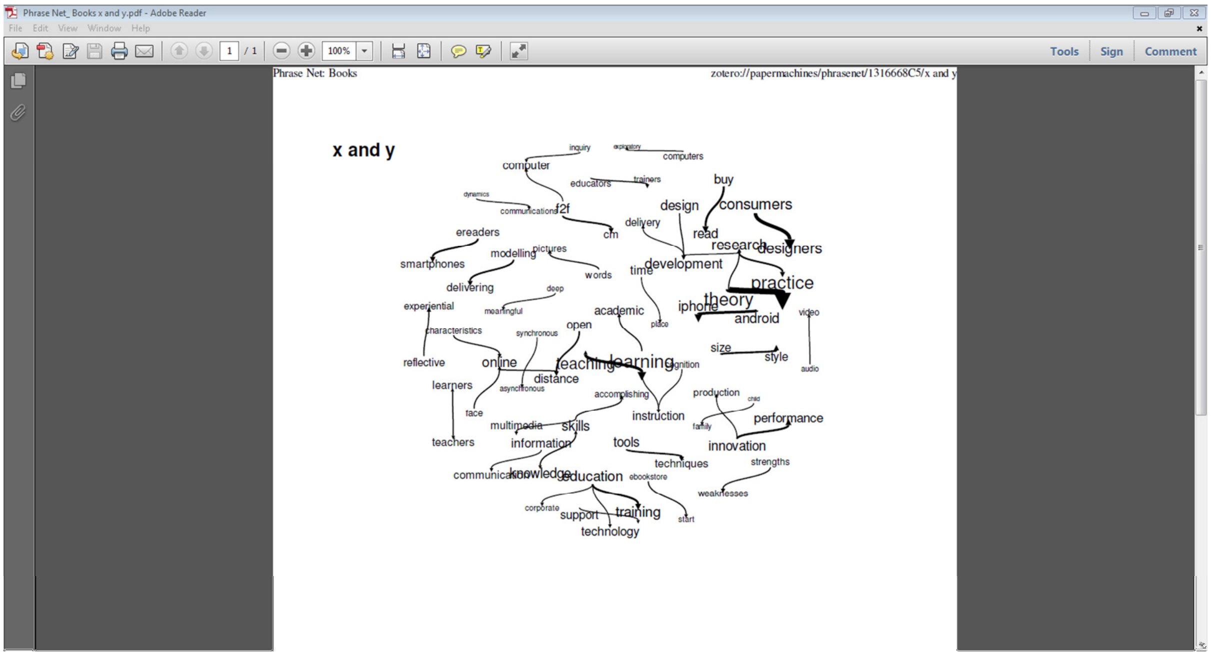

FIGURE 30 X AND Y BOOKS

We first look for relationships that might suggest that the data is valid and reliable and we see:

Strengths and weaknesses

Child and family

Audio and video

Educators and trainers

Words and pictures

Deep and meaningful

Time and place

Such relationships support the hypothesis that the data is reliable and valid. The x and y for books also show at least three significant groupings related to the data. The first of which we will term community of practice and is made up of the following:

Theory and practice

Research and practice

Theory and research

Research and development

Design and development

Development and delivery

Consumer and designers

All of which suggest some community of practice related on building informed technology for educational purposes.

The second group is made up of:

Teaching

Learning

Instruction

Academic

Cognition

And is related to teaching and learning and the use of cognitive theory in instruction.

The **third** group is a grouping between:

Education and corporate

Education and technology

Education and training

Support and technology

Knowledge and skills

Information and communication

Skills and accomplishing

Information and accomplishing

This theme we will term the competence or practical application of elearning in corporate or training situations.

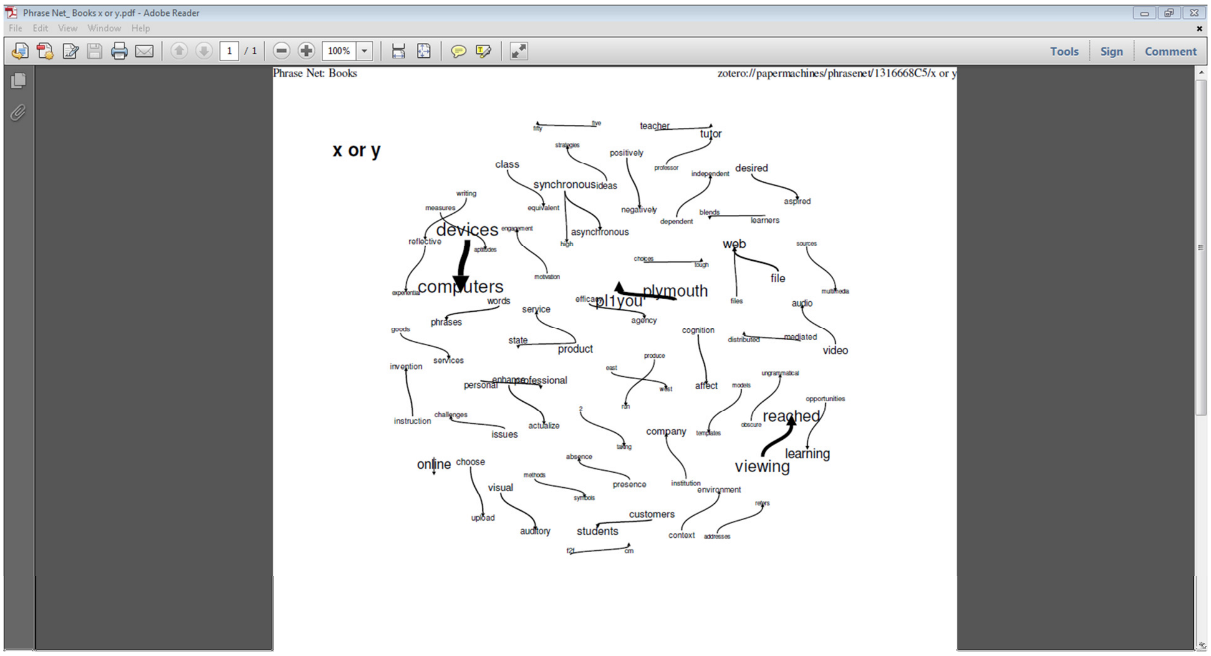

FIGURE 31 X OR Y BOOKS

We will first examine the data to see if there is evidence of meaning between the x or y relationships so we can judge the reliability and validity of the data. We see

Video or audio

Desired or aspired

Positively or negatively

Dependent or independent

East or west

Presence or absence

Customers or students

Goods or services

These relationships suggest the reliability and validity of the data. The relationships in the x or y diagram are not as strong or interconnected as they were on the x and y diagram.

We see a relationship between *Professor or tutor* and *teacher or tutor* which indicates some difference that may reflect the need for one person to lead a course in an elearning context whilst others are more supportive to the learner in tutorial based settings. More interesting is the relationship that is shown between *Writing, reflective* and *experiential* which may indicate some language learning as an applied topic within the literature.

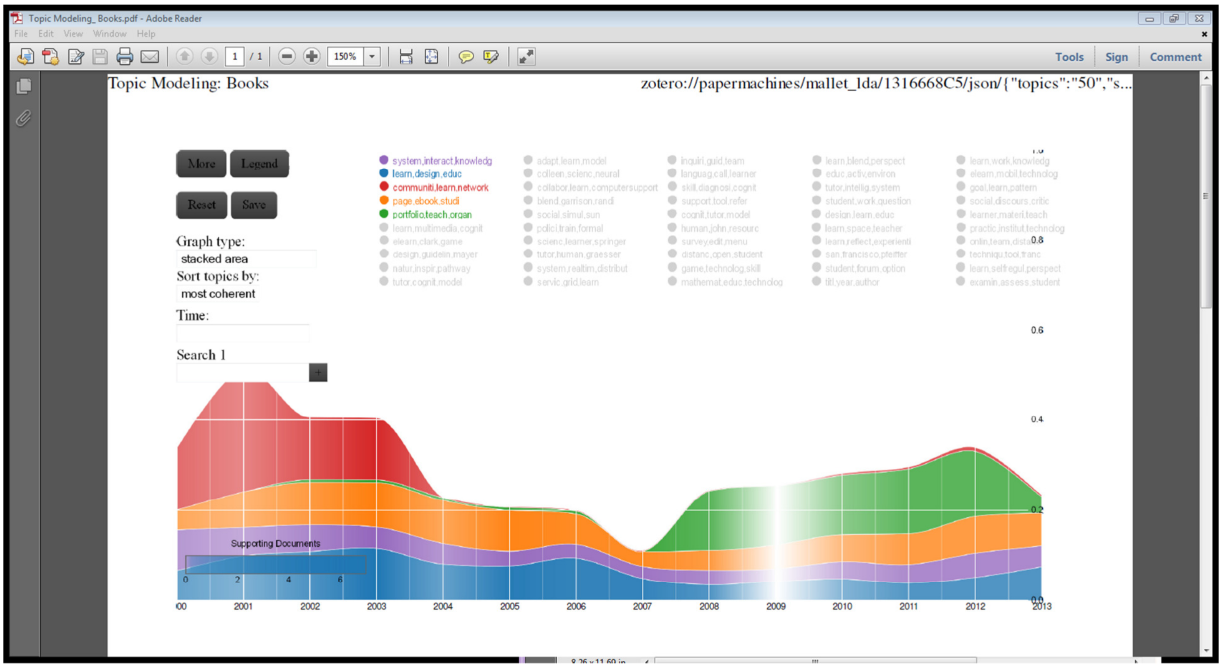

FIGURE 32 TOPIC MODELLING BOOKS

When the data set of books has a regression applied to it via its entire list of tags, five factors are identified. These are

System, interact, knowledg

Learn, design, educ

Communiti, learn, network

Page, ebook, studi

Portfolio, teach, organ

These would appear to be useful themes with respect to understanding the corpus of books.

System, interact, knowledg

This factor appears to be related to how interactivity within the system affects knowledge acquistion.

Learn, design, educ

How the design of learning impacts education

Communiti, learn, network

Related to how networks and communities impact learning

Page, ebook, studi

Related to e books and studies

Portfolio, teach, organ

Related to the use of portfolios within teaching.

These five themes may well be very useful as a framework for understanding how the literature is modelled over the thirteen years of our review.

COMPARISIONS BETWEEN THE DATA VISUALISATIONS FOR THE THREE DATA SETS

COMPARISON OF ANALYSES

First we will discuss the differences that emerge from looking at the 3 different data sets –

Full Set (681 items)

Top Ten Percent – (67 items)

Books – (60 items)

There are three types of analysis which we will compare. These are the Word Cloud, Phrase Net x and y, and Topic Models as applied to the full collection, the top ten percent and to books respectively.

WORD CLOUDS

All data sets have the commonality that *learning* is by far the most common repeated word. The word cloud for the full data set has a much more even distribution of terms in that most of the words are shown at a similar size and although *learning, students, educational, education, design, technology, information* are the largest terms the remaining terms such as *research, knowledge, support, environment, computer, student, learners* are quite evenly spread. When we compare that to the top ten percent by citation although there are a similar number of terms in the word cloud many of the words are much larger in size showing a much larger frequency in proportion to the data set size. When looking at the differences between the words in the top ten percent cloud *collaborative, hypermedia, cognitive, adaptive, interaction, group* and *social* are significantly larger indicating that they are more frequently encountered in the top ten percent by citation.

When looking at the books Word Cloud, we see a similar pattern to the larger data sets word clouds in terms that we have *learning* as the largest word followed by the other terms such as, *education, educational, students, learners, online* but these terms are all or at least most of them are at a similar level in terms of their size indicating a much more even distribution of the terms than are found in the top ten percent by citation. We also see a more coherent linkage of the words in the word cloud for the books data set than we find in the full data set. The top ten percent has some cohesion between the terms but not to the same extent as we see in the book cloud.

The most significant difference that is seen between the three word clouds is the far greater representation of the terms related to social and collaborative learning in the top ten percent citation data set.

PHRASE NET X AND Y

Looking at the x and y phrase nets the strongest relationships between *teaching and learning* remain. The main difference between the books x and y chart and those for the full data set and the top ten percent is that there is a strong relationship shown between *theory and practice* in the books set. There is also a marked difference in the way that the books show relationships between *education, training and support.* These differences would seem to indicate that the book data set is more related towards practical applied principles for the implementation or the use of technology enhanced learning. When comparing the top ten percent x and y chart there is a stronger relationship for *multimedia, hypertext and hypermedia* than we see in the full data set although the same relationships are shown i.e. between *multimedia, hypertext and hypermedia* they are much weaker relationships in the full data set. There is also a relationship shown in the top ten percent between *theory and game* and *social and learning* that is not shown in the full data set or in the book data set.

The topic modelling for the full collection revealed five factors

Systems, user, information

Learning, students, design

Learning, learners, knowledge

Learning, students, pedagogical

Learning, dummy, social

The top ten percent in contrast came up with eight factors

Social, learn, communic

Student, instruct, scaffold

Cognit, multimedia, learn

Learn, environ, work

Effect, experi, learner

Learn, blend, program

Elearn, learn, classroom

Journal, article, learn

The topic modelling for books came up with five factors

System, interact, knowledge

Learn, design, educ

Communiti, learn, network

Page, ebook, studi

Portfolio, teach, organ

None of these factors are identical. Learning appears to be a primary consistency appearing in all three topic models. The larger data set is split into what would appear to be studies related to the implementation of systems, studies related as to how design impacts students learning, how learners learn knowledge and how students can be taught and the impact of social factors on learning.

In comparison the top ten percent would appear to indicate that there is a factor related to the impact of social communication on learning, how students can scaffold their knowledge for instruction, how cognitive factors in multimedia impact learning, how learning environments can be used at work. The abbreviations make it more difficult to extrapolate but it could be that experience or looking at experiments and their effects on learners are the main topics related to this factor. The next factor is related to blended learning, then we have how elearning effects learning in the classroom and finally a factor related to learning within articles and journals.

In the books data set, the first factor would appear to be related to how interactivity within the system impacts knowledge, the second factor would appear to be how the design of learning impacts education, the third factor is related to how networks and communities impact learning, the fourth factor is related to ebooks and studies and the fifth and final factor is related to the use of portfolios within teaching.

Although the three data sets are clearly related there is a far more pragmatic influence on the factors within books than are seen within the main data set, and further the topic models that appear for the top ten percent are more coherent and useful for categorising and understanding the journal based material.

As part of the data analysis we examined the literature that had been cited by works within our main corpus "“Tel Survey TEL DICT ITEMS” and created a sub collection of those works called “Key Texts referenced by Corpus”. This contained 17 items.

WORD CLOUD

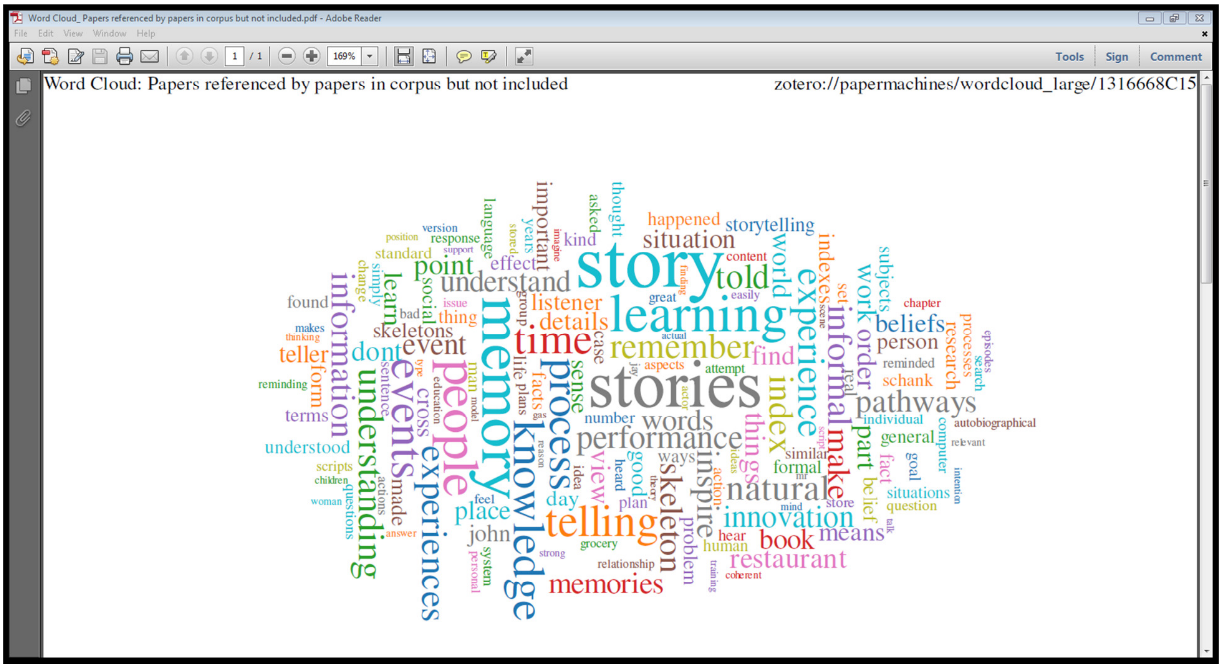

FIGURE 33 WORD CLOUD KEY TEXTS

The word cloud for the key texts is substantially and thematically different from those produced from the main corpus. It is much more reflective of the social sciences and even of the humanities than those word clouds that we have seen from the main corpus which were much more focused towards technology enhanced learning. Although the term *learning* and *memory* and *knowledge* are substantial sized components of the word cloud there are dramatic differences so that *story, stories, people, events, understanding, understand, remember, experience, pathways, innovation, telling*, and *book* form major elements of the word cloud.

It is proposed that this difference reflects the fact that these texts are the inspiration for the later work and themes that emerge within technology enhanced learning. The use of terms such as *restaurant, feel, place, kind, storytelling, pathways, autobiographical* and even *skeleton* suggest the origins of many of our principals come from the softer more philosophical areas of human endeavour. Learning is definitely a component but it is learning within the context of real life and a much richer set of experiences and philosophical reflection. We note the mention of Schank as a real name that requires further investigation and an unknown reference to John.

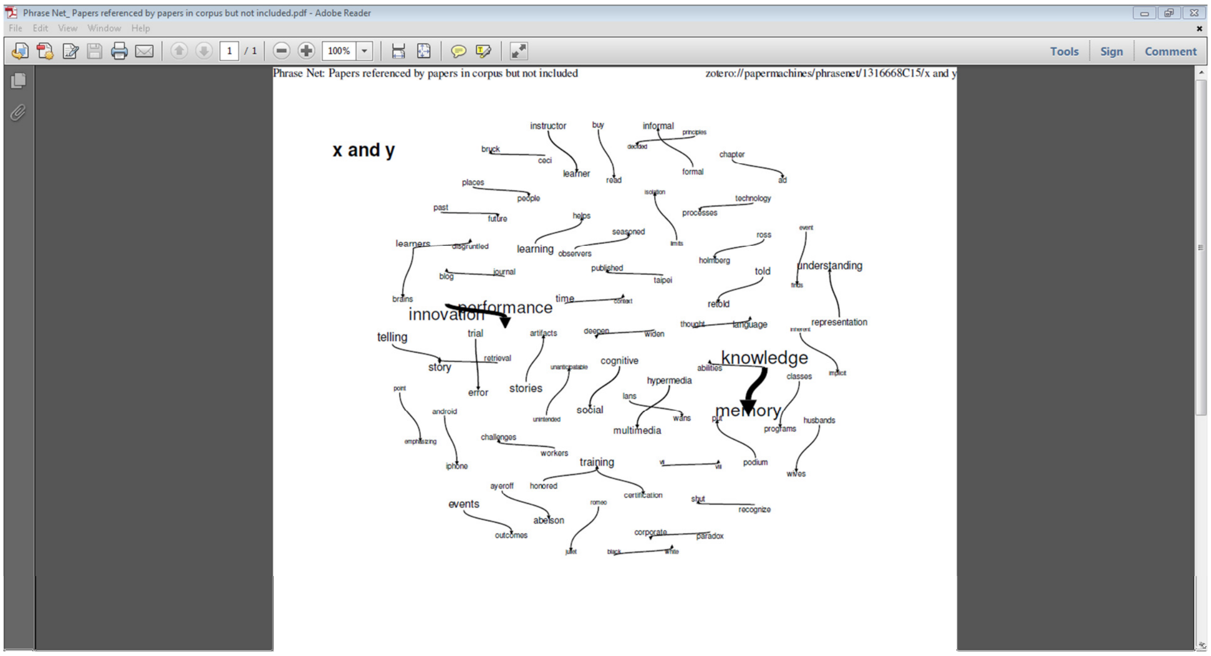

FIGURE 34 X AND Y KEY TEXTS

First of all we will look at whether the phrase net makes semantic sense so that we can have some check as to the reliability and validity of the work. So we see:

Husbands and wives

Android and iphone

Trial and error

Past and future

Formal and informal

Widen and deepen

Black and white

Romeo and Juliet

Events and outcomes

Thought and language

These terms confirm the reliability and validity of the data as they seem consistent with pairings that one would expect. Looking at the relationships that are implied by the data we see a strong relationship between *knowledge and memory* and *knowledge and abilities*, relationships between *representation and understanding, innovation and performance, learners and brains, and learners and disgruntled*, which is quite interesting as it implies that not all learners are happy with the learning process. There is also a relationship between *telling and story* and *retrieval* *and story*. We also note some author names that appear to be suggested and must be researched further to determine if they are publications that are further key texts that were used by these papers. They are:

Ceci and Bruck

Ross and Holmberg

Ayeroff and Abelson

Topic Modelling

Only one tuplet emerged, that is

Learn, inform, perfom

Which may reflect the more social science or humanistic basis of these key texts.

INVESTIGATION INTO WHAT APPEARS TO BE NAMES OR CITATIONS IN THE PAPER MACHINES ANALYSIS FOR THE KEY TEXTS

Word cloud

Schank and Abelson appear as one of the Key Texts. There are two main publications 'scripts, plans and knowledge (1975) and 'knowledge and Memory, an essay (1995).

John could be an abbreviation for Rickel Johnson with a journal article 'animated Pedagogical Agents'(2000) in the Key Texts.

Phrase Nets

Ceci does not appear within the Key Texts or main corpus but in Google Scholar is cited with a 1986 book 'The Handbook of Cognitive, Social, and Neuro-psychological aspects of learning disabilities'.

Stephen J. Ceci and Maggie Bruck produced a report titled 'Child Witnesses: translating research into policy'(1993). Both Ceci and Bruck worked together for over a decade examining the role of memory in children particularly focusing on how memories could be made unreliable by emotional trauma or suggestion.

Ross and Holmberg do not appear in the main corpus or Key Texts. From Google Scholar it would appear that they did not work with each other but Holmberg heavily cited Ross' 1976 work 'The role of tutoring in problem solving' in his own paper 'The evolution of the character and practice of distance education' (1995).

The combination of Ayeroff and Abelson does not appear in the key texts. From Google Scholar we see that they did collaborate in 1976 on a paper titled 'ESP and ESB: Belief in personal success in mental telepathy' in the Journal of Personality and Social Psychology in which they came to the conclusion that belief influences performance. Abelson however was prolific in his own right in the area of memory and learning and extensively cited this study where he collaborated with Ayeroff in his writings and it is for this reason the combination of Ayeroff and Abelson has appeared in the x and y diagram for the key texts.

Donnell and Dansereau do not appear within the key texts or main corpus. From Google Scholar we see that they wrote extensively together in the 1990's in the area of knowledge maps as scaffolds for cognitive processing and in the area of scripted cooperation. Their primary reference that is extensively cited within the literature of scripted cooperation is a paper titled 'scripted cooperation in student dyads: a method for analysing and enhancing academic learning and performance (1992) in a book 'Interaction in cooperative groups: the theoretical anatomy of group learning' (pp120 – 141). However through Google Scholar we could not get access to this material.

WORD CLOUD

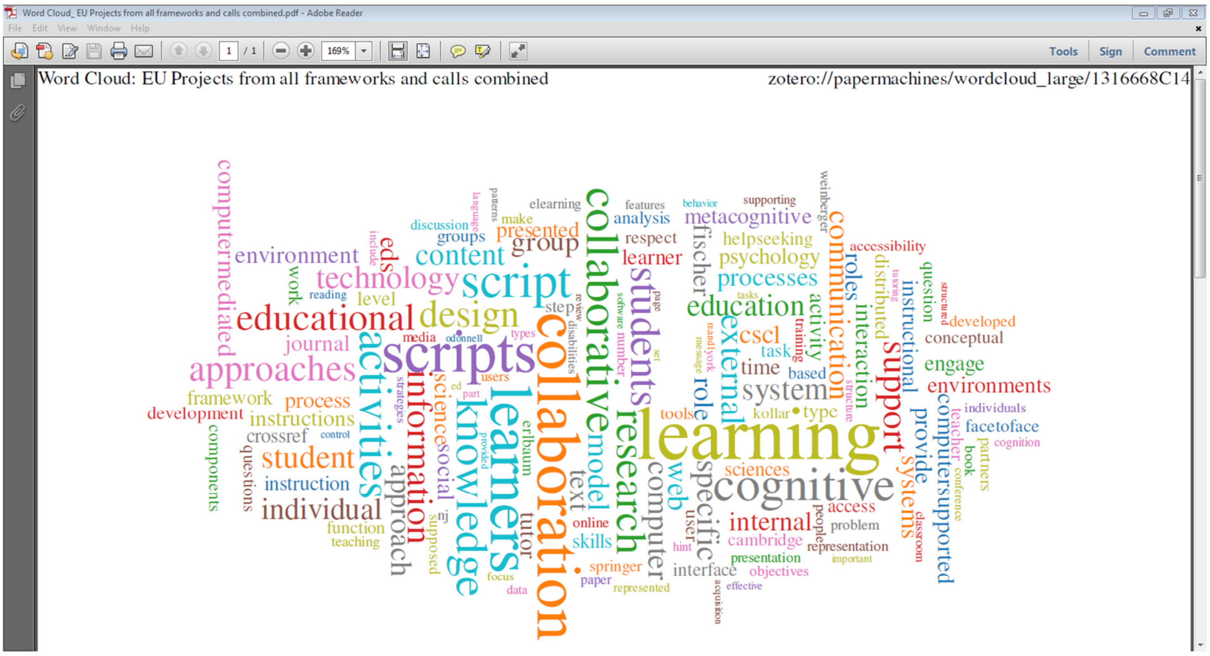

FIGURE 35 WORD CLOUD EU PROJECTS

This word cloud has as its primary focus *learning, collaboration, collaborative, students, cognitive, learners, scripts, educational, activities, metacognitive, instructional, computersupported,* and *approaches*. This strongly suggests that the EU projects were primarily focused around computer supported collaborative learning as there is very little else featured within the word cloud. The only term that may require further research is Kollar which would appear to be an author name.

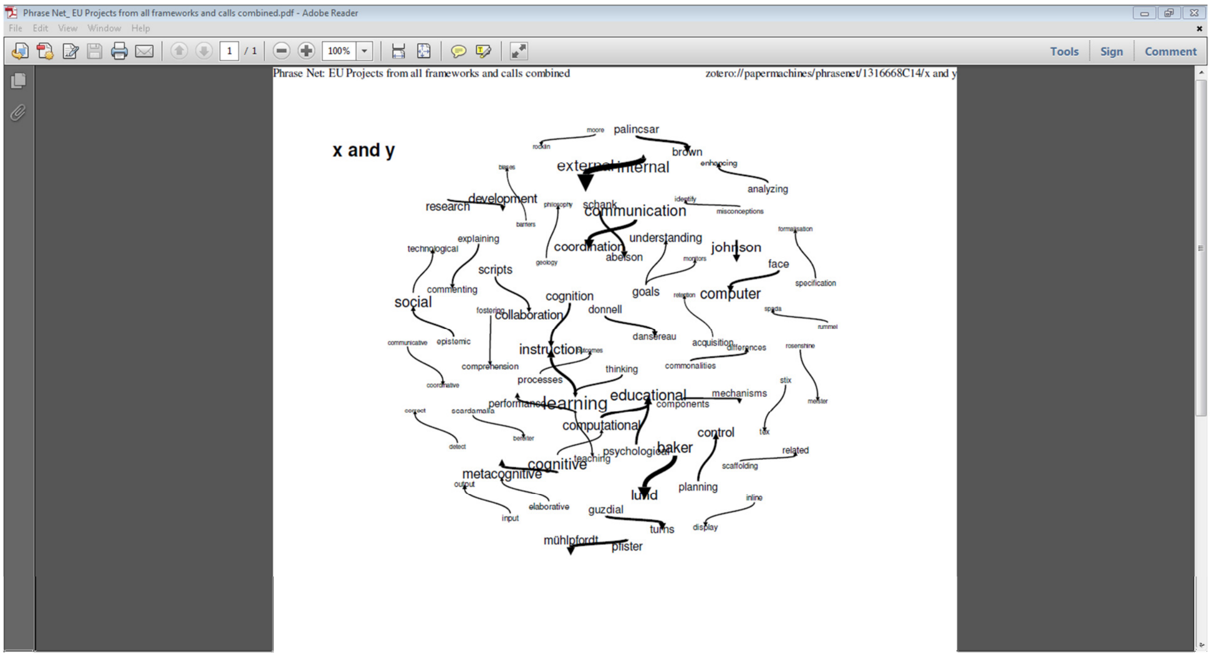

FIGURE 36 X AND Y EU PROJECTS

First of all we will look at reliability and validity.

We find:

Research and development

Input and output

Commonalities and differences

Fostering and comprehension

Explaining and commenting

Detect and correct

These word combinations appear in normal use and we therefore propose that we have evidence therefore of reliability and validity.

We note in the EU projects we have many more names than we have seen before that will require further investigation. Before addressing the names we will note that *communication and coordination* are shown to be linked, *goals and understanding* and *goals and monitors* are linked, as are *scripts and collaboration*, and we have a network formed between *computational and educational and mechanisms, between learning and teaching*, between *cognitive and metacognitive*, between *learning and performance*, between *learning and instruction*, between *cognition and instruction* and between *thinking and learning*. All of which are consistent with the indications provided by the word cloud that is that the research is focused on computer supported collaborative learning.

We will now refer to the author names that appear in the phrase net. These will need to be further investigated to find the key publications that were referenced within the EU project corpus:

Moore and Rocklin

Palincsar and Brown

Schank and Abelson

Johnson

Donnell and Dansereau

Rummel and Spada

Rosenshine and Meister

Scardamalia and Bereiter

Baker and Lund

Guzdail and Turns

Pfister and Muhlpfordt

There is also a linkage that may or may not be names - Stix and Tex

TOPIC MODELS

There was insufficient text in the corpus for each project entry (especially on the earliest projects) for the regression analysis to complete.

INVESTIGATION INTO WHAT APPEARS TO BE NAMES OR CITATIONS IN THE PAPER MACHINES ANALYSIS FOR THE EU PROJECTS

WORD CLOUD

Kollar appears in a number of publications within the main corpus in relation to scripts and computer supported collaborative learning. His publications are therefore already within our database.

PHRASE NET

Moore and Rocklin. Moore appears in one publication in the main corpus in a journal article titled 'designing and building online communities' (2001). From Google Scholar we find Moore and Rocklin wrote a paper titled 'the distribution of distributed cognition' (1998) Educational Psychology Review.

Palinscar and Brown wrote a report titled 'guided cooperative learning and individual knowledge acquisition' (1986). This appears within the key texts.

Schank and Abelson appear in the key texts having written 'Scripts, plans and knowledge'.

Johnson wrote 'Animated Pedagogical Agents' in 2000 which can be found in the key texts.

Rummel and Spada appear within the main corpus 'Learning to cooperate while being scripted or by observing a model' (2009) which refers to earlier works, such as 'Learning to collaborate in a computer mediated setting' Proceedings of the 7th International Conference on Learning Sciences. They are not highly cited, the greatest number of citations being 40 which would explain why the other publications have not been included in the main corpus.

Rosenshine and Meister do not appear in the main corpus or key texts. In Google Scholar they appear a number of times in the 1990's, their highest cited work being 'Reciprocal teaching, a review of the research' published in the Review of Educational Research in 1994.

Scardamalia and Bereiter do not appear in the main corpus or key texts. They wrote together extensively in the 1980's and 1990's, their most highly cited work is the 'Psychology of Written Composition' (1987) followed by 'Computer Support for Knowledge Building Communities' (1994) which is most likely the text that is being referenced.

Baker and Lund appear in our key texts in the journal article 'Promoting reflective interactions in a CSCL environment' (1997).

Guzdail and Turns do not appear in the main corpus or key texts. They worked together extensively in the 1990's and their most cited work is 'Effective discussion through a computer mediated anchored forum' Journal of Learning Sciences (2000).

Pfister and Muhlpfort appear in the key texts with the paper 'Supporting discourse in synchronous learning environments'.

Stix and Tex do not appear in the key texts or main corpus. Having performed extensive searches on both terms, it is proposed that Stix refers to STIX fonts that are used in some ebook readers and within the programming languages of Python and Flex and the other term TEX refers to some of the archiving components in LATEX the screen formatting language.

WORD CLOUD

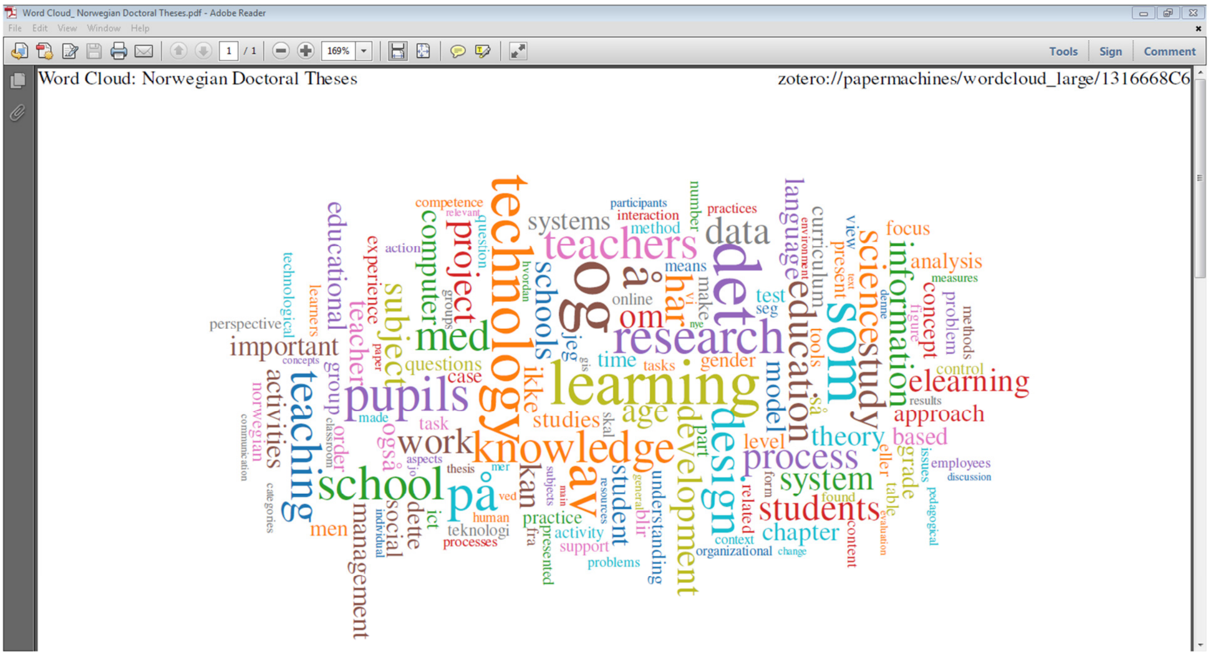

FIGURE 37 WORD CLOUD NORWEGIAN PHDS

The word cloud for the Norwegian doctoral theses shows a cloud that is primarily devoted towards schools, pupils and teaching in contrast to those we have seen from the other word clouds derived from the corpus or the EU projects. The largest words are *learning, technology, pupils, research, school, teaching, teachers* and *design*. We also note the presence of several Norwegian words but these words are more conjunctions or personal pronouns than subject defined terms.

The other words that are significant within the word cloud are *process, system, students, development, information, data, elearning, teacher, important, activities, management, language* and *approach*. There is some evidence of theoretical work from the cluster of words *model, theory, process* and *system*. There is also some evidence of practical application with the cluster *practice, activity, support* and on school management with the cluster *social, school, management* and *teaching*. Finally we notice that the phrase *Norwegian* appears giving some indication of self-reflective analysis.

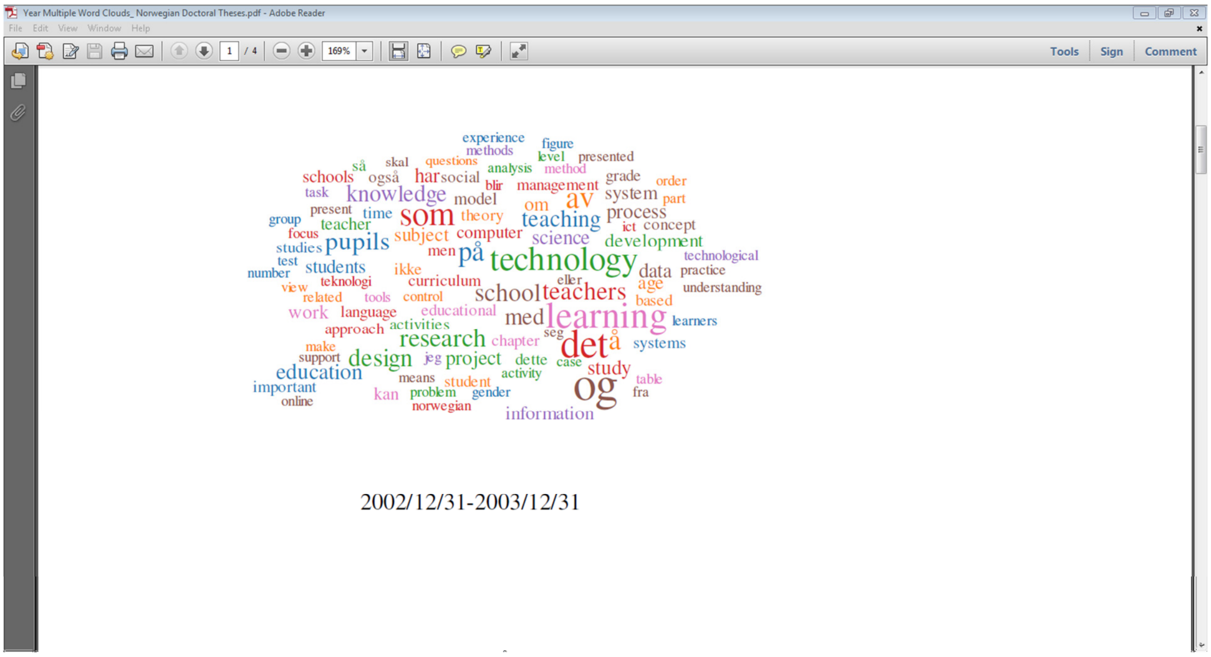

FIGURE 38 2003 PHDS

The first period shown in our report for the Norwegian phd's is 2002 to 2003. The primary focus is on *technology, learning, school, teachers, pupils, students* and *grades*. Clearly this word cloud reflects a focus on school based implementations or studies of elearning in primary and secondary settings.

FIGURE 39 2004 PHDS

The next cloud for 2003 to 2004 is primarily focused on *learning, design* and *theory*. There is also mention of *simulations, animations,* and *multimedia pictures*. This would seem to reflect a thesis or series of theses directed towards a theory of learning in simulation based learning environments.

FIGURE 40 2005 PHDS

The 2005 cloud is more populated with words reflecting *learning, technology, research, school, teachers, knowledge, design* and *education*. This word cloud is much more general in its theme but does still have some focus on schools and teachers.

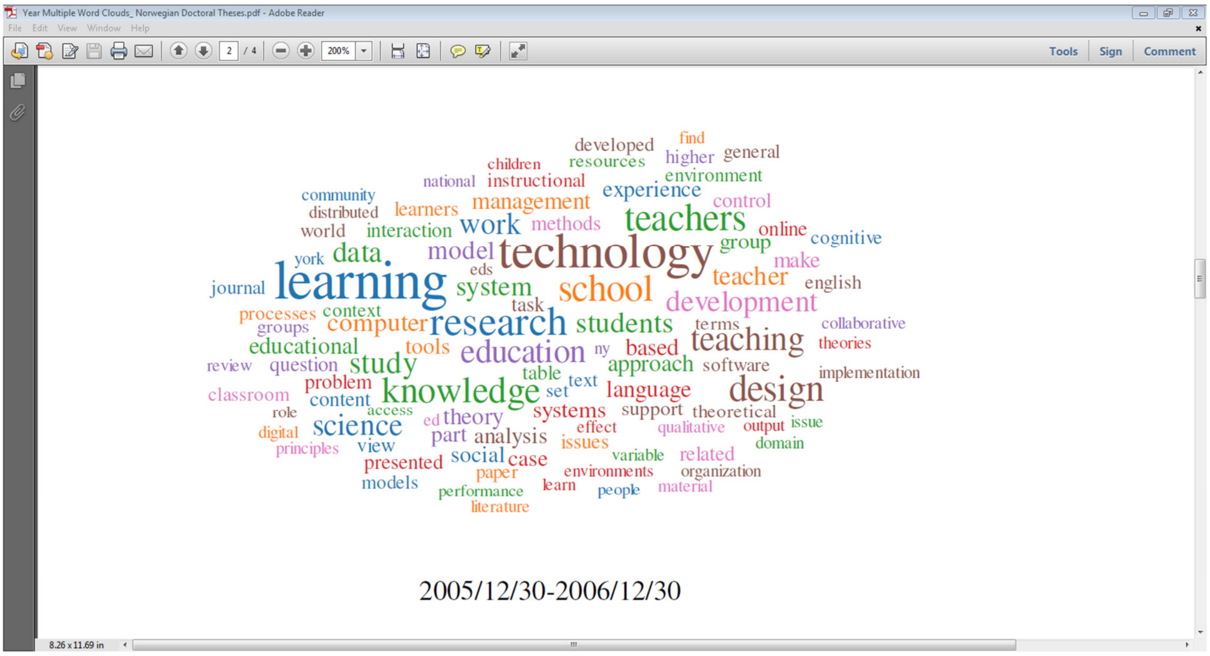

FIGURE 41 2006 PHDS

The word cloud for 2006 has the primary words of *learning, technology* and *research* followed by a secondary level of words *teachers, teaching, school, education, knowledge* and *study*. Again this word cloud implies a strong focus toward school based settings.

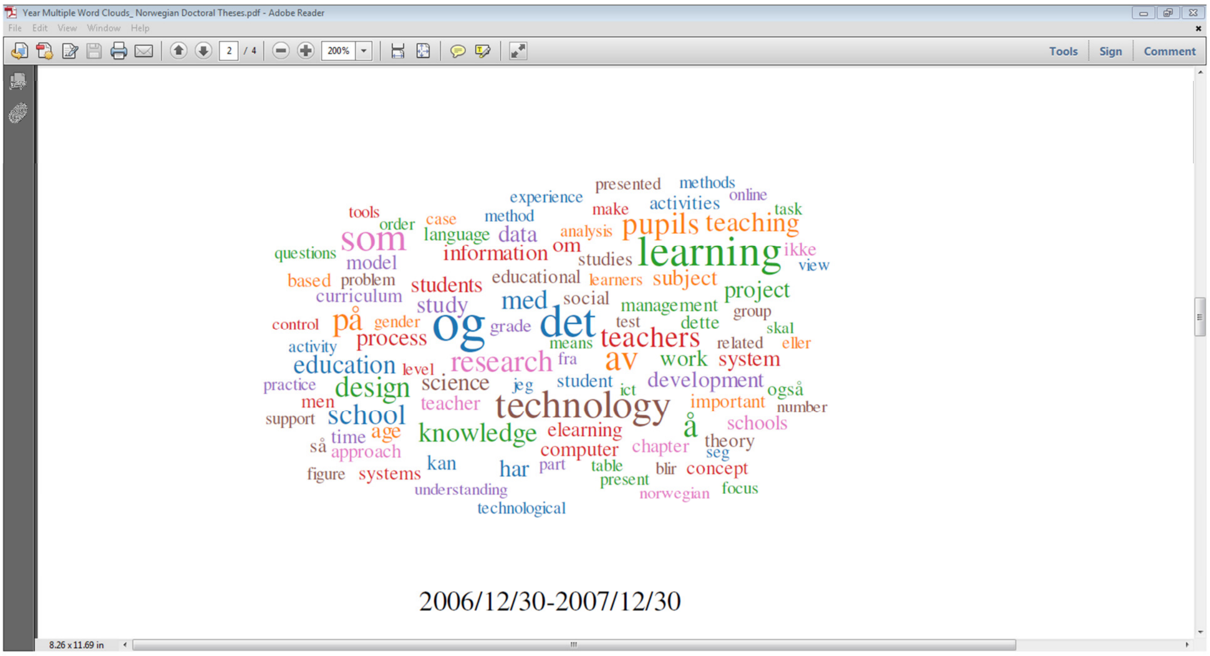

FIGURE 42 2007 PHDS

In 2007 the primary words are *learning* and *technology*, followed by a subset of *pupils, teaching, teachers, design* and *research*. Again this word cloud reflects a focus on schools and teachers.

FIGURE 43 2008 PHDS

The word cloud for 2008 has the primary words of *learning* and *technology* followed by the secondary level words *research, design, teachers, knowledge, school* and *education*. Once again a word cloud focused on school issues.

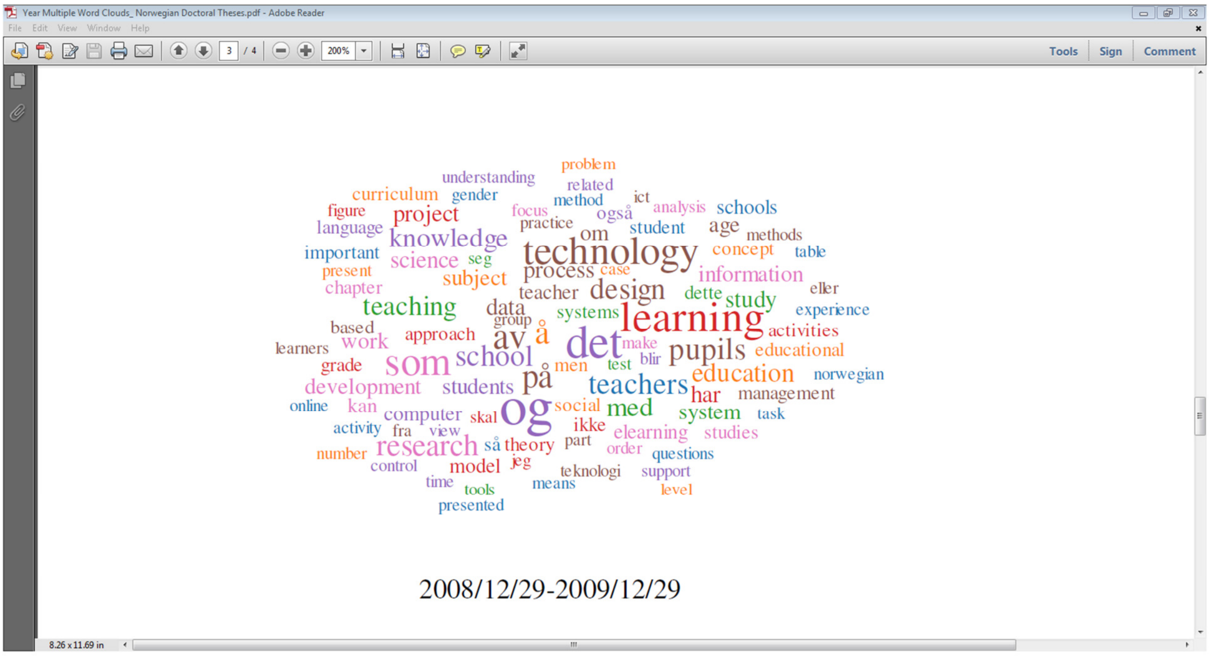

FIGURE 44 2009 PHDS

The next word cloud in 2009 has the primary words of *learning and technology* followed by secondary levels of *pupils, teachers, education, school, teaching, knowledge* and *research*. This seems to follow the same pattern and focus on schools and teachers.

FIGURE 45 2010 PHDS

In 2010 the primary words area again *learning* and *technology*. The secondary level shows *teachers, teaching, research, design* and *knowledge*. We note in this that there is a slight change in focus implied towards teachers and teaching as opposed to students and learning.

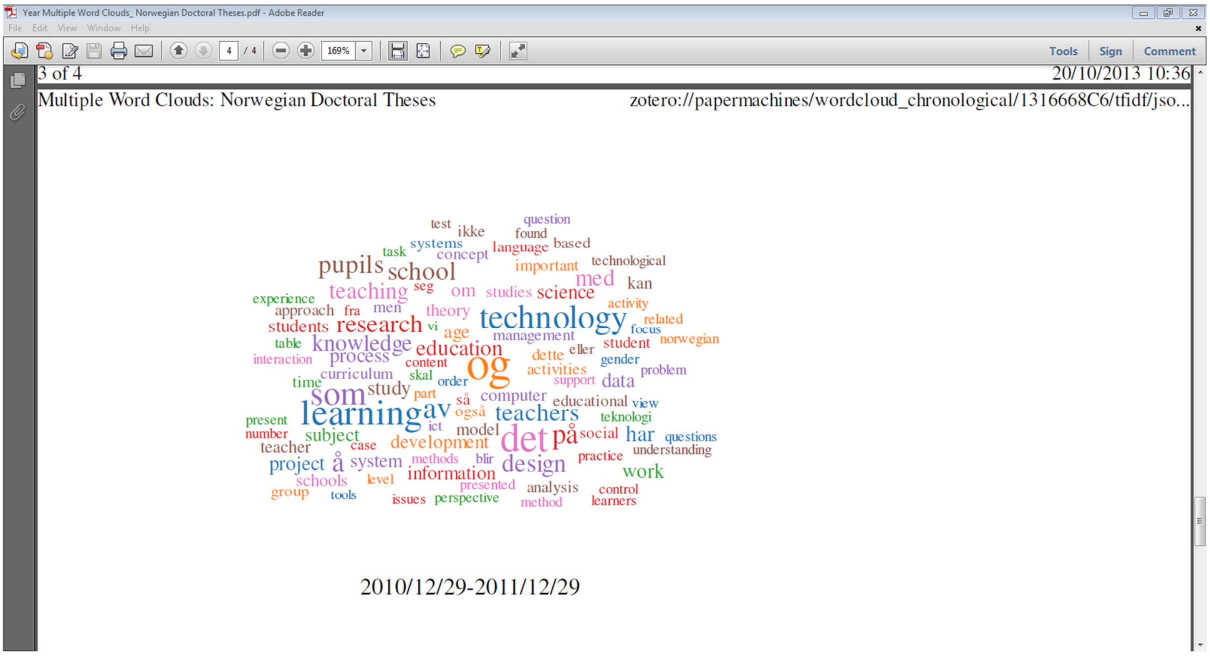

FIGURE 46 2011 PHDS

The word cloud for 2011 has the primary words of *learning* and *technology*. The secondary words are *pupils, school, teachers, research, knowledge* and *design*. We note that the use of the term *pupils* has occurred and that in English usage the term pupil can be a more formal setting where a teacher is in authority and the learner is in a less participatory setting.

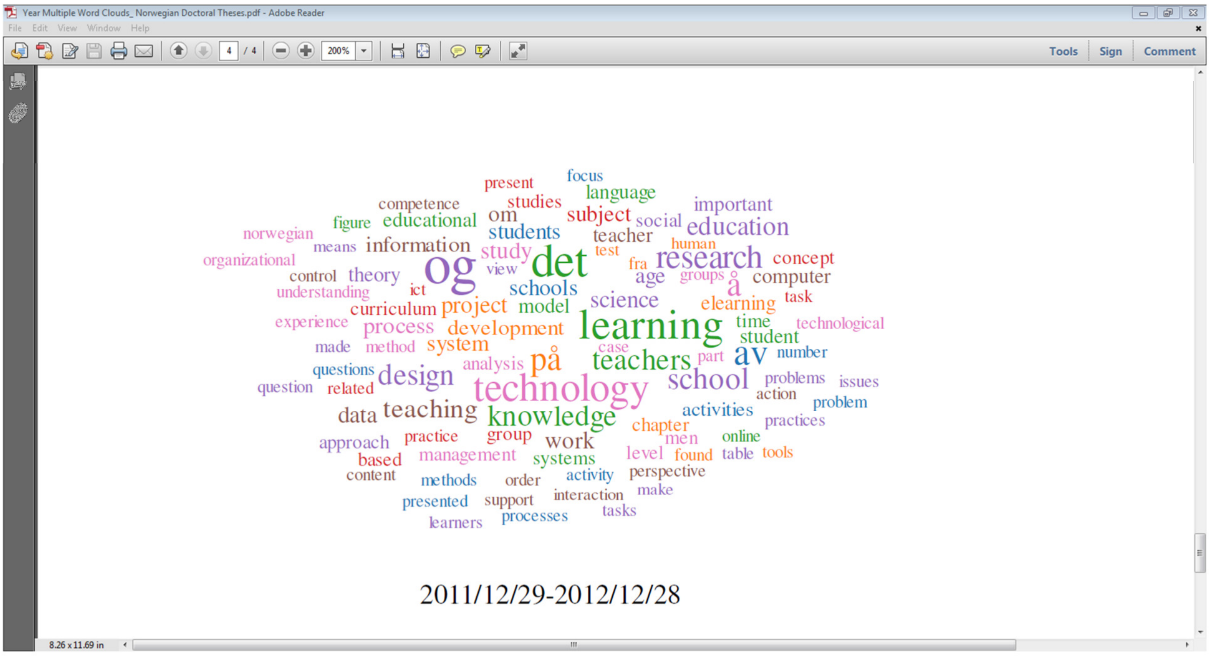

FIGURE 47 2012 PHDS

The cloud for 2012 has the main words once again of *learning* and *technology*. The second level words are *research, knowledge, teaching* and *teachers*. Again in this word cloud students are again of less importance in terms of focus than are teachers or learning.

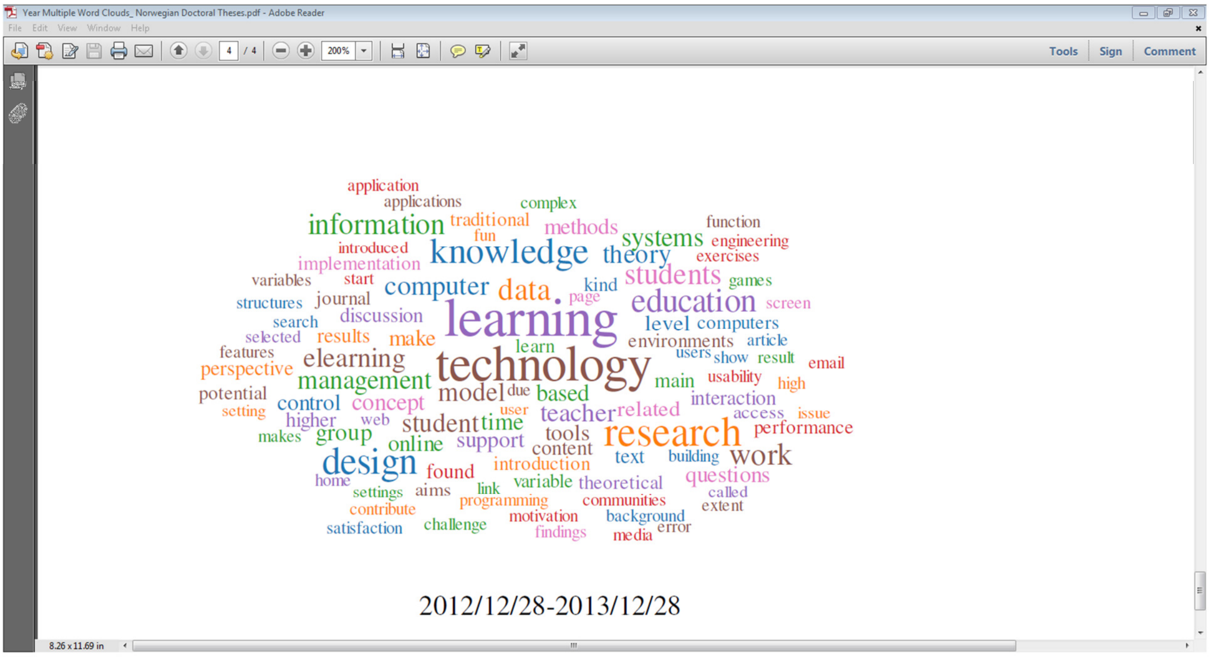

FIGURE 48 2013 PHDS

In 2013 the primary words are *learning, technology, research* and *knowledge* followed by *information, design* and *education*. Interestingly *teachers* are no longer shown with such importance and the word *students* although of a lesser focus than the primary words of *learning* and *technology* is larger than the word *teacher* indicating a broadening in focus away from teachers and teaching to a more balanced view of the field. In fact this final word cloud is much more similar to those we have seen in the main corpus and the EU projects.

PHRASE NET: X AND Y

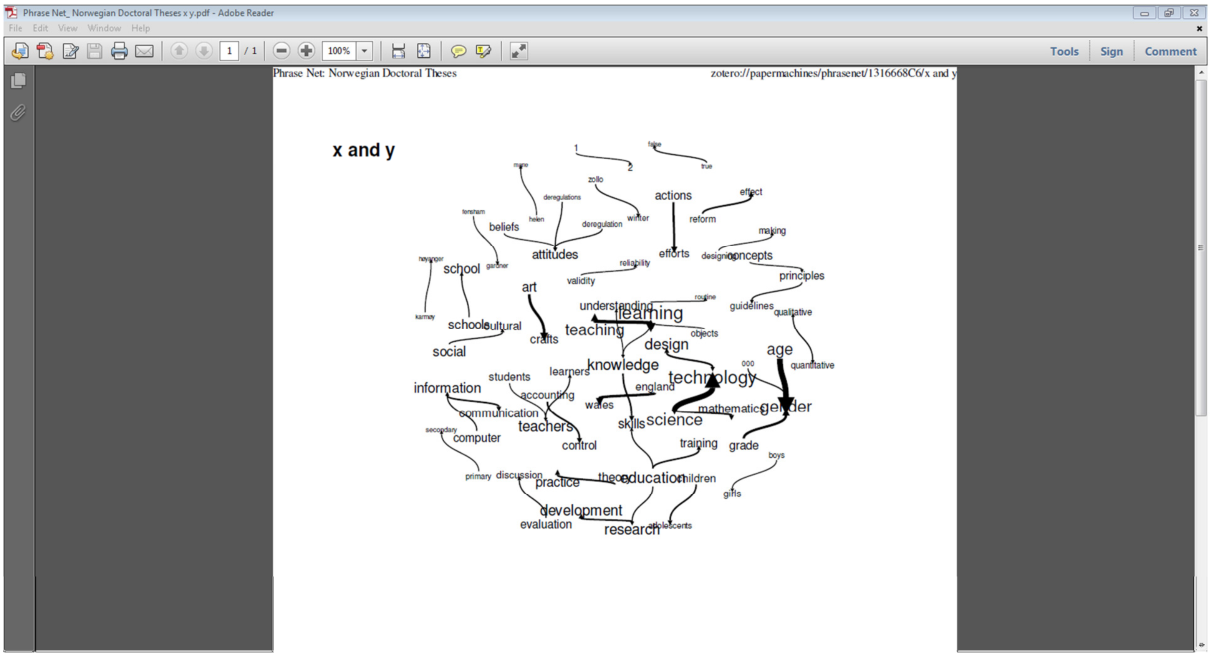

FIGURE 49 X AND Y PHDS

The first thing we will do is look for evidence of validity and reliability.

We find the phrases

True and false

One and two

Concepts and principles

Learning and understanding

Research and development

Primary and secondary

Students and teachers

Art and crafts

These conjoined words give a strong indication that we are looking at a valid and reliable data set. In terms of the interesting linkages we see strong linkages between

Age and gender

Grade and gender

Science and technology

Science and mathematics

Technology and design

Design and technology

For the first time in our analysis of x and y phrasenets we are encountering strong inter linkages between words. There is a strong linkage between *teaching, understanding, knowledge* and *learning* and a linkage between *knowledge, skills, education, training research* and *development.*

There is also a discussion indicated around the theme of *deregulation and deregulations*, *attitudes* and *belief* and between *concepts, principles* and *guidelines*.

There are also what maybe author's names

Høyanger and Karmøy

Fensham and Gardiner

Helen and Marie

But it is notable that there are few of them and this is surprising since one might expect a close grouping of PhD studies to have a greater shared literature as we saw in the main Corpus.

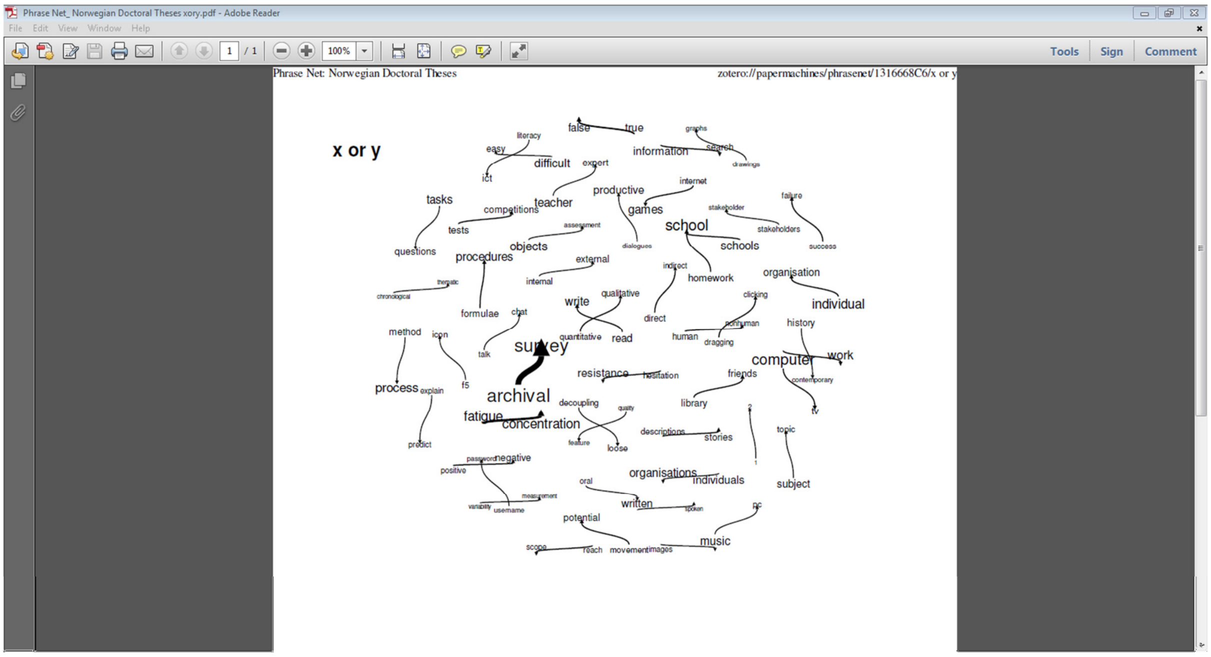

FIGURE 50 X OR Y PHDS

In looking at the x or y phrase net we will first look for indications of reliability and validity within the data. We see

True or false

Success or failure

Individual or organisation

Human or non-human

Method or process

Positive or negative

Subject or topic

Internal or external

These linkages appear to indicate the reliability and validity of our data.

Looking at the main phrase nets there appears to be a strong relationship between the words *archival or survey* which is perhaps indicative of some methodological questions. Also there is a strong linkage between *homework and school*, which may indicate some debate about assessment methods, as there is between *tests and competitions*, *tasks* and *questions* and between *variability* and *measurement*, all of which could be indications of discussions or investigations into assessment paradigms. There do not appear to be any proper names in this phrase net.

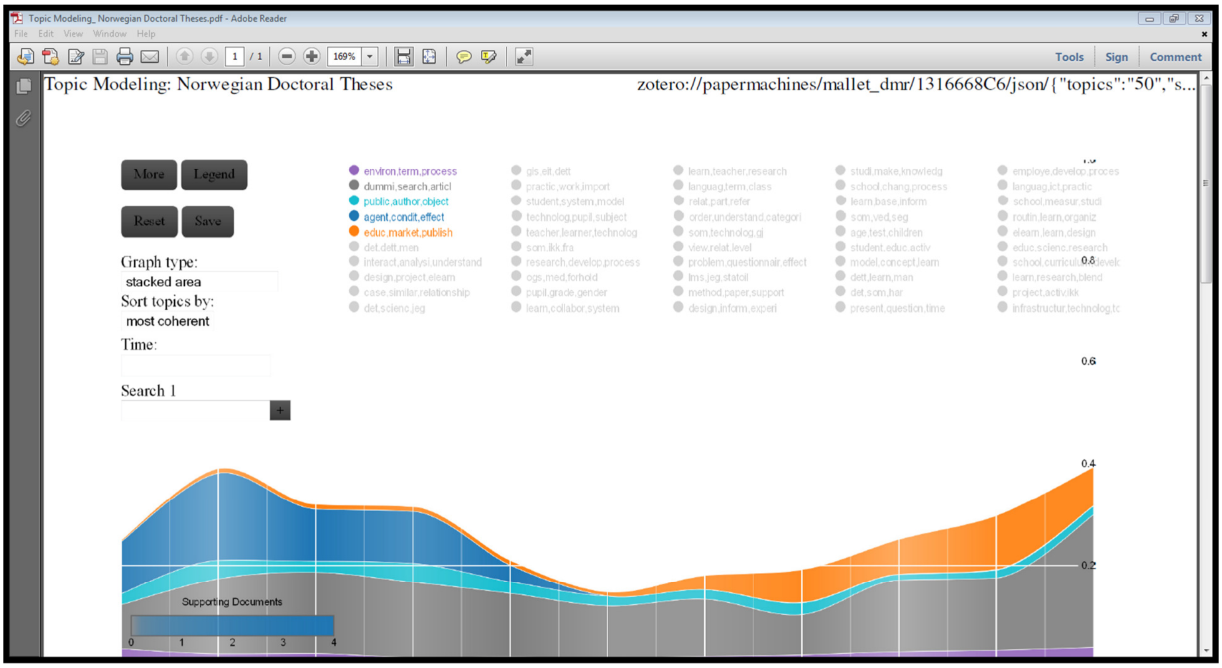

FIGURE 51 TOPIC MODELLING PHDS

There are five topic models that have been produced by the regression analysis on the Norwegian doctoral theses. They are

Environ, term, process

Dummi, search, articl

Public, author, object

Agent, condit, effect

Educ, market, publish

The first observation that we have about the topic modelling is that the terms do not appear to be directly related to the subject matter of technology enhanced learning. Instead they appear to be more related towards publishing, or towards the implementation of learning systems or search terms. For example *environ, term, process* is linked towards the implementation of an elearning platform or some kind of search mechanism within a corpus of literature, as does *dummi, search and articl*; *public, author, object*; *educ, market, publish*. The only exception being *agent, condi, effect* which could refer to areas of intelligent tutoring systems, pedagogical agents or computer supported collaborative work.

The tuplet *educ, market, publish* which exhibits remarkable growth within the dissertation corpus from 2009 to 2013, could reflect a movement towards understanding the production of learning materials for schools as could *public, author,object*. As we have noted in the topic modelling for the main corpus the tuplet *dummi, search, articl* is probably related to the internal mechanisms of zotero and paper machines when executing regression analysis.

COMPARISON TO MAIN CORPUS

When comparing the data visualisations for the Norwegian PhDs and the main corpus the most striking difference is the focus on schools and teachers within the Norwegian materials. In contrast the Main Corpus has much more of a focus on the broad conceptual ideas such as collaboration, cognitive and pedagogical approaches. Although we also note that neither shows any strong applied practical outcomes.

It is also interesting that the main tuplets that emerge from the main Corpus are related to learning, whereas the PhD materials seem to focus much more on publishing and searching. It could be that this reflects the use of smaller raw data from the PhDs used in a regression process that is better suited to large text data sets.

COMPARISON TO TOP 10 PERCENT

When comparing the PhDs with the top 10 percent we again find that the Norwegian materials have a stronger focus on school settings and teachers than the top 10 percent sub collection which has a focus on *interaction, adaptive, students* and specific areas such as *agents* and *hypermedia*, reflecting a quite different perspective.

The regression analysis for the top ten percent was also much broader with the term *learn* appearing in most tuplets. The Norwegian materials were, in contrast, focused on publishing.

COMPARISON TO EU PROJECTS

The word cloud for the EU Projects was focused on *collaboration, learners, scripts* and *approaches*. We feel this reflects a greater focus on higher education and conceptual problems within the field of Computer Supported Collaborative Learning. Given that the European Union views its research funding as being as much to do with building strong linkages and understanding between scientists in member states as it is about advancing knowledge the preference towards collaboration as a research theme is perhaps not surprising.

ODDITIES FROM PAPER MACHINES ANALYSIS

During the course of the analysis we found repeated references to the terms "FAID" and "DUMMI".

FAID

The term does not occur in any of the visible fields or in any of the exportable meta data within our collections. There is no formal mention of the term at the Zotero site documentation. However when a search is conducted looking for the term in the forums two instances are shown in the forums history in 2007 talking about future enhancements – but a search of those web pages does not reveal the term on the pages. One must conclude that it is some part of the internal workings of Zotero.

DUMMI AND DUMMY

The term does not appear within our database, nor in an extracted raw data with meta tags. However searching the Zotero site one finds mention in the forums that during regressions the Zotero system creates a dummy record. This is proposed to be the most likely explanation for the term dummi appearing.

Alternatively one of the most frequently cited books in google scholar are the handbooks for "Dummies" – these may have been cited or used either within our texts or even by the Zotero coders as comments.

ANALYSIS OF HOW PAPERS WERE TAGGED

This section discusses the analysis of tags found on the main corpus and the top 10% corpus.

TAGS IN ZOTERO

Items automatically added to a Zotero collection bring with them associated tags (or keywords) that have been assigned by either the author or the journal in which the item has been published (or publisher for book chapters or books). In addition, it is possible to add your own tags, both as articles are being automatically added or after, or after manually adding an item to a collection. In addition to adding the search term as a tag, we added either WoS (Web of Science) or Google Scholar to each entry to indicate the origin of the article. In many cases the authors had used the search term as a tag, so the articles were double tagged with that term. The tag selector of the standalone version of Zotero lists all tags used in the collection. Figure x shows a picture of all the tags that appear on the main corpus. While it is basically impossible to read the tags in the figure, it does give an impression of the plethora of tags that have been used for the 680 journal articles.

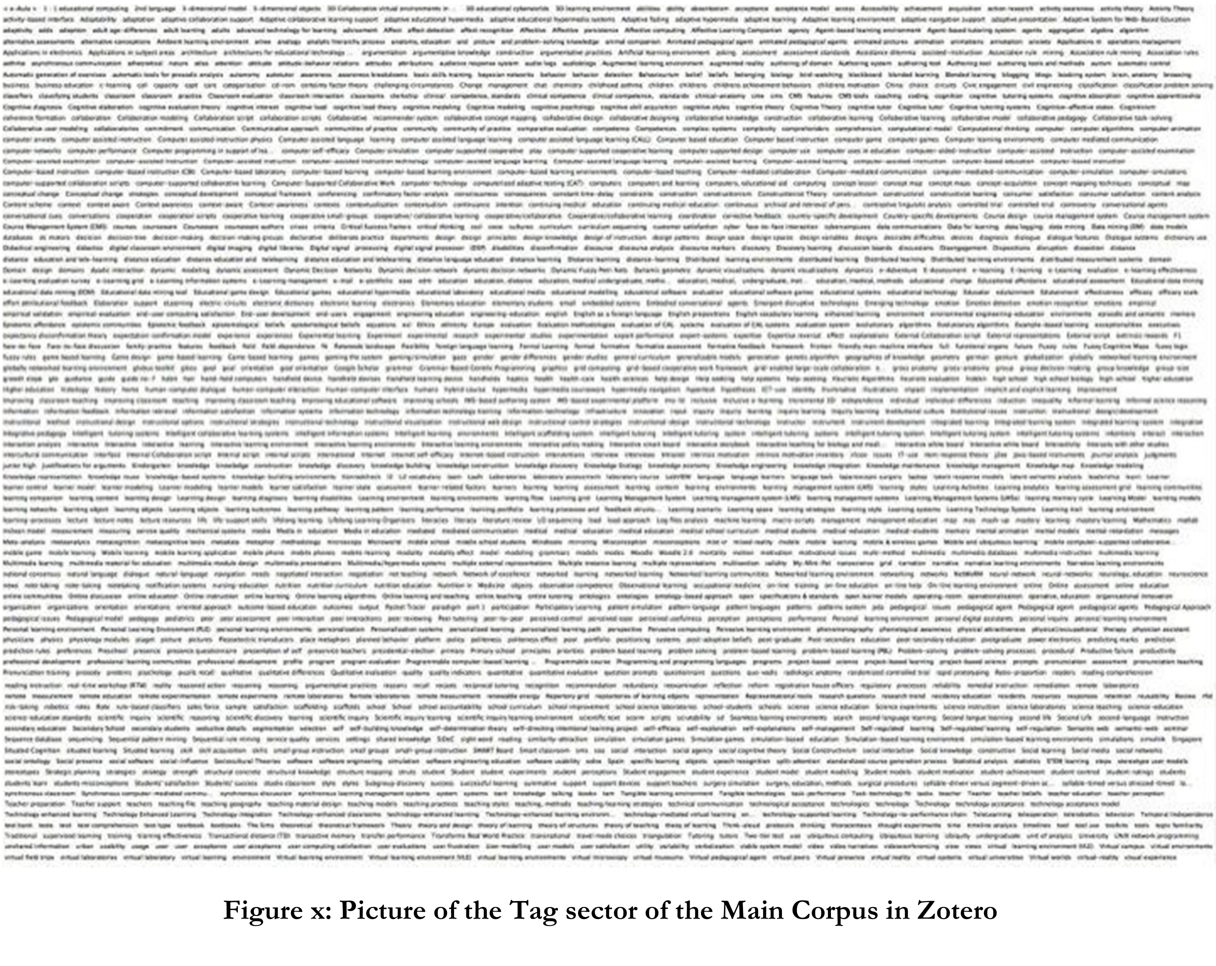

Figure x: Picture of the Tag sector of the Main Corpus in Zotero

Each tag is clickable in Zotero, and clicking on one tag results in only articles tagged with that tag to be shown in the item window, see figure x which shows the selection of tag "computer supported collaborative learning" and the 13 articles from the main corpus that are tagged with this tag. As can be seen in figure x, once one selects a tag in the tag selector, the only tags visible (of the ones shown in figure x above), are those tags associated with the articles tagged with this tag; in this case those tags visible in figure x are all the tags associated with the 13 articles tagged with "computer supported collaborative learning". In this way, one can study the collection via the tags.

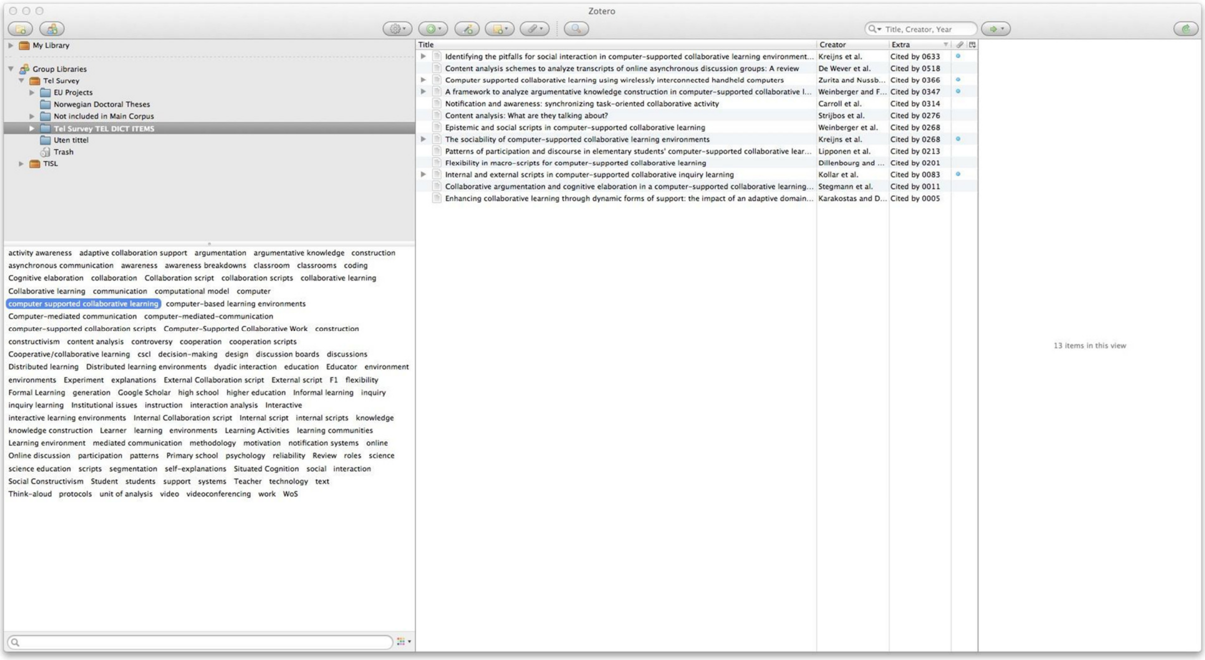

Figure x: Picture of the Tag sector of the Main Corpus in Zotero with computer supported collaborative learning selected

METHOD

In our proposal we said that we would look at both formal and informal learning, thus the target audience is of interest. In addition, we identified a number of dimensions of learning domains (or themes) that were of interest, see figure 2. Finally, we were interested in Impact.

While working with the tags two additional strong themes were emerging, Design and Evaluation. This was not surprising as these themes also emerged from the Paper Machines topic modelling on the full corpus.

Thus, the analysis of the tags was carried out with the following themes:

- **Sub fields of TEL: "**Technology Enhanced Learning (TEL)" was used instead of "ICT and Learning" as this refers to the European Research Area with which the TEL dictionary is associated
- **Target audience**: educational sector, informal/formal, workplace, etc.
- **Models of Learning**
  Theories
- **Learning Space**
  Technologies
- **Pedagogical Approaches**
- **Temporal & Geographical Activities**
- **Learning Activities**
- **Competence**
- **Impact on Real World**
- **Design**: new theme, related to both design of learning environments & learning activity (scenarios, feedback, etc.), as well as support for designers.
- **Evaluation** (sub-groups Methods & Theoretical Concept / Analytical Focus / Understanding): new theme related to concepts that are in focus under data collection or data analysis.

The TEL thesaurus is methodologically linked to the TEL Dictionary and was used in the tagging analysis in order to provide the widest possible interpretations of the research themes represented by the tagged items.

First, the number of articles tagged with each TEL thesaurus term was recorded, both for the Main corpus and the top 10% corpus. Second, the TEL thesaurus terms that appear in the set of Zotero tags were sorted into the themes. As it is impossible to know the exact context of use of the term without reading the article, some terms have been assigned to multiple themes (e.g., the term "collaborative learning" could be a pedagogical approach, or it could be a theory of learning). Third, in some cases similar tags, not appearing in the TEL thesaurus but used by the authors, that could be grouped with a theme were included in the list (e.g., those related to theory or design); these will be described. Fourth, each theme was analysed in turn; it should be noted that during the analysis and for some special cases, the entire corpus was searched (through the search mechanism) using the name of a tag as the search term (e.g., the entire corpus was searched with the term "higher education"), and such cases will be mentioned in turn.

THE ANALYSIS OF TAGS

This section discusses the analysis of tags found on the main corpus and the top 10% corpus, using the functionality provided through the tag selector in Zotero.

Of the 472 terms in the TEL Thesaurus, 209 appear as tags on the Main corpus, while 263 were not used at all. Appendix X lists each of the 209 terms that have been used together with the number of times it appears in each corpora, and Appendix X lists the 263 terms that were not used as tags. Table x lists the top 20 tags used in each corpora, by order of usage.

Table x Top 20 tags in the Main and Top 10% corpora, listed by usage

Main Corpus	**Top 10% Corpus**
higher education (125 / 40)	learning activities (52 / 52)
learning activities (52 / 52)	higher education (125 / 40)
experiment(s) (46 / 37)	experiment(s) (46 / 37)
students (44 / 5)	high schools (33 / 32)
interactive learning environment(s) (ILE) (36 / 4)	pedagogical approach (26 / 26)
e-learning (35 / 8)	formal learning (24 / 24)
high schools (33 / 32)	primary school(s) (19 / 19)
knowledge (27 / 3)	secondary education / school (20 / 12)
education (27 / 0)	constructivism (17 / 12)
pedagogical approach (26 / 26)	informal learning (17 / 10)
school(s) (25/ 2)	e-learning (35 / 8)
formal learning (24 / 24)	collaborative learning (23 / 7)
collaborative learning (23 / 7)	multimedia learning (10 / 7)
mobile learning (23 / 2)	students (44 / 5)
classrooms (23 / 2)	blended learning (14 / 6)
intelligent tutoring systems (ITS) (22 / 1)	computer-supported collaborative learning (13 / 5)
secondary education / school (20 / 12)	interactive learning environment(s) (ILE) (36 / 4)
computer-assisted instruction (CAI) (19 / 3)	computer-based learning environment(s) (17 / 4)
primary school(s) (19 / 19)	learning environment(s) (7 / 4)
science (18/ 2)	knowledge (27 / 3)

Higher education is the most used term in the Main corpus, and second most used in the Top 10% corpus. This can be read as 125 articles were tagged with "higher education" in the Main corpus, while 40 of these also appear in the Top 10% corpus. "Learning activities", the second most used in the Main corpus (52 times) and all articles appear in the Top 10% corpus making it most used term in that corpus. Interestingly, all articles tagged with "learning activities" appear in both corpora, as do those tagged "pedagogical approach, formal learning, primary school, computation thinking, cooperative learning, computer-supported cooperative work, experiential learning, and interaction analysis". Six tags appearing in the most frequently used list for the Main corpus, do not appear in the Top 10% corpus list (in the table) as they were used less than 3 times, or not at all; these include: education (27 / 0), school(s) (25 / 2), mobile learning (23 / 2), classrooms (23 / 2), intelligent tutoring systems (ITS) (22 / 1), and science (18 / 2). Similarly, the tags that most frequently appear in the Top 10% corpus, appear further down the list of frequency of use in the Main corpus and thus do not appear in the table, including blended learning (14 / 6), computer-supported collaborative learning (13 / 5), computer-based learning environment(s) (17 / 4), and learning environments (7 / 4). Finally, 127 tags used in the main corpus, fell out in the top 10% corpus, including the frequently used tag "education".

The remainder of this section visits each of the tag themes in turn. A list of the tags that are grouped under the theme (listed in descending order of frequency) is given as: tag name (the number of articles tagged with that tag in the main corpus / number of articles tagged with that tag in the top 10% corpus).

SUB FIELDS OF TEL

In general, it appears that authors use one tag that associates their articles with a sub-field of TEL. In our corpus these include:

e-learning (35 / 8)

education (27 / 0)

mobile learning (24 / 3)

computer-assisted instruction (CAI) (19 / 3)

computer-based instruction (19 / 3)

interactive learning environment(s) (ILE) (19 / 2)

distance learning (18 / 2)

computer-assisted learning (17 / 1)

computer-based learning environment(s) (17 / 4)

game-based learning (16 / 3)

computer-assisted language learning (CALL) (15 / 0)

computer-supported collaborative learning (15 / 6)

technology enhanced learning (TEL) (14 / 1)

intelligent tutoring systems (ITS) (14 / 1)

learning communities (6 / 1)

edutainment (6 / 0)

web-based learning (4 / 0)

computer-based learning (2 / 1)

educational systems (2 / 1)

personal learning environments (PLE) (2 / 0)

educational technology / technologies (1 / 0)

tele-learning (1 / 0)

learning sciences (0 / 0)

learning networks (1 / 0)

Fourteen articles were tagged with "technology enhanced learning (TEL)", indicating their link to the field. The general term "education" was used on 27 articles in the main corpus (0 in the top 10% corpus). Interestingly the term "learning sciences", which is more often used in the USA to refer to the field that studies learning and how it may be facilitated with and without technology, was used on 0 articles. A search of the corpus with "learning sciences" as a search term resulted in 5 articles that were published in the International Journal of the Learning Sciences (ijLS).

Many of the tags identify the articles as part of research communities that fall under the umbrella of TEL. If we look at the historical presentation of the field in our application, see figure 1, we see the earliest approaches (historically) from the 1960's tagged in the corpus as "computer-assisted instruction (CAI)" (19 / 3 articles), "computer-based learning" (2 / 1 articles), "computer-based instruction" (15 / 3 articles), "computer-assisted learning" (17 / 1 articles), "computer-based learning environment(s)" (17 / 4 articles), and the more specialised "computer-assisted language learning (CALL)" (15 / 0 articles) are still the subject of research in the 2000's (recall that our corpus only includes publications from 2000 until present). The 1970's saw the advent of the ITS field and 22 articles in the main corpus (1 in the top 10% corpus) were tagged with "intelligent tutoring systems", which indicates it is still a strong research field. From the late 1980's the sub-field tagged "computer-supported collaborative learning" (and "computer-supported cooperative work") emerged, and again is still a strong research field with 15 articles in the main corpus, of which 6 appear in the top 10% corpus. "Tele-learning" also emerged as a field around this time (only 1 article used this tag), and build on traditions that had been linked to "distance learning" (18 / 1 articles) and "computer-supported collaborative learning" (13 / 5 articles), and developed into fields such as "web-based learning" (4 / 0), "learning networks" (0 / 0 articles), "learning communities" (6 / 1) and "e-learning" (3 / 8). "Interactive learning environments" (36 / 4 articles) emerged as a field in the late 1990s with the proliferation of the web. More recently, "mobile learning", "edutainment", "game-based learning" , and "personal learning environments (PLE)" (15 / 2 articles) have been emerging fields.

The most used tag in this category, "e-learning (35 / 8)", is more often used with respect to higher education and workplace learning; "higher education (126 / 41)" is the tag that appears most often in our main corpus, and second most often in the top 10% corpus.

TARGET

Target refers to the educational sector, informal/formal, workplace, etc. to which the article's research is targeted. As these were not terms found in the TEL dictionary, we browsed the tags listed in the tag selector for our main corpus and identified tags that referred to targets. In our corpus these include:

higher education (125 / 40)

students (44 / 5)

school(s) (25 / 2)

high schools (33 / 32)

formal learning (24 / 24)

classrooms (23 / 2)

secondary education / school (20 / 12)

primary school(s) (19 / 19)

informal learning (17 / 10)

children(s) (5 / 0)

teachers (5 / 1)

teacher learning / education (2 / 0)

professional development(s) (1 / 0)

learners (1 / 0)

teacher support (1 / 0)

Of those articles tagged with their target population, 24 were tagged with formal learning, while 17 were tagged with informal learning. The remainder of the tags, however, address formal learning situations, indicating that there is much more focus on formal learning; this is to be expected if one has followed the call for research, etc the last years, however, informal learning, and the relationship between formal and informal has come more into focus (e.g., in the USA LIFE[1], a multi-institutional NSF funded Science of Learning centre, is focused on just this).

"Higher education" was targeted almost 4 times more frequently than "high school", while "secondary education" and "primary school(s)" appeared 20 and 19 times respectively. "Schools" was used as a tag 24 times. Furthermore, "teacher learning / education" and "professional development(s)" were tags on only 2 and 1 articles, respectively, but tags "teacher support" and "teachers" indicate also a focus on teachers. One article was tagged with "learners", 5 with "children" and 44 with "students" (without looking at the articles it is not clear what is meant by student; in Norway student is reserved for higher education students, while pupil

[1] http://life-slc.org/

refers to the formal schooling system learner). The 23 articles tagged “classroom” and the 24 articles tagged “school” also indicate a focus on the formal education system. “Informal learning” was used on 17 articles.

Table x: Target tags sorted by Formal / Informal Learning

Formal Learning			**Informal Learning**
formal learning (24 / 24)	high schools (33 / 32)	teachers (5 / 1)	informal learning (17 / 10)
higher education (125 / 40)	school(s) (25 / 2)	teacher support (1 / 0)	
students (44 / 5)	classrooms (23 / 2)	teacher learning / education (2 / 0)	
	secondary education / school (20 / 12)	professional development(s) (1 / 0)	
	primary school(s) (19 / 19)		
	children(s) (5 / 0)		
	learners (1 / 0)		

MODELS OF LEARNING/THEORIES

The tags related to the Models of Learning being employed are better referred to as Theories. The terms appearing in the TEL Dictionary do not include theory terms, with the exception of "constructionism", so the terms in the TEL Thesaurus were perused for theoretical terms, and many of them appeared in the main corpus. Thus, theory related tags used in the corpus include:

constructivism (17 / 12)

learning strategies (16 / 1)

situated learning (9 / 3)

cognitive load (8 / 3)

metacognition (4 / 1)

social learning (3 / 0)

mental models (2 / 1)

activity theory (2 / 0)

constructivist learning (2 / 0)

cognitive psychology (1 / 0)

cognitive skill acquisition (1 / 0)

community of practice (CoP) (1 / 0)

theoretical framework(s) (1 / 0)

constructionism (1 / 0)

conceptual frameworks (1 / 0)

learning styles (1 / 0)

When working with the theory tags, however, it was clear that the authors themselves were using "theory" tags that were in our list of search terms, and as several of the expected theories that are applied in TEL research were missing from the TEL dictionary and thesaurus (e.g., situated cognition), we have chosen to include all tags that contain "theory" found in the tags selector for the main corpus. These include:

theory (16 / 1)

situated Cognition (10 / 10)

social constructivism (10 / 10)

theory of teaching (9 / 1)

cognitive load / cognitive load theory (8 / 3)

theory of learning (6 / 0)

item response theory (4 / 0)

cognitive theory (3 / 1)

cognitive theory (3 / 1)

Sociocultural Theories (2 / 2)

social cognitive theory (2 / 0)

behaviourism (1 / 1)

expectancy disconfirmation theory (1 / 1)

self-determination theory (1 / 0)

constructionist theory (1 / 0)

certainty factor theory (1 / 0)

cognitive evaluation theory (1 / 0)

theory of structures (1 / 0)

The theory papers in the main corpus total 68, found through 24 tags. Six of the tags are original search terms, while 18 are automatic tags. In the top 10% database there are only 22 papers with theory related tags, 2 found by the search terms, and 18 author tags (NOTE: one paper may share several tags).

One would expect to find papers addressing theories in paradigms such as behaviourism, cognitivism, constructivism, and socio-cultural theories, as well as particular theories such as activity theory, distributed cognition, constructionism, and situated cognition. Most of these are represented in the full TEL database, with only "activity theory" articles falling out of the top 10%, and "distributed cognition" not appearing as a tag, either in the search terms or in the author tags. A search for "distributed cognition" on the main corpus, however, returned 3 papers, of which 1 is part of the top 10% (this article is also tagged with situated cognition).

LEARNING SPACE

The learning space captures the physical, technological, and virtual organization of the learning space, (these correspond to the Technologies topic identified in the Topic Analysis). While 45 tags relating to the learning space were used in the main corpus, only 10 of these tags are found in the top 10% corpus:

web (17 /0)

intelligent tutoring systems (ITS) (22 / 1)

learning management system(s) (LMS) (16 / 0)

personal learning environments (PLE) (15 / 2)

computer mediated communication (CMC) (15 / 0)

games (15 / 0)

pedagogical agents (14 / 2)

courseware(s) (14 / 0)

course management systems (CMS) / CMS (14 / 0)

e-portfolios (14 / 0)

Internet (12 / 2)

remote laboratories (12 / 0)

computer-based laboratories/laboratory (11 / 1)

authoring tools (11 / 0)

learning companions (11 / 0)

multimedia (10 / 2)

learning grid (8 / 0)

virtual reality (8 / 0)

learning environment(s) (7 / 1)

seamless learning environments (7 / 1)

programmable computer-based learning environment(s) (6 / 1)

hypermedia (6 / 0)

web-lecturing technologies (4 / 0)

adaptive hypermedia (4 / 0)

adaptive learning environments (4 / 2)

computer simulation (4 / 0)

knowledge management (KM) (4 / 0)

student models (4 / 0)

animated pedagogical agents (3 / 0)

web 2.0 (3 / 0)

narrative learning environments (NLE) (3 / 0)

ubiquitous computing (3 / 0)

learner model(s) (3 / 0)

information retrieval (2 / 0)

databases (2 / 0)

social software(s) (2 / 0)

semantic web (2 / 0)

simulation-based learning environments (18 / 0)

networks (2 / 0)

information systems (2 / 0)

learning object repositories / repositories of learning objects (1 / 0)

e-mail (1 / 0)

knowledge based systems / knowledge-based systems (1 / 0)

metadata (1 / 0)

user models (1 / 0)

These 45 learning space tags address various aspects of the learning space, thus have been further grouped in sub-categories environments, components, tools, and general ICT. Each of these is addressed in turn.

Environments:

intelligent tutoring systems (ITS) (22 / 1)

simulation-based learning environments (18 / 0)

learning management system(s) (LMS) (16 / 0)

personal learning environments (PLE) (15 / 2) games (15 / 0)

e-portfolios (14 / 0)

courseware(s) (14 / 0)

remote laboratories (12 / 0)

computer-based laboratories/laboratory (11 / 1)

learning environment(s) (7 / 1)

seamless learning environments /7 / 1)

programmable computer-based learning environment(s) (6 / 1)

adaptive learning environments (4 / 2)

narrative learning environments (NLE) (3 / 0)

The environments tags refer to learning environments of various flavours. Only 7 articles are tagged with the general tag “learning environment”, while 22 articles are tagged “intelligent tutoring systems (ITS)”, 16 are tagged “learning management system(s) (LMS)”, 14 are tagged “e-portfolios”, and 14 are tagged “courseware(s)”. E-portfolios can be a learning environment in itself, or can be a component of a larger learning environment, a tool from which a learning environment could be created, or it could even be an assessment method; thus it appears in several places.

Several tags refer to articles that mention laboratories, including 12 articles tagged with “remote laboratories” and 11 tagged with “computer-based laboratories/laboratory”. Six tags have been used on articles that refer to various specialty environments, including 18 “simulation-based learning environments”, 15 “personal learning environments”. 7 “seamless learning environments”, 6 “programmable computer-based learning environment(s)”, 4 “adaptive learning environments”, and 3 “narrative learning environments”. Finally, the tag “games” (15 articles) could be interpreted as referring to a gaming learning environment.

The next group of tags refers to components of learning spaces.

Components:

pedagogical agents (14 / 2)

learning companions (11 / 0)

student models (4 / 0)

animated pedagogical agents (3 / 0)

learner model(s) (3 / 0)

user models (1 / 0)

learning object repositories / repositories of learning objects (1 / 0)

The 6 component tags address software components that can be used in learning environments, where 14 articles have been tagged with “pedagogical agents”, 11 with “learning companions”, 4 with “student models”, 3 with “animated pedagogical agents”, 3 with “learner models”, and 1 with “user models”. Only 2 of these articles made it to the top 10% corpus. Finally, the “learning object repositories / repositories of learning objects” tag has been used on 1 article, which most likely addresses the use of learning object repositories in a learning environment.

The next group of tags refers to tools that can be used in learning spaces.

Tools:

course management systems (CMS) / CMS (14 / 0)

e-portfolios (14 / 0)

authoring tools (11 / 0)

web-lecturing technologies (4 / 0)

discussion forums (1 0)

e-mail (1 / 0)

The 6 tools tags refer to various tools that could be used to facilitate learning spaces. Fourteen articles are tagged with “course management systems (CMS) /CMS”. The 14 articles tagged with “e-portfolios” could refer to the use of an e-portfolio tool that could be used to create a learning environment. The “authoring tool” tag has been used on 11 articles, while 4 articles have been tagged with “web-lecturing technologies”, 1 with “discussion forums”, and 1 with “e-mail”. None of these tags are used in the top 10% corpus.

The final groups of tags identify general information and communication technologies (ICT) that can be used to create learning spaces.

GENERAL ICT:

web (17 /0)

Internet (12 / 2)

multimedia (10 / 2)

learning grid (8 / 0)

virtual reality (8 / 0)

hypermedia (6 / 0)

ontologies (5 / 0)

adaptive hypermedia (4 / 0)

ubiquitous computing (3 / 0)

web 2.0 (3 / 0)

semantic web (2 / 0)

networks (2 / 0)

databases (2 / 0)

information systems (2 / 0)

information retrieval (2 / 0)

social software(s) (2 / 0)

computer simulation (1 / 0)

computer mediated communication (CMC) (1 / 0)

metadata (1 / 0)

knowledge based systems / knowledge-based systems (1 / 0)

Several of the tags have been used on articles that make use of the Internet, including 17 tagged "web", 12 tagged "Internet", 8 tagged "learning grid", 3 tagged "web 2.0", 2 tagged "semantic web", and 2 tagged "networks". Other tags refer to particular ICT such as "multimedia" (10 articles), "virtual reality"(8 articles), "hypermedia" (6 articles), "adaptive hypermedia" (4 articles), "databases" (2 articles), "information systems" (2 articles), "knowledge based systems / knowledge-based systems" (1 article).

Others refer to general ICT techniques such as "ontologies" (5 articles), "information retrieval" (2 articles), "computer simulation" (1 articles), "computer mediated communication (CMC)" (1 article), "metadata" (1 article), while the final tag "ubiquitous computing" (3 articles) refers to an ICT concept of computer everywhere and anywhere. Only 4 of these tags appear in the top 10% corpus.

PEDAGOGICAL APPROACHES

Pedagogical approaches encompass tags that indicate the pedagogical strategy that is employed (what is taught, how it is taught, and why it is taught). The pedagogical approaches tags, in descending order:

pedagogical approach (26 / 26)

formal learning (24 / 24)

collaborative learning (23 / 7)

mobile learning (23 / 2)

learning objects (18 / 3)

informal learning (17 / 10)

game-based learning (16 / 3)

blended learning (14 / 6)

distributed learning (14 / 3)

e-portfolios (14 / 0)

inquiry learning (11 / 1)

feedback (10 / 0)

multimedia learning (10 / 7)

learning scenarios (9 / 0)

self-explanation(s) (8 /2)

teaching strategies (6 / 0)

self-regulated learning (5 / 2)

argumentation (4 / 0)

curriculum(s) (4 / 0)

knowledge construction (4 / 0)

scientific inquiry learning (4 / 2)

scaffolding (3 /1)

self-regulation (3 / 1)

problem-based learning (2 / 0)

experimentation (3 / 0)

tutoring (3 / 0)

computer programming in support of learning (2 / 1)

pedagogy (2 / 1)

e-assessment (2 / 0)

interactive learning (2 / 0)

assessment (2 / 0)

concept maps (2 / 0)

discovery learning (1 / 0)

pedagogical models (1 / 0)

discovery learning (1 / 0)

teaching practices (1 / 0)

didactics (1 / 0)

formative assessment (1 / 0)

experiential learning (1 / 1)

adaptive learning (1 / 0)

cooperative learning (1 / 1)

tutors (1 / 0)

training (1 / 0)

The tag "pedagogical approach" was used on 26 articles in the main corpus, and all of these articles are found in the top 10% corpus. In addition to "pedagogical approach", the general tags "pedagogy" "pedagogical model" and "learning scenario" were used on 2, 1, and 9 articles, respectively. In addition, "formal learning" tagged 24 articles, "informal learning" 17, and "blended learning" 14 articles. "Training" also appeared on 1 article, and "curriculum" appeared on 4 articles.

The collection of tags comprises the major pedagogical approaches one would expect, including "cooperative learning", "adaptive learning", experiential learning", "knowledge construction", "discovery learning", "interactive learning", "problem-based learning", "self-regulated learning", "self-explanation", "multimedia learning", "experimentation", "inquiry learning", "distributed learning", "mobile learning", "game-based learning" and "collaborative learning". Also, unexpected tags such as "computer programming in support of learning" have been used.

Other terms related to a pedagogical approach could be found in the tags, including "teaching practices" and "didactics". Tags indicating roles for those involved (i.e., teacher or computer tutor) include "tutors" and "tutoring". "Assessment" and "e-assessment", as well as "formative assessment" and "e-portfolios" are tags that indicate articles that also address pedagogical approaches.

TEMPORAL & GEOGRAPHICAL INDEPENDENCE

Temporal & Geographical tags are used for indicating support for and tolerance of temporal and geographical independence of learners and learning. Tags used in our corpus include:

e-learning (35 / 8)

distance learning (18 / 1)

networked learning environments (15 / 2)

virtual campus (13 / 0)

virtual learning environments (14 / 1)

ubiquitous learning (13 / 0)

networked learning communities (9 / 1)

learning space (7 / 0)

distance education (5 / 1)

networked learning (3 / 0)

virtual environments (3 / 0)

online learning (2 / 0)

virtual laboratories (2 / 0)

virtual universities (1 / 0)

The majority of the tags in this category indicate some form of virtual or networked learning situation, where one would expect there to be support for temporal and geographical independence, including e-learning (35 articles), distance learning (18 articles) and networked learning environments (15 articles) / networked learning (2). In the main corpus, "virtual" tags take several forms, including "virtual campus" (13 articles), "virtual learning environments" (14 articles), "virtual environments" (3 articles), "virtual laboratories" (2 articles), and "virtual universities" (1 article). Of these 32 "virtual" tags in the main corpus, 28 are used in the top 10% corpus. A less used tag was online learning (2 articles), which is somewhat surprising, as it is a popular term and a search of the main corpus with "online" results in 30 articles and "online learning" in 26 (although only 2 of these were tagged with "online learning"). A search of the tags used for the main corpus for “online” results in the terms “online”, “online assessment”, “online education”, “online communities”, “online discussion”, “online education”, “online instruction”, “online learning algorithms”, “online learning and teaching”, “online teaching”, and “online tutoring”.

LEARNING ACTIVITIES

Learning Activities was the theme that was most difficult for which to select terms. Which terms, in addition to "learning activities", should be included was not straight forward, and the choice was to include terms that could refer to whether a particular type of learning activity was a simulation or face-to-face (a term not found in the TEL thesaurus):

learning activities (52 / 52)

face-to-face (3)

simulation(s) (16 / 1)

The "learning activity" tag appeared on 52 articles in the main corpus, all of which survived in the top 10% corpus. Further, there were three tags (not from the TEL thesaurus) indicating the types of learning activities that were written about in the articles. Collaboration was used as a tag on 11 articles, "problem-solving / problem solving" on 7, and "simulation" on 16 articles.

We were also interested in whether or not the activities were collaborative, and as this is a term used in conjunction with many other terms, we carried out a search of the main corpus for the term "collaborative activities", not a term in either the TEL dictionary or thesaurus, but might indicate that a paper discusses collaborative activities:

collaborative activities (23 / 9)

Another term that appeared in the main corpus tag set, but not in our search terms, was "blended learning":

blended learning (14 / 6)

There were 14 articles tagged with blended learning, and 6 of these appear in the top 10% corpus. This is not surprising as blended learning is an approach has emerged in the last years.

COMPETENCE

Competence is meant to refer to competences such as creativity, digital skills, participation, inquiry and collaboration, etc. that are addressed in TEL research. We included tags related to subject disciplines, as well as tags related to competences, including:

knowledge (27 / 3)

science (18 / 2)

collaboration (11 / 2)

problem-solving (9 / 3)

geometry (5 / 1)

science education (5 / 1)

dynamic geometry (4 / 0)

reflection (2 / 1)

literacy (1 / 0)

computational thinking (1 / 0)

equations (1 / 0)

critical thinking (1 / 0)

cooperation (1 / 0)

There were 65 articles with tags that refer in some way to competence. These include 28 related to "knowledge" in general and 30 articles addressing specific disciplines, including 25 tagged with "science" and "science education", 5 tagged with "dynamic geometry" and "geometry", and 1 with "equations". A further 7 articles address 21st Century competences (skills, knowledge, attitudes) including "literacy", "computational thinking", "critical thinking", "reflection", "collaboration", "problem-solving" and "cooperation".

Neither "digital literacy" or "digital literacies" or just plain "literacies" were listed in the TEL dictionary or thesaurus, but "literacy" and "literacies" each were used as a tag on 1 article:

literacy (1 / 0)

literacies (1 / 0)

A free search of the main corpus, however, returned 7 and 2 articles respectively.

IMPACT ON REAL WORLD

There were no TEL dictionary terms, and only 1 TEL thesaurus terms related to impact on real world, "policy":

policy / policies (1 / 0)

Thus, we also selected the tag "impact" which appeared in the list of tags for the main corpus:

impact (8 / 0)

This is both surprising and not-surprising, but is nevertheless disappointing, so further investigation of the main corpus was carried out. A free search on the main corpus for "impact" gave 58 articles. Similarly, a search for "guidelines" returns 3 articles and "policy" returns 15 articles.

DESIGN

Design is a new theme, related to both design of learning environments & learning activity (scenarios, feedback, etc.), as well as support for designers. Tags from the TEL dictionary (0) and thesaurus (4) related to design include:

learning design (11 / 1)

instructional design / development (6 / 1)

design patterns (3 / 0)

design knowledge (1 / 0)

While examining the tags in the tag selector for the main corpus it became clear that in addition to these 4 tags, there were numerous other automatic tags, 20 to be exact, which contained the term "design". Table x organises the "design tags" used in the main corpus; on the left we have the 4 original terms (from the TEL thesaurus) that include "design", and on the right the additional 20 terms including design.

Furthermore, a full search on "design" in the full corpus returns 222 papers (32 % of the papers in the corpus mention "design"). This is interesting and explains why DESIGN emerges in the topic modelling.

TEL Thesaurus term	**Automatic tags**
design knowledge, instructional design/development, learning design, design patterns	collaborative design, collaborative designing, computer supported design, course design, design, design principles, design of instruction, design space, design variables, designs, domain design, educational game design, game design, help, instructional design, instructional web design, instructional-design, multimedia module design, teaching material design, theory and design

Other original tags (from the TEL dictionary and thesaurus) that have been categorised as related to DESIGN include:

learning objects (18 / 3)

collaboration scripts (12 / 0)

feedback (10 / 0)

authoring systems (7 / 4)

scripts (4 / 1)

scaffolding (3 /1)

self-regulation (3 / 1)

didactical engineering (3 / 0)

epistemic affordance(s) (3 / 0)

awareness (2 / 1)

usability (2 / 0)

pattern language (2 / 0)

cooperation scripts (1 / 0)

teacher support (1 / 0)

EVALUATION

Evaluation is a new theme related to concepts that are in focus under data collection or data analysis. The evaluation tags fall into two sub-groups: Methods, and Theoretical Concept / Analytical Focus / Understanding.

One tag was directly related to evaluation:

evaluation (4 / 0)

Four articles were tagged with "evaluation", which implies a main focus of the article might be on evaluation related to some aspect of TEL.

The remaining tags fall into one of the two sub-groups, each of which is described below.

METHODS

experiment(s) (46 / 32)

educational data mining (14 / 1)

learning analytics (14 / 0)

learner modelling / modeling (11 / 0)

ontologies (5 / 0)

methodology / in technology enhanced learning (TEL) (5 / 0)

data mining (4 / 1)

design patterns (3 / 0)

user modelling (1 / 0)

assessment (2 / 0)

cognitive modelling (2 / 0)

student modelling (2 / 0)

questionnaire(s) (2 / 0)

Bayesian networks (1 / 0)

cognitive diagnosis (1 / 0)

knowledge engineering (1 / 0)

knowledge modelling (1 / 0)

knowledge representation (1 / 0)

interaction analysis (1 / 1)

machine learning (1 / 0)

In the main corpus, 119 articles had "method" mentioned; however, only 37 of these remained in the top 10% corpus. While 46 papers in the main corpus were "experiments", with 32 remaining in the top 10% corpus, it was surprising that there were no articles tagged with "design-based research (0 / 0)", which was one of the TEL thesaurus terms. Five articles are tagged with "methodology / in technology enhanced learning (TEL)", which implies that the article deals with methodological issues. Tags on 32 articles included one or more of "Educational data mining" and "data mining", which are methods employed in the collection and analysis of data, and "learning analytics", a term that has been adopted in the last years. "Machine learning" is also an intelligent method to have a system learn about something from data, and 1 article was tagged with this. "Learner modelling", "user modelling", and "student modelling" tags refer to methods used in intelligent systems to build belief models about the learner/user/student's competence development, and "ontologies" and "Bayesian networks" are sometimes a part of this approach, although there were only 1 and 2 articles, respectively, that received these tags. "Assessment" is a method to generate student data, but the exact emphasis on its use is impossible to tell without reading the 2 papers (which has not been done at this point). "Questionnaires" are used to collect data (2 articles), while "interaction analysis" (1 article) is a method often employed in socio-cultural research on student learning. That "interaction analysis" only shows up on 1 article is not surprising given the low number of socio-cultural articles in the corpus. In articles describing research ascribing to cognitive methods, relevant tags might be "cognitive modelling", cognitive diagnosis", knowledge engineering", "knowledge modelling", "knowledge representation.

THEORETICAL CONCEPT / ANALYTICAL FOCUS / CONCEPTUAL UNDERSTANDING

motivation (13 /2)

conceptual change (5 / 0)

knowledge management (KM) (4 / 0)

epistemic affordance(s) (3 / 0)

experiences (7 / 0)

participation (3 / 0)

awareness (2 / 1)

learning outcomes (2 / 1)

annotation(s) (2 / 0)

classification (2 / 0)

external representation(s) (2 / 0)

social interaction (2 /0)

epistemic feedback(s) (1 / 0)

external script(s) (1 / 0)

internal scripts (1 / 0)

learning paths / pathways (1 / 0)

shared knowledge (1 / 0)

conceptual frameworks (1 / 0)

social networks (1 / 0)

The tags in this category are related to a theoretical concept, an analytical focus, or a conceptual understanding. While 13 of the articles are tagged with "motivation", 5 with "conceptual change", and 4 with "knowledge management (KM)", only 2 of the "motivation" papers are included in the top 10% corpus. The remainder of the tags in this category are used for 1 to 3 articles, and all but 2 of them are dropped from the top 10% corpus. One article tagged "learning outcomes" and one tagged "awareness" are included in the top 10% corpus.

SUMMARY OF TAG ANALYSIS

There is a lot to learn from a set of tags used on a corpus of articles. In our case, 112 terms were used to create the corpus, and as evidenced from figure x with these terms come a plethora of automatically generated terms[2], either from the author's own tags (e.g., keywords supplied on an article), or by the journal's own terms used as a descriptor of the article. While the terms we used to create the corpus represent a set of terms used in the European TEL dictionary project, many of the additional terms used in the TEL thesaurus also appear in the set of tags. Furthermore, an analysis of the tags with respect to the categories defined in the description of our method, shows that the corpus does indeed represent a wide view of the field of ICT and learning (or TEL as we have chosen to call it in this section). One could have worked with tag analysis for the entire length of this project, but this was not possible given time constraints.

There were some surprises, however. One would have expected to see more papers using socio-cultural theories, even though it is not surprising that there are more cognitive and constructivist papers. It was also somewhat surprising that so many of the papers addressed the target of higher education, there are so few papers addressing schools. Higher education was the target of 126 papers, almost 4 times more than papers addressing high school. Primary school(s) were the target of 19 articles, 6 times more than secondary education.

It was also surprising that 36 of the articles dealt with medical education, a term that was not in either the TEL dictionary or thesaurus, but when working with the main corpus and noticing a number of papers addressing medical education, a search of the main corpus was carried out using "medical education", resulting in 36 papers, 4 of which appear in the top 10% corpus.

One shortcoming of the work with the tags is that it is not possible to tell from the tags alone the true essence of the tag terms meaning in the paper. For example, for papers tagged with "theory" it was not possible to know from the tag alone if the paper is focused on theory development, or rather theory is being used for design, or for understanding and explaining learning; one needs to read the full paper to know this.

Finally, authors are not very good taggers! For example, a search in the full corpus for

- "e-learning" gave 101 articles versus the 35 that are tagged as such
- "intelligent tutoring systems" gave 35 articles versus the 14 tagged as such

[2] The exact number has not been determined. Numerous attempts to have them exported to a format whereby they could be counted failed. They were too many to count in a manual manner.

- “game-based learning” gave 27 articles versus the 16 tagged as such
- “mobile learning” gave 48 articles versus the 24 tagged as such
- “distributed cognition” gave 3 articles versus the 0 tagged as such

THEMATIC ANALYSIS

One of our goals for the project was to identify the research themes that exist within the Corpus of literature that we had gathered. Rather than use one single method to identify these themes we approached the problem by three independent methodologies

Topic Modelling

Tag Analysis (see section on Analysis of Tags)

A detailed analysis of the themes represented in the literature from within the main corpus.

TOPIC MODELLING

THE TOPIC MODELLING FOR THE FULL COLLECTION REVEALED FIVE PRIMARY FACTORS THAT DESCRIBE THE FULL CORPUS OF RESEARCH PAPERS

Systems, user, information

How the technology was implemented - which we will label "TECH"

Learning, students, design

How design impacts learning - which we will label "DESIGN"

Learning, learners, knowledge

How to support learners constructing knowledge - which we will label "KNOWLEDGE"

Learning, students, pedagogical

How teaching methods influence student learning - which we will label "PEDAGOG"

Learning, dummy, social

How social activity (collaboration) influences learning - which we will label "SOCIAL"

THE TOPIC MODELLING FOR BOOKS ALSO GENERATED FIVE FACTORS

System, interact, knowledge

How technology and interactivity influences knowledge construction – KNOWLEDGE

Learn, design, educ

How design impacts learning and education - DESIGN

Communiti, learn, network

How communities and networks impact learning - SOCIAL

Page, ebook, studi

How the technology was implemented (e books) - TECH

Portfolio, teach, organ

How teaching methods (portfolios) are organised - PEDAGOG

There appears to be some strong similarities between the themes represented by these two separate topic models focused on 5 themes

KNOWLEDGE

TECH

DESIGN

PEDAGOG

SOCIAL

WITH THE SMALLER DATA SET OF 70 PAPERS WITHIN THE TOP TEN PERCENT COLLECTION WE FOUND EIGHT FACTORS

Social, learn, communic

How social activity and communication influence learning - which we will label "SOCIAL"

Student, instruct, scaffold

How instruction can scaffold student knowledge - which we will label "DESIGN"

Cognit, multimedia, learn

How multimedia can stimulate cognitive scaffolding and learning - which we will label "KNOWLEDGE"

Learn, environ, work

How work based learning is influenced by environmental factors - which we will label "WORK"

Effect, experi, learner

How experience affects learning - which we will label "EXPERIENCE"

Learn, blend, program

How blended learning can be implemented in programs - which we will label "BLENDED"

Elearn, learn, classroom

How classroom practices influence elearning effectiveness - which we will label "PEDAGOG"

Journal, article, learn

Use of learning materials – which we will label "MATERIALS"

These eight factors do not elegantly map with the five factors but we note that this is a much smaller data set and regression analysis may not be as sound with such a restricted corpus.

FACTORS FROM TAG ANALYSIS

As we discussed in the Tag Analysis two new themes emerged which match those identified within the Topic Modelling Analysis

Design – a theme, related to both design of learning environments & learning activity (scenarios, feedback, etc.), as well as support for designers.

Evaluation (sub-groups Methods & Theoretical Concept / Analytical Focus / Understanding) - a theme related to concepts that are in focus under data collection or data analysis.

EXAMINING THE DEVELOPMENT OF THEMES OF RESEARCH WITHIN THE CORPUS

Given that we have selected the papers in our corpus based on citations for any author to appear in our corpus is a significant recognition of their contribution to the field of technology enhanced learning.

However there are some researchers who appear multiple times in our corpus and a few who appear consistently over a number of years publishing in related areas and developing their ideas and their work. These consistently performing authors provide a method for identifying the consistent themes that is independent of Topic Modelling or Tag Analysis.

In preparing this list we have focused on first authors who appear in our corpus more than once over multiple years publishing in the same theme.

We have deliberately excluded authors who have multiple publications in a short period of time (see "Analysis Appendix 1 - Authors over time").

This analysis then shows us those researchers who have made a consistently significant contribution to the area. It also allows us to generate the list of primary research themes that have been active through the period of our analysis.

These are

- **Learning Design**
- **Collaborative Learning**
- **Intelligent Systems**

These themes have sub divisions within them (see Analysis Appendix 1 and 2 respectively for details) and can be seen to have linkages to the five factors identified in our topic modelling: KNOWLEDGE, TECH, DESIGN, PEDAGOGY AND SOCIAL.

So that

KNOWLEDGE could be seen to link with Intelligent Systems;

SOCIAL could link directly with Collaborative Learning;

and finally DESIGN with Learning Design.

The other two terms, PEDAGOG and TECH have links within sub categories of Learning Design, Collaborative Learning and Intelligent Systems.

KNOWLEDGE

Intelligent Systems

TECH

Learning Design

Collaborative Learning

Intelligent Systems

DESIGN

Learning Design

PEDAGOG

Learning Design

Collaborative Learning

Intelligent Systems

SOCIAL

Collaborative Learning

To take this conceptualisation a stage further the author's contributions from Analysis Appendix 1 can be organised into coherent thematic groups (see "Analysis Appendix 2 Themes over time").

This work formed the basis of the three strategic reviews in the Results section of this report.

ANALYSIS APPENDIX: AUTHORS PUBLICATIONS OVER TIME

This appendix provides a list of researchers and their publications who appear multiple times in our corpus and a few who appear over a number of years publishing in related areas and developing their ideas and their work.

In preparing this list we have focused on first authors who appear in our corpus more than once over multiple years publishing in the same theme. We have deliberately excluded authors who have multiple publications in a short period of time.

This analysis shows us those researchers who have made a consistently significant contribution to the area. It also allows us to generate the list of primary research themes that have been active through the period of our analysis.

These are Learning Design, Collaborative Learning and Intelligent Systems, respectively.

These themes have sub divisions within them and can be seen to have linkages to the five factors identified in our topic modelling: KNOWLEDGE, TECH, DESIGN, PEDAGOGY AND SOCIAL.

So that KNOWLEDGE could be seen to link with Intelligent Systems; SOCIAL could link directly with Collaborative Learning; and finally DESIGN with Learning Design. The other two terms, PEDAGOG and TECH have links within sub categories of Learning Design, Collaborative Learning and Intelligent Systems.

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ANALYSIS APPENDIX: RESEARCH THEMES OVER TIME

This document lists the author's contributions from Analysis Appendix 1 and shows how they can be organised into coherent thematic groups based around Learning Design, Collaborative Learning, and Intelligent (Tutoring) Systems. These are illustrated in this appendix and formed the basis for the Strategic Reviews in the Results Section.

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Year	Articles (Full)	Articles (Top 10%)
2000	50	7
2001	40	11
2002	51	10
2003	61	11
2004	57	8
2005	71	7
2006	61	6
2007	66	4
2008	67	3
2009	60	0
2010	37	0
2011	31	0
2012	19	0
2013	9	0

REVIEW OF COMPUTER SUPPORTED COLLABORATIVE LEARNING (CSCL)

We have conceptually separated the papers from our corpus related to Computer Support for Collaborative Learning (CSCL) into 3 subordinate research themes, which have been identified based on the content of the papers and an examination of the works cited as sources from the corpus papers. This process provides an understanding of how the themes have developed over time and also where research principles originated.

Our 3 themes:

CSCL environments

- Operationalise theory
- Support Collaborative Learning Pedagogy

CSCL Design

- Scripts
- Design based Research

Knowledge productive interactions

- Collaborative Argumentation
- Collaborative and Inquiry Learning

First a short review of collaborative learning and computer support for collaborative learning is given before we address each of these in turn and provide recommendations for future research in each area.

COLLABORATIVE LEARNING

Collaborative learning is a *collection* of perspectives based on principles of interpersonal interaction (Sørensen, 1997). While there may not be agreement on a definition among researchers, Littleton and Häkkinen (1999) write that there is a consensus that "collaboration involves the construction of meaning through interaction with others and can be characterised by a joint commitment to shared goal" (p. 23). This is similar to what Fjuk found from the literature review in her dissertation (Fjuk, 1998), where she identified three perspectives of collaborative learning, which place emphasis on *different goals*:

- Joint construction of knowledge (e.g., joint problems-solving by mutual refinement)
- Joint negotiation of alternatives (e.g., through argumentation), and
- Students rely on each other (and teacher) as a resource to support their own learning and to get feedback

Furthermore, Dillenbourg (1999) describes collaborative learning as a *situation* where particular forms of *interaction* among people are expected to occur, which triggers *learning mechanisms* in the learners; however, there is *no guarantee* that learning will occur. In Dillenbourg (2000) he identifies three generations of research on collaborative learning, where: *Generation I* focused on comparative experiments, which aimed to determine if collaborative learning is more effective than learning alone. Research showed that collaboration works under some conditions, but which ones? This was very difficult to answer; *Generation II* tried to answer under which conditions collaborative learning was efficient, only to find that the possible variables interact with each other in such a complex way that it was impossible to tease out an answer; *Generation III* turned to research that tried to identify which interaction takes place during collaborative learning, and found that collaborative learning is effective if the group members engage in rich interactions, such as explaining oneself in terms of conceptions and not simple answers, or arguing about the meaning of terms and representations, or when learners shift roles. Thus, research began to focus on regulating the collaborative process to favour the emergence of these types of interactions. Research on Computer Support for Collaborative Learning (CSCL) has focused on regulating the collaborative process.

COMPUTER SUPPORT FOR COLLABORATIVE LEARNING (CSCL)

Computer Support for Collaborative Learning (CSCL) focuses on the use of information and communications technology (ICT) as a *mediational tool for interpersonal interaction* in collaborative learning situations (e.g., peer learning and tutoring, reciprocal teaching, project- and problem-based learning, simulations, games) (Wasson, 1998). Understanding of learning in CSCL can either be from a Piagetian position where collaboration promotes socio-cognitive conflict, or from a Vygotskian position where individual change is a result of regulator activities such as coordination of, and interaction in constructive activities. In particular, it draws upon research traditions from those disciplines such as anthropology, sociology, linguistics, and communication science that are devoted to understanding language, culture, and other aspects of the social setting (Scott, Cole & Engel, 1992). In particular, its intellectual heritage draws upon social constructivism (Doise, 1990), the Soviet cultural-historical psychology (e.g., Vygotsky (1978), Leont'ev (1978), Davydov (1988)) and situated cognition (Suchman, 1987; Lave, 1988). Social constructivism focuses on the individual's development with respect to *social interaction* (i.e., an extension of Piaget's theory). Soviet cultural-historical psychology (e.g., Vygotsky, Leont'ev, Davydov) stresses the *cultural basis* of human intellect (e.g., learning is first inter-individual, then intra-individual (Vygotsky, 1994)), and situated cognition stresses the learning environment within which learning takes place (both the physical and social contexts), where learning is entering a "community of practice". This rich heritage highlights notions such as socially shared cognition (Resnick, Levine & Teasley, 1991), coordinated effort to solve a problem (Teasley & Rochelle, 1993; Rochelle & Teasley, 1995), genuine interdependence (Salomon, 1992, 1993), jointly accomplished performance (Pea, 1993), and interactivity, synchronicity, and negotiability (Dillenbourg, 1999).

In the most recent published historical perspective on CSCL, Stahl, Koschmann & Suthers (2006) eloquently write:

> "*CSCL researchers form a community of inquiry that is actively constructing new ways to collaborate in the design, analysis and implementation of computer support for collaborative learning. A broad range of research methods from the learning sciences maybe useful in analysing computer supported collaborative learning. Having appropriated ideas, methods and functionality from cognate fields, CSCL may in its next phase collaboratively construct new theories, methodologies and technologies specific to the task of analysing the social practices of intersubjective meaning making in order to support collaborative learning."* (p. 424).

It has been argued that CSCL environments can play a role in providing learning situations where interpersonal interactions can lead to inter-subjective meaning making. Understanding how various pedagogical arrangements, supported by such environments, lead to learning has been a focus of CSCL research (Baker, 2003).

CSCL ENVIRONMENTS

CSCL environments began to emerge in the early 1990s. The earliest systems include: CSILE (Scardamalia, Bereiter, McLean, Swallow & Woodruff, 1989; Scardamalia, Bereiter & Lamon, 1994; Scardamalia & Bereiter, 1996), the first networked classroom project (grade 6 at a Toronto school) facilitated a knowledge-building community by providing an application where students filled an empty database with notes (either a text or a drawing) and with comments on each other's notes; 5thD (Cole, 1996), which offered an integrated set of computer-based activities designed to enhance reading and problem-solving skills of students participating in an after school programme; and CSCWriting (Bruce & Rubin, 1993; Gruber, Peyton & Bruce, 1995), which provided a chat-like writing environment for deaf or hearing impaired students and their instructor to conduct text-mediated conversations. These were radically new ideas about how to support learning with computers, enabled through local area networks (LAN). Scardamlia (2004) writes "From the start the CSILE/Knowledge Forum initiative has aimed at revolutionary change: from a focus on carrying out tasks and activities to a focus on the continual improvement of ideas; from an emphasis on individual learning and achievement to the building of knowledge that has social value; from a predominantly teacher-directed discourse to distributed knowledge building discourse." (p. 191).

OPERATIONALISE THEORY

These early systems illustrate how some researchers have attempted to operationalise theory in the design of learning environments that support meaning making. For example, building on their theory of *intentional learning* (Bereiter & Scardamalia, 1989), Scardamalia and Berieter aimed at operationalising the theory in a computer based learning environment and related classroom pedagogy. Others built on *theories of argumentation* (e.g, Toulmin, 1958) including Belvédère (Suthers, Weiner, Connelly & Paolucci , 1995) and Vermann's Allaire Forums (Veerman, Andriessen & Kanselaar, 2000), or on the pedagogical model and epistemological framework *progressive inquiry learning* (Hakkarainen, 1998), which was operationalised in the FLE2 and FLE3 (Muukkonen, Hakkarainen & Lakkala, 1999) CSCL environments. *Trialogical learning* (Paavola & Hakkarainen 2005; Lakkala et al. 2009; Hakkarainen & Paavola 2009) has formed the basis for the development of a groupware system to support learning around the advancement of shared artefacts.

SUPPORT COLLABORATIVE LEARNING

Another aim of designed CSCL environments is to support a particular collaborative learning method, concept, technique, or pedagogy. Early CSCL environments supported knowledge building (Scardamalia, Bereiter, McLean, Swallow & Woodruff, 1989), peer assessment and/or feedback (Boud, 1995; Brown et al., 1997; Dochy et al., 1999; Topping, 2003), conversation skills (Sollar, 2001), socio-cognitive conflict (Doise & Mugny, 1984), problem-solving (Cole, 1996), etc. Furthermore, the psychological concept of mutual regulation, where one partner focuses on low-level aspects of a task while the other pays more attention to metacognitive aspects (Miyake 1986; O'Malley, 1987) underlies several pedagogical methods aimed to trigger epistemic conflicts among team members (Dillenbourg & Hong, 2008) by having the team members assume these different roles. In a reciprocal tutoring method (Palincsar & Brown, 1984) students take turns, for example, in reading a passage and asking comprehension-monitoring questions, then the students shift roles thus the learners articulate and share their understandings.

Research has shown that collaborative learning can lead to deeper level learning, critical thinking, shared understanding, decision-making, and long term retention of the learned material (e.g., Garrison, Anderson, & Archer, 2001; Johnson & Johnson, 1999) and it provides opportunities for developing social and communication skills, developing positive attitudes towards co-members and learning material, and building social relationships and group cohesion (Johnson & Johnson, 1989, 1999).

ISSUES AND FUTURE DIRECTIONS: CSCL ENVIRONMENTS

The goal of developing CSCL environments that support interpersonal interactions and intersubjective meaning making is not without challenge. It is a challenge to transform theoretical ideas into implementations, which are usually reified in the interface, and it is also a challenge to find how the environment fits best with the practical arrangements in learning situations (e.g., classrooms), and in institutional contexts (e.g., within a higher educational institution, or in a school). Yet another challenge is how to understanding the learning process, and how to measure the impact of the CSCL environment (beyond learning).

Developing CSCL environments that support collaborative learning method, concept, technique, or pedagogy faces the same challenges as operationalising theory in a CSCL environment. A focus on purely functional aspects needs to be balanced with the use of the environment in a social arrangement (e.g., a classroom). Yet another challenge is how to understand the learning process, and how to measure the impact of the CSCL environment (beyond learning).

Operationalisation of theory in a CSCL environment or designing support for collaborative learning is often the first step in a design process that then needs to be studied first as a proof of concept and later, if promising, studied for its impact on learning. Studies of these CSCL environments are most often of short-term use of systems under development, and we actually need cycles of tool development and evaluation, and if promising then long-term impact studies.

A major challenge is the move from research to practice where issues of scalability, integration into institutional or social contexts, and how and what to assess, understanding the learning process, the social interaction, and how to measure the impact of the environment (beyond learning) need to be addressed. Again, this calls for cycles of tool development and evaluation, and if promising then long-term impact studies.

CSCL DESIGN

CSCL Design is concerned with design for improved meaning making and is tightly tied to existing praxis (Stahl, Koschmann & Suthers, 2006), resulting in a symbiotic relationship where "design must be informed by analysis, but analysis also depends on design in its orientation to the analytic object" (Koschmann et al., 2006).

There are two approaches to the design of CSCL environments emerged in the corpus, scripts and design-based research.

SCRIPTS

As Dillenbourg (2002) writes, "Free collaboration does not systematically produce learning. One way to enhance the effectiveness of collaborative learning is to structure interactions by engaging students in well-defined scripts" (p. 61). Collaboration scripts are based on Schank & Abeslson's (1977) notion of "scripts" as representing personal or culturally shared knowledge about everyday knowledge as generalized procedures. The goal of Collaboration scripts (O'Donnell & Dansereau, 1992), then, is to describe the interaction for successful collaborative learning. They can be seen as a set of instructions that prescribe how to organize groups, how the group should interact, how they should collaborate, and how they should solve a problem (Dillenbourg, 2002) and these scripts are operationalised (or reified) in the interface of a learning environment. A well-known collaborative script is the Jigsaw (Aronson et al., 1978) where each member of a group is only given a subset of the information required to solve a problem, thus requiring group members to collaborate to solve the problem. This has been implemented in CSCL environments (Hoppe & Ploetzner (1999); Jermann & Dillenbourg, 1999; Hermann, Rummel & Spada, 2001). Other well-known collaboration scripts include Problem-based learning (Barrows & Tamblyn, 1980), Reciprocal teaching (Palincsar & Brown, 1984), Peer tutoring (O'Donnell & Dansereau, 1992), Peer teaching (Reiserer, Ertl & Mandl, 2002). For Kollar, Fischer, and Hesse (2006) an *external script* refers to the pedagogical scenario that students are asked to play, while an *internal script* describes the mental representation that students construct of the external script, while Dillenbourg and Hong (2008) distinguish between *micro-scripts* (dialogue models) and *macro-scripts* (pedagogical models), which can be embodied in CSCL environments, and shape group interaction. Nevertheless, despite their focus in the last year, there is a challenge for scripts as identified early by Dillenbourg (2002), who describes a script as a playable description of a hypothesis related to social interactions with respect to learning goals and as such has the danger of 'didactising' collaborative interactions" (p. 79) such that interactions become "fake" or un-natural. Thus, a real challenge is balancing the design and the freeness of collaboration.

DESIGN-BASED RESEARCH

Much CSCL environment development is carried out from a design-based research (DBR) approach where technological interventions are conceptualized and then iteratively implemented in natural settings in an attempt to bridge "the chasm between research and practice" (Andersen & Shattuck, 2011, p. 16) and thereby increasing "the impact, transfer, and translation of education research into improved practice" (Andersen & Shattuck, 2011, p. 16). DBR has its roots in design experiments (Brown 1992) and design-experiments (Collins, 1990, 1992), which according to Brown involves both engineering new designs and studying the effect of the design. In DBR "researchers working in partnership with educators seek to refine theories of learning by designing, studying, and refining rich, theory-based innovations in realistic classroom environments" (DBR Collective [http://www.designbasedresearch.org/dbr.html[3]]). This evidence-based refinement of design has had resurgence in recent years led by Barab et al.'s (2007) expansion of the scope of change resulting from design-based research beyond the artefacts, tools and curricula in educational practices, to include a critical social agenda. Thus, design-based research entails exposing what "could be" (Barab et al., 2007, p. 264) in addition to that which exists or not, in relation to the socio-political aspects of curriculum and school practices.

ISSUES AND FUTURE DIRECTIONS: CSCL DESIGN

The goal of designing CSCL environments and pedagogy that support interpersonal interactions and intersubjective meaning making is not without challenge. For scripting approaches the danger is in over scripting, which can result in fake, or un-natural collaborations. Furthermore, to date, scripts have been a researcher's tool, and it would be recommended to see how those other than the developer could use scripts. DBR research is time-consuming and disruptive to on-going practice, so it is necessary to find teachers and school leaders that are willing to invest the time and resources needed to participate with researchers.

One problem is that research funding (e.g., especially European funding) can often not be spent on buying teacher time for involvement in projects. This is a large hindrance, especially for DBR approaches, as it is necessary to have the daily practitioner involved, and support from school leadership. Funds have to be made available for such research efforts.

KNOWLEDGE PRODUCTIVE INTERACTIONS

Research on productive interactions that can lead to learning has been the focus of CSCL research since it's beginning. Collaborative argumentation and collaborative inquiry learning are two examples that emerged in the corpus.

[3] http://www.designbasedresearch.org/dbr.html

COLLABORATIVE ARGUMENTATION

One "practice of meaning-making in the context of joint activity" (Koschmann 2002) that has been extensively studied in CSCL (Bell, 1997; Baker & Lund, 1997; Andriessen, Baker & Suthers, 2003; Baker, 2003) is that of argumentation. Much of this work builds on Toulmin's (1958) model of arguments, which comprises six components: *claim, data, warrant, backing for warrant, rebuttal,* and *modal qualifier*. Arguments constructed with these elements facilitate self-explanation (Baker, 2003). Evidence, however, shows that individual learners rarely create arguments on their own (Kuhn, 1991) and prompting, such as a CSCL environment that visualises the argument (e.g., Bellvedere: Suthers, Weiner, Connelly & Paolucci , 1995;), or peers participating in a counterargument discourse (Leitão, 2000), can scaffold the process. Argumentative writing is difficult for most, and in particular, research shows that before 11 or 12 years of age, students have difficulty in recognising bias and cannot conceive an opposing point of view (Golder & Coirer, 1996; Brassart, 1996).

Argumentative knowledge construction "is based on the assumption that learners engage in specific discourse activities and that the frequency of these discourse activities is related to knowledge acquisition" (Weinberger & Fischer, 2006, p. 4-5). Recent approaches investigate how to facilitate specific processes of knowledge construction and the development of a framework for their analysis (Weinberger & Fischer, 2006).

COLLABORATIVE AND INQUIRY LEARNING

Another practice of meaning-making that has been studied in CSCL is that of collaborative and inquiry learning (van Joolingen et al., 2005; Manlove, Lazonder & de Jong, 2006, 2008). In inquiry learning environments students are enculturated into a scientific way of working and thinking (Dewey, 1964; Brown, Collings & Duguid, 1989; Greeno, Collins, & Resnick, 1996), and by enhancing this practice with collaboration (van Joolingen et al., 2005) teams of students collaboratively experiment, model and reflect on both domain knowledge and on scientific methods.

Originally inquiry learning was conceived as the *discovery* of concepts (Bruner, 1961), however, it was reconceived to be the discovery of rules (de Jong & van Joolingen, 1998). Using data collected from simulations, databases, or labs, students proceed through transformative processes (Njoo & de Jong, 1993) of analysis, hypothesis generation, experiment design, data interpretation, and conclusion. Complementing these transformative processes are regulatory processes, which "manage and control the inquiry learning process" (van Joolingen et al., 2005, p. 674), such as planning, monitoring, and evaluation. Other researchers, such as Edelson et al., 1999) distinguish between this perception of inquiry learning as discovery, where discovery is only one mechanism for learning (Edelson et al., 1999), and inquiry learning, which involves "general inquiry abilities include posing and refining research questions, planning and managing an investigation, and analyzing and communicating results" (Edelson, Gordin & Pea, 1999, p. 393).

Collaborative inquiry learning environments (e.g., BGuiLE: Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone, 2001; CoLAB: van Joolingen, et al., 2005; WISE: Slotta & Linn, 2000) provide tools that support these transformative and regulatory processes, including collaboration.

Particular research on the provision of regulative support in TEL environments aims to support cognitive regulation (Pintrich, 2000), a recursive process that directs "learning based on feedback loops generated by goals, monitoring of compression or progress, and evaluation of outcomes" (Manlove et al., 2008, p. 795). Cognitive regulation is based upon theories of self-regulation (Butler & Winne, 1995; Winne & Perry, 2000; Schraw, 1998: Zimmerman, 2001).

Complementary to the focus on the TEL environments for collaborative and inquiry learning are efforts for integration of the technology with curriculum (e.g., Linn, Songer, & Eylon, 1996; Edelsen, Gordin & Pea, 1999).

ISSUES AND FUTURE DIRECTIONS: PRODUCTIVE INTERACTIONS

One of the challenges for knowledge productive interaction is scalability; how to support productive interactions in large groups. A second challenge is how and what to assess. Both these challenges are timely as we see the rapid growth of international interest in interactive learning environments, online learning, and in Massive Open Online Courses (MOOCs), in particular.

We recommend further funding for research on productive interactions in distributed collaborative settings. Targeted research on applying what we already know about how to elicit productive interactions in TEL environments to online learning or MOOCs, for example, should be funded. Furthermore, targeted research on how to assess these productive interactions is required. Movement has already been made in various 21C research efforts, but again, how this work can apply in large groups needs to be studied.

Collaborative Problem-Solving is a new focus of PISA 2015, and interestingly ties CSCL and ITS together.

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REVIEW OF INTELLIGENT TUTORING SYSTEMS

We have conceptually separated the papers from our corpus related to Intelligent Tutoring Systems into 5 subordinate research themes, which have been identified based on the content of the papers and an examination of the works cited as sources from the corpus papers. This process provides an understanding of how the themes have developed over time and also from where the research principles originated.

Our 5 themes are:

- Intelligent Tutoring Systems
- Cognitive Tutors
- Pedagogical Agents
- Context Aware Systems
- Educational Data Mining

We will address each of these themes in turn and provide recommendations for future research in each area.

INTELLIGENT TUTORING SYSTEMS

Since the middle of the 20th century the field of Cognitive Science has emerged as a sub discipline within the intersections of Psychology, Neuroscience and Computation. This new field took the findings from medicine, psychology and computational methods to examine the underlying principles that comprise the human mental processes of Perception (Gibson, 1950; Chase & Simon, 1973), Cognition (De Groot, 1946 & 1965; Schneider & Shiffrin, 1977 & 1977) and Memory (Miller, 1956; Peterson & Peterson, 1959; Atkinson & Shiffrin, 1968; Simon & Gilmartin, 1973; Penney, 1989; Baddeley, 1992; Ericsson & Kintsch, 1995) respectively.

As the models from Cognitive Science became more accurate and effective in explaining and predicting human mental behaviour it was a natural progression to examine how these models could be integrated into educational practice (Egan & Schwartz, 1979; Larkin et al, 1980; Chi, Glaser & Rees, 1982; Sweller & Cooper, 1985; Sweller & Chandler, 1994; Paas & Van Mërrienboer, 1994) and eventually into digital expressions of educational practice (Cooper & Sweller, 1987; Sweller, Chandler, Tierney & Cooper, 1990; Tindall-Ford, Chandler & Sweller, 1997; Sweller, van Merriënboer & Paas, 1998). From these studies a new field emerged in the intersection of cognitive science, educational psychology and educational technology called Intelligent Tutoring Systems (Jeffries, Turner, Polson & Atwood, 1981; Chandler & Sweller, 1991; Marcus, Cooper & Sweller, 1996).

The primary goal of such Intelligent Tutoring Systems (ITS) is to provide learners using digital learning systems with customised instruction, feedback or support, during the learning process so that the intervention of a human teacher is either minimised or removed completely (Psotka & Mutter, 1988; Anderson, Boyle, Farrell & Reiser, 1987). Secondary goals that have emerged from the field are the development of a deeper understanding of the learning process, the affective, situational and motivational factors that directly impact the effectiveness of learning, how learning materials should be presented in order to maximise learning (Eliot & Woolf, 1994; Mayer, 2001; Sweller, 2003; Paas, Renkl & Sweller, 2004) and investigations into how ITS can support the development of metacognitive skills that are vital to learning how to be a successful learner (Roll, Aleven, McLaren & Koedinger, 2007 & 2011).

ISSUES AND FUTURE DIRECTIONS: INTELLIGENT TUTORING SYSTEMS

The primary goal of ITS, of providing automated support for learners, does have challenges in real world application due to the resources required to develop the system components (300 hours of preparation has been quoted as being needed for each single hour of instruction (Murray, 1999)) and the rate at which such systems are rendered technologically obsolete. These two challenges make any ITS implementation an expensive short term investment for research funding.

It is also problematic to properly evaluate ITS and although some evaluation techniques have been developed, the field would benefit with some guiding principles to assist researchers to select appropriate evaluation methods for specific settings and contexts.

In fact, although the secondary goals of developing greater understanding of the learning process is often undervalued by researchers within the field of ITS (Mayer, 2001; Paas, Renkl & Sweller, 2004), this work provides one of the strongest rationales for continued substantial research investment in this area, since the findings have such widespread application in the broad domains of education beyond ITS.

Based on the literature we recommend research investment should be directed towards greater understanding of the role of tone of speech, inflection, body language, and facial expression in learners and determining appropriate responses to such aspects of human communication and how they affect learning.

We also recommend that research actions be targeted towards greater understanding of the role of emotion in learning, to develop systems that will interpret emotion and understand how to adapt responses to emotional states in learners.

Finally we suggest that research actions be targeted towards an understanding of how gaze and visual focus can be used to detect interest and disinterest in learners.

COGNITIVE TUTORS

Cognitive Tutors are a subclass of the ITS domain that use theoretical models of the learner's mental states and processes (cognitive models) to provide personalised feedback to the learner as they are working through learning materials, with the goal of maximizing learning (Atkinson & Shiffrin, 1968; Gagné, 1985; Carlson, Sullivan & Schneider, 1989; Carlson, Khoo & Elliot, 1990; Chandler & Sweller, 1991; Anderson, 1993; Cerpa, Chandler & Sweller, 1996; Anderson & Lebiere, 1998).

The models of learner cognition used within this field are primarily derived from two rival perspectives called "symbolic" or "connectionist" respectively (Van Merriënboer & de Croock, 1992; Van Merriënboer & Luursema, 1996; Willoughby, Wood, Desmarais, Sims & Kalra, 1997; Van Merriënboer, Clark & de Croock, 2002).

Symbolic theories propose that human knowledge can be divided into two irreducible kinds of representations: declarative and procedural. This matches the conceptual properties of traditional Turing/Von Neumann computation where data and instructions are segregated. The alternative perspective of the connectionist is more closely aligned with the computational model of neural networks where the knowledge is an emergent property of the system and builds incrementally on existing interconnections or knowledge (Salomon, 1998; Sweller, 2004; Prince & Smolensky, 2006).

The type of feedback provided to the learner as they are learning depends on the specific cognitive model that has been selected or favoured by the instructional designers of the Cognitive Tutor (Van Merriënboer, 1997; Tuovinen & Sweller, 1999). Such feedback may typically inform the learner of the correctness or otherwise of their responses and provide hints or suggestions to improve understanding. The model also aims to provide clear indications of the most effective moments to provide learners with appropriate feedback (Sweller, van Merriënboer & Paas, 1998; Tabbers, Martens & van Merriënboer, 2001; Tabbers, 2002).

One of the most frequently cited cognitive models used within Cognitive Tutors is the Adaptive Control of Thought—Rational (ACT-R) model (Anderson, 1993; Aleven & Koedinger, 2002; Koedinger & Aleven, 2007). This has been used in a variety of settings sometimes with reports of remarkable results, such as a 227% improvement in student performance (Koedinger, Corbett, Ritter & Shapiro, 2000). One of the main research themes within the field has been to determine how and when help should be provided to learners who are encountering difficulties mastering learning materials (Aleven, Stahl, Schworm, Fischer & Wallace, 2003) and how learners can improve their own learning skills by teaching self-reflection and self-directed help seeking abilities (Aleven, Mclaren, Roll & Koedinger, 2006).

ISSUES AND FUTURE DIRECTIONS: COGNITIVE TUTORS

The two rival perspectives within the field of Cognitive Tutors differ in how they envisage the underlying implementation of human cognition but, although conceptually different the two approaches tend to produce similar system behaviour in terms of learner feedback, so they both probably reflect abstractions of the actual process of human cognition.

Cognitive Tutors, like ITS (see previous section) are costly to implement with references in the literature of 200 hours of preparation for every 1 hour of learning (Anderson, Corbett, Koedinger & Pelletier, 1995).

However like ITS they provide researchers with unique ways to explore different cognitive models and how these models impact learning. For this reason they deserve continued funding and support.

Based on the reviewed literature we recommend targeted research actions to determine the optimum balance between giving assistance and withholding it and under what conditions such provision of assistance aids learning. This is known within the field as the "assistance dilemma" and it remains an essential question for advancing the field.

PEDAGOGICAL AGENTS

Pedagogical Agents are software sub components of an ITS which assist learners to comprehend or complete learning components. They frequently take the form of an animated avatar which plays the part of a tutor or exemplar within the learning material.

The recognition that learning is assisted by the provision of commentary or assistance is well established (Thorndike, 1913; Norman, 1993; Bransford, Brown & Cocking, 1999). It is therefore logical that researchers would evaluate how software systems could artificially provide such assistance (Cuban, 1986; Paivio, 1986; Chi, Bassok, Lewis, Reimann & Glaser, 1989; Landauer, 1995).

Early attempts were simple text based prompts (Paivio, 1986; Chi, Bassok, Lewis, Reimann & Glaser, 1989) but advances in the capabilities of educational technology allowed researchers to explore the potentials of animation (Lester, Converse, Stone, Kahler & Barlow, 1997; Lester, Stone & Stelling, 1999; Choi & Clark, 2006), sound, human-like gestures (Craig et al, 2002 & 2004) and simulated social/emotional responses (Gulz, 2004; Gulz & Haake, 2006) to enhance learner involvement and understanding (Mayer & Anderson, 1991 & 1992; Catrambone, 1994, 1996 & 1998; Cognition and Technology Group at Vanderbilt, 1996; Mayer, 2001).

Research into the use of simulated speech by animated agents has shown that emotional inflection in the simulated voice has a significant impact on learner response and efficiency of learning (Atkinson, 2002).

Attempts to develop a theoretical basis for the use of Pedagogical Agents have been primarily focused on how multimedia technologies should be used to support different learning styles and learning goals, including such factors as inflection of voice, simulated ethnic background of avatars and the simulated gender of the avatar (Mayer & Anderson, 1991 & 1992; Mayer, 2001; Moreno, Mayer, Spires & Lester, 2001; Moreno & Mayer, 2004 & 2005; Moreno & Flowerday, 2006). Approaches such as the Multiple Intelligent Mentors Instructing Collaboratively (MIMIC) (Baylor, 2001 & 2002; Baylor & Ryu, 2003) have also proposed frameworks to give guidelines for the timing of interventions, degree of animation and use of degrees or layers of different content related assistance.

ISSUES AND FUTURE DIRECTIONS: PEDAGOGICAL AGENTS

Those researchers who are critical of Pedagogical Agents feel they are "expensive technological apparatuses which may not necessarily improve student's performance" (Choi and Clark, 2006). Since the animated agents are often the primary focus of the experience for anyone using an ITS they frequently elicit strong and diametrically opposed reactions.

Supporters will point to how this field has allowed us to minutely examine the ways in which learners learn and educators can effectively impart new understanding, in a controlled condition where variables can be manipulated with fine tolerances in order to tease out the best learning conditions.

Detractors will cite the risk that with animated agents and their increasing feature list we are seeing a classic application of the Hawthorne effect, where so called "novelty effects" cause on average 30% of a standard deviation (SD) rise in performance (50%–63% score rise), which decays once the learners have become used to the aspect of the learning situation that was novel (Clark & Sugrue, 1991; Clark, 2001). However such objections do not recognise that this field addresses some important fundamental educational issues that go beyond simple visio-aesthetic experiences.

We therefore recommend that targeted research actions investigate not just the visio-aesthetic aspects of the avatars but also sponsor more in-depth investigations into the impact on learning, from variations in the content of the support and the competence levels of the agents themselves. Such findings will have important ramifications for educational practice beyond the specialised fields of ITS.

CONTEXT AWARE SYSTEMS

While the classic ITS has provision of temporal independence on behalf of the learner, allowing them to study whenever it was convenient (Hulin, Henry & Noon, 1990), the advent of mobile technologies has meant that increasingly learners are accessing their learning environment from a variety of locations and under a much wider set of circumstances (Schilit & Theimer, 1994; Kester, Kirschner, van Merrienboer & Baumer, 2001).

Enabling the ITS to be aware of where the learner is accessing the system (noise levels, ambient lighting, vibration, power supplies), who they are with (shared knowledge and shared gaps in understanding) (Hwang, Shi & Chu, 2011) and what resources are nearby allows the ITS to use the total environment to make the learning situation more dynamic and relevant to the immediate needs of the learner (Ackerman, 1987, 1988 & 1990; Abrahamson, 1998; Clark, 2000; Anderson & Gluck, 2001).

This is however a complex challenge for an intelligent system as it needs underlying models for the range of locations, modalities for the possible network connections, co-learners and resource limitations, along with action rule sets that accompany each possible condition (Hwang, Tsai & Yang, 2008 & 2009; Hwang, Kuo, Yin & Chuang, 2010; Hwang, Shi & Chu, 2011). Full contextual awareness may never be possible, since even human beings struggle for appropriate action rule sets when placed in novel situations (Norman, 1993).

ISSUES AND FUTURE DIRECTIONS: CONTEXT AWARE SYSTEMS

The increasing demands of learners to be to able to access learning systems via a wide range of mobile devices means that this sub domain of ITS will experience dramatic growth. However, it lacks any coherent theoretical framework or standardized guidelines for how studies should be conducted and evaluations performed. We therefore recommend that a focused research action be undertaken to develop a theoretical framework that can underpin contextual awareness and that guidelines should be developed for how studies in this area should be implemented and evaluated.

EDUCATIONAL DATA MINING

The term Data Mining is often confused with data extraction or data analysis, where information is gathered (often manually) from data sources to make some inference or evaluate some process. Data Mining is in contrast more complex, being the process of discovering patterns in large data sets using automated intelligent processes that can be applied to subsequent applications or actions. As such true Data Mining is more closely related to artificial intelligence and machine learning than it is to manual approaches of extracting meaning from a large data set (Fayyad, Piatetsky-Shapiro & Smyth, 1996).

When we examine studies within the field of Educational Data Mining we find some of this confusion where sometimes a manual large scale data extraction from student records is presented as Data Mining, without any automated process being involved or the ability to extract previously unknown interesting patterns (cluster analysis), dependencies (association rule mining) and unusual records (anomaly detection).

Educational Data Mining can involve automated processes, novel algorithms (Romero, Ventura & De Bra, 2004), database and data management, pre-processing, model based inference, metric & complexity comparisons, processing of discovered structures, forms of visualization, and real time updating of large data repositories related to people's learning activities in educational settings.

The main applications for Educational Data Mining have been directed to understanding students, assisting instructors and addressing institutional issues (Romero & Ventura, 2007).

UNDERSTANDING STUDENTS

Techniques have been developed that include student modelling (Sheard, Ceddia, Hurst, Tuovinen,2003), predicting student performance (Wang & Mitrovic, 2002; Wang & Newlin, 2002; Minaei-bidgoli, Kashy, Kortmeyer & Punch, 2003; Mcdonald, 2004) , making automated courseware recommendations for students (Ma, Liu , Wong , Yu & Lee, 2000; Lemire, Boley, Mcgrath & Ball, 2005) , detecting and predicting unproductive student behaviours (Kotsiantis, Pierrakeas & Pintelas, 2003), predictive grouping of students for effective study and predicting social interactions (Romero, Gonzalez, Ventura, del Jesus & Herrera, 2009).

ASSISTING INSTRUCTORS

Applications for instructors have included automated analysis and visualisation of student progress through learning materials and objectives (Yu, Jannasch-Pennell, Digangi & Wasson, 1999; Yu, Own & Lin, 2001; Wu & Leung, 2002), providing automated feedback for instructors to improve their teaching effectiveness and developing concept maps of student understanding (Novak & Cañas, 2006; Romero, Ventura & Garcia, 2008).

INSTITUTIONAL ISSUES

At the institutional level applications have included constructing courseware (Tang, Yin , Li , Lau , Li & Kilis, 2000; Myller, Suhonen & Sutinen, 2002), automating course planning and scheduling (Monk, 2005), student cohort comparisons within regions and instructor performance analysis (Romero & Ventura, 2010; Romero, Espejo, Zafra, Raul Romero & Ventura, 2013).

ISSUES AND FUTURE DIRECTION: EDUCATIONAL DATA MINING

The main challenges for Educational Data Mining are in determining the reliability and validity of the results that are generated from these techniques and to provide some control conditions. Often there is no empirical way to validate if the assumptions that have been generated are valid, or, for example, if any one student would have performed better if they had experienced an alternative configuration of class grouping, courseware presentation or feedback scenario.

We therefore recommend that some targeted research actions are initiated to provide guidelines to assist researchers on understanding how to check the validity and reliability of the recommendations produced by Educational Data Mining methods.

A further research action would be to fund work to provide standardized rules for specific data usages and an ethical framework to prevent abuse of usage information from students, instructors and institutions.

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REVIEW OF LEARNING DESIGN

We have conceptually separated the papers from our corpus related to Learning Design into three subordinate research themes, which have been identified based on the content of the papers and an examination of the works cited as sources from the corpus papers. This process provides an understanding of how the themes have developed over time and also where research principles originated.

Our three themes are:

- Understanding the Learner
- Designing the Learning Experience
- Theoretical Approaches to Learning Design

We will address each of these themes in turn and provide recommendations for future research that is required in each area.

UNDERSTANDING THE LEARNER

DOES THE MENTAL STATE OF THE LEARNER IMPACT LEARNING

The fundamental challenges related to online and digital forms of education are shared with more traditional approaches and are the age old demands of keeping the learner or learners focused on the material and the desired learning outcomes (Bloom, 1984; Clifford, 1988).

This requires that educators and designers of learning systems understand the different types of learners who will use a digital learning system, the idiosyncratic differences in their cognitive capabilities, behaviour, preferred learning approaches and their motivations in trying to master any particular programme of study (Bower, 1981; Savidis et al, 2005, 2006 & 2007).

Traditional face to face instruction has the advantage of having the educator physically present in the learning environment at the same time as the learner or learners.   However digital and online forms of education are often separated geographically and temporally from the educator.   Under these kinds of circumstances learners can easily lose focus on the learning materials and enter negative mental states that are associated with poor learning outcomes (Sylwester, 1994).

So it is important to design the learning scenarios and systems in such a way that they remain interesting to the learner and can withstand the attempts of some learners to compromise the digital learning environment to their own advantage.

In a series of studies Baker et al explored the mental and emotional states of learners that are most frequently associated with cheating in online environments. Baker's teams examined the literature related to deception (Ekman, & Friesen, 1969), negative learner emotions (Ang et al.,2002), poor learning outcomes (Sylwester, 1994) and then conducted their own series of lengthy empirical studies.

They reported that boredom and not frustration, was most predominately associated with attempts to cheat or breach digital learning systems.   It was further reported that delight and interest were comparatively rare emotions experienced when using digital learning systems (Baker et al 2008, 2009 and 2010).   This theme of research has evolved from its initial purpose of understanding the mental states of learners associated with attempts at cheating and are now more focused on the mental states most frequently associated with successful and unsuccessful learning outcomes (Baker, 2010).

ISSUES AND FUTURE DIRECTIONS: MENTAL STATES

Determining student mental states is problematic as they are self-reporting and often have to be described to someone who will also be involved in determining their assessment for the program in question. It is notoriously difficult to measure internal mental states or to agree on a list of possible mental states.

It would therefore be of great benefit to the field if detailed and controlled longitudinal studies could be conducted to determine if such mental states can be determined in a valid and reliable manner and if they can be so determined, to provide the field with standardized measures and recommendations for applying mental states to effective digital learning design.

DOES LEARNING STYLE IMPACT LEARNING SYSTEM DESIGN

It has long been proposed within traditional educational literature that each learner has a preferred learning style (Dunn & Dunn, 1978; Kolb, 1984). This literature proposes that learners have the best predisposition towards successful learning outcomes when there is a match between their learning style and the way in which learning materials are presented (Dunn & Dunn, 1978).

It is therefore natural that researchers should try and understand how learning styles could be incorporated into digital learning systems, such that each learner would experience a digital learning environment that closely corresponded to their preferred learning style (Maris, 1995; Schofield, 1995; Corbett & Anderson, 1995).

Cook (2005 - 2007) described a review on how the theories related to students' Cognitive Learning Styles (CLS) could be used to help improve web based education. Cook performed a meta-analysis of studies which reported applying cognitive learning styles and concluded that there was empirical evidence to encourage designers to accommodate learners CLS defined by the *wholist-analytic* and *active-reflective* constructs and that active learners preferred interaction and reflective learner's preferred methods that promote reflection. However Cook acknowledged that further work needed to be done to understand CLS and its possible role in the design of learning systems.

ISSUES AND FUTURE DIRECTIONS: LEARNING STYLES

For those researchers and practitioners who support the constructivist model of learning there is considerable appeal in the concept of individual learning styles. However there remains considerable debate about the validity, reliability and applicability of learning styles, not least about how they can be measured and of course, how they can be applied (Greenberg, 1987; Stahl, 2002; Coffield, 2004; Pashler, 2008).

There is a clear need to conduct well-structured longitudinal studies to objectively determine if learning styles do impact effective learning, if they can be measured and if they can, to give designers guidelines about how this field should be interpreted and applied. Although we came to this recommendation independently through our review we note that such a detailed and controlled investigation into the reality and applicability of learning styles has also been recommended by the American Psychological Association (Pashler, 2008).

HOW MUCH MATERIAL IS ENOUGH?

As technology has advanced over the past 30 years the capabilities of digital systems have increased to the point that it very easy for such systems to quite literally overwhelm the sensory and cognitive capabilities of the human nervous system (Salomon, 1979). One very important research question is therefore to determine the optimum cognitive and sensory limits for learners when exposed to digital learning environments (Clark & Salomon, 1986; Jonassen, Campbell & Davidson, 1994; Ainsworth, Bibby, & Wood, 1998; Mayer et al, 2001).

Further work by Mayer et al , (2002 - 2005) investigated how animation or static media can best be used to facilitate learning and developed seven principles: multimedia principle (present animation and narration rather than narration alone), spatial contiguity principle (present on-screen text near rather than far from corresponding animation), temporal contiguity principle (present corresponding animation and narration simultaneously rather than successively), coherence principle (exclude extraneous words, sounds, and video), modality principle (present animation and narration rather than animation and on-screen text), redundancy principle (present animation and narration rather than animation, narration, and on-screen text), and personalization principle (present words in conversational rather than formal style. This work also developed similar guidelines for agent based use of multimedia materials (Mayer et al, 2003).

ISSUES AND FUTURE DIRECTIONS: COGNITIVE AND SENSORY OVERLOAD

The findings from this research theme are essential if designers are to have guidelines about optimal human performance in digital learning environments. The challenges for this area of investigation are that each cohort of learners has highly variable tolerances and expectations with respect to levels of sensory stimulation and cognitive limits. Not only is there variation between learner groups there is also considerable variation even within single individual learners, depending on environmental, physical and lifestyle effects.

A useful future direction would be to establish sets of broad heuristics that can be applied to each media and medium of instruction and to sets of learners, depending on age and other individual differences.

DESIGNING THE LEARNING EXPERIENCE

The powerful capabilities of modern information and communications technologies mean that there must be careful consideration by designers of how to make best use of the visual, aural and tactile potentials made possible by educational technology with the known optimal sensory capabilities of learners (see earlier section on *Understanding the Learner*).

DYNAMIC REORGANISATION AND REUSE OF LEARNING MATERIALS

The idea that digital learning environments could be designed so that they change the ordering and context of the learning materials emerged as designers took note of the growing recognition that not all learners are identical and that each individual comes to a learning situation with their own strengths and weaknesses (Gerard, 1967; Wiley, 2000; Koper, 2001; Barrit et al, 1999).

Early work in this sub theme focused on designing systems that tried to match the ability of the learner with the difficulty of the material by applying Item Response Theory (IRT) to see if it could effectively plan the order and level of course materials. Over time IRT was replaced with genetic algorithms, pre-use assessments and libraries of pre-existing learning materials (Chen et al, 2005, 2006 & 2008). The effectiveness of these exploratory implementations was assessed by controlled experimental evaluations and reported considerable success.

As an alternative to automated configuration of learning scenarios Azevedo et al. (2004 - 2007) investigated if self-regulated learning (where the learner is involved in controlling aspects of the learning environment) was more effective than more traditional approaches. This work reported a number of approaches for self-regulated learning where students can set their own goals for learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour; guided and constrained by their goals and the contextual features in the environment. Complementing this work on self-regulated learning Van der Meij et al (2006) investigated the impact of how alternative multimedia presentations could be presented within digital learning environments. It was found that dynamic representations were associated with improved test score results and learners feeling that the material was easier to understand. Later work Van der Meij et al. (2011) showed that providing multiple representations of materials and prompts of key issues within multimedia learning situations resulted in improved learning.

Other investigators explored the potential of fully automated elearning course generation by extending the idea of dynamic reorganisation of material to the entire generation of digital courses by means of libraries of reusable learning repositories (Gamma et al, 1995; Wiley, 2000; Collis et al, 2004) (also see learning objects below) and complex models of course element ordering using principles from artificial intelligence, such as Dynamic Fuzzy Petri Nets (Huang et al, 2006). Such principles evolved over time to be applied to mobile devices and distributed eLearning (Huang et al, 2008) and finally towards systems that supported totally ubiquitous learning (Huang et al, 2011).

Closely linked with research looking at changing the ordering and content (usually difficulty) of learning materials were investigations into developing reusable learning objects, which although first proposed in the late 1960s (Gerard, 1967) emerged properly in the late 1990s as the cost of developing high quality learning materials became a limitation to having large repositories of digital learning materials (Barrit et al, 1999; Wiley, 2000; ADL/SCORM, 2001; IEEE, 2002; Collis et al, 2004). Learning objects became a field of detailed study (Downes, 2001), developing rival models (ADL/SCORM, 2001; IEEE, 2002), learning outcome frameworks (Harden et al, 2005), and even detailed ontologies to help integrate learning design with the object contents (Knight et al, 2005, 2006).

ISSUES AND FUTURE DIRECTIONS: DYNAMIC ORGANISATION AND REUSE OF LEARNING MATERIALS

It is certainly easy to appreciate why the goals of automatically generating learning materials for specific learners or specific learning demands is highly attractive. It is also easy to understand the attractiveness of reusable learning materials. However, these two approaches are not without their criticism.

With respect to the automated generation of tailored learning materials the rapid assessment of the learning needs and abilities of any given learner is at best problematic. Human beings are highly complex and a short pre-test or set of adaptive questions are not ideal mechanisms to fully understand the learner. It is suggested that a focused research programme should be targeted on establishing reliable and valid measures for determining learner needs and abilities. These could then become standardised to help developers of future learning systems and also make it easier to conduct comparisons between rival systems.

Also many of the studies that have demonstrated these kinds of technologies have not done so with valid comparison to comparable learning scenarios that have been implemented without dynamic configuration. For this reason many claims of successful implementation lack a reliable or valid comparison of learning outcomes. Funding bodies should consider recommending the inclusion of comparable alternative systems during studies to enable valid comparisons to be made for any claims of increased or improved learning effect.

Reusable Learning Objects have to make a number of assumptions about their use, users and objectives, which are problematic. Even strong proponents of Reusable Learning Objects have raised philosophical objections to their use (Wiley, 2000), some even arguing that learning is by its essence very context specific and for this reason alone learning objects are "*antithetical ... to pedagogy and teaching*" (Friesen, 2004). Focused research should therefore be conducted on determining the constraints on how effective any reuse of learning materials might be by controlling a variety of conditions which might directly affect the useful application of reusable learning materials. The outcome from such controlled studies would be useful to future designers and educators to know where and where not to apply such technologies.

DESIGNING ARTIFICIAL REALITIES AND OBJECTS

New digital technologies have presented designers with the opportunity to develop artificial realities and artificial objects that can enhance a learner's understanding of complex topics (Rogoff, 1990; Winn, 1993; Clements, 1995; Riner, 1996). However, such rich design possibilities require detailed understanding of the affordances (Gibson, 1977) of the real world before they can be used with learners. There is a long history of research focused on how the limitations of the real world impacts learning (Aristotle, 322 BC; Piaget, & Inhelder, 1967; Ackerman, 1996). Researchers such as Prasolova-Forland (2006 – 2008) have produced guidelines for the best application of place metaphors in virtual 3D campuses. And dedicated teams such as Price et al. (2003 – 2011) have systematically investigated the educational properties of virtual reality and augmented reality objects in learning scenarios. The simple novelty of these types of presentations and interactions can increase interest and motivation in learners who would otherwise find topics difficult to master (Price et al., 2011).

Dickey, (2005) provided a summary of two case studies looking at the use of 3 dimensional worlds as learning spaces and reported finding evidence that experiential learning and situated learning (Brown et al, 1996) were easily supported. In a later development of this work Dickey (2006) presented a summary of how adventure games could be adopted as instructional and narrative tools.

In 2007 Dickey provided an analysis of the then new concept of Massively Multiple Online Role Playing Games (MMORPGs), giving an overview of the two primary elements in MMORPGs game design: character design and narrative environment. Dickey speculated on the intrinsic motivation in character role-playing, and a discussion of how the narrative structure of MMORPGs might foster learning in various types of knowledge.

Mavrikis et al. 2010, discussed the obstacles to modelling user knowledge in virtual environments and of the issues related to design of affordances with virtual worlds and their architecture. This work was further developed (Mavrikis et al., 2013) by looking at how epistemology and the design of micro worlds can support or hinder learning.

Kneebone (2003 & 2004) described the role that simulator systems could play in training specific motor skills that can then be applied in safety critical real world settings. By detailing how such systems provide safe, realistic learning environments for repeated practice, underpinned by feedback and objective metrics of performance. In 2005 Kneebone developed a framework for evaluating such clinical training simulators and proposed four key areas that underpin effective simulation-based learning. These were: gaining technical proficiency (psychomotor skills and learning theory, the importance of repeated practice and regular reinforcement); the place of expert assistance (a Vygotskian interpretation of tutor support, where assistance is tailored to each learner's needs); learning within a professional context (situated learning and contemporary apprenticeship theory); and finally the affective component of learning (the effect of emotion on learning).

ISSUES AND FUTURE DIRECTIONS: ARTIFICIAL REALITIES AND OBJECTS

Many of the studies that report the development or use of virtual reality or augmented reality systems do so with strong coupling to the specific characteristics of the hardware or software involved. As such their findings and recommendations are often very constrained to the technology that exists at the time of their work. It is recommended that focused research could be applied to more abstract studies that examine the conceptual limits of virtual objects and environments so that more general guidelines can be produced that would not be so closely linked to the technology of any period.

DESIGNING FOR COLLABORATION AND GROUP INTERACTIONS

It has long been recognized that many aspects of human civilization are associated with a cumulative socio-cultural interaction between people, objects and concepts (Vygotsky, 1978; Palincsar, 1998). Education is, in many ways, a cultural phenomenon where one generation passes on to the next those ideas and skills that are judged to be essential for the culture to continue (Krumboltz, 1965 ; Glaser & Strauss, 1967). It is not surprising therefore that within digital education a major focus has been upon how to provide design affordances that support, encourage and guide learners towards group interactions, shared realisation of concepts and generation of knowledge (Johnson, 1981; Chevallard, 1988; Dede, 1995; Cognition and Technology Group at Vanderbilt, 1996; Scardamalia & Bereiter, 1996; Bransford, Brown, & Cocking, 1999).

A key focus in the design of effective collaboration has been how to inculcate a sense of community within the learners (Gardiner, 1994 & 1998). Rovai et al (2004 – 2007) found that Blended Learning (where online learning is complemented with face to face real world interactions) could increase self-perceived learning effectiveness and a sense of community amongst learners.

Strijbos et al (2004 & 2006) proposed some aspects of collaborative system design that promoted group interactions and group learning. These were learning objectives, task-type, level of pre-structuring, group size and computer support.

ISSUES AND FUTURE DIRECTIONS: COLLABORATION AND GROUP INTERACTIONS

Collaboration has become a key component of most modern learning environments, whether it is a group discussion forum, shared work spaces, wikis, social media or personal profiles (Abrahamson, 1998; Colis, & Moonen, 2001). The range of design possibilities within this sub theme is enormous and often researchers spend considerable effort and resources implementing studies into very specific technologies and platforms that rapidly become obsolete. As a result many of the findings from the research studies are linked very specifically to technologies, methods, mediums and media that have become superseded as digital technologies advanced.

What would be useful to this sub discipline would be to develop some fundamental and standardised measures of communication, interaction and group cohesion that would be independent of the changes in technology, and respected enough to be universally adopted. This would allow for the retrospective analysis and comparison of previous studies and for a cumulative advancement of design principles for successful collaborative learning, regardless of the physical capabilities of the technology.

DESIGNING FOR MOBILITY AND MOBILE DEVICES

One of the trends of the early 21st century has been the increasing miniaturization of digital technologies, their increased mobility, growing functionality, reduced cost and pervasiveness into almost every aspect of modern life. As a result there has been a systematic investigation into how such mobile technologies can be integrated into the design of digital learning systems (Kay & Goldberg, 1977; Pask, 1975 & 1976; Karmiloff-Smith, 1992; Bentley, 1998).

Some of the researchers who had been active in other sub fields (such as the *dynamic organisation and reuse of learning materials)* were early pioneers in adapting these sub disciplines into mobile forms (Virvoi et al, 2000, 2005 & 2008). Others explored how the new features of common mobile devices, such as mobile/cell phones, could be integrated into traditional learning systems (Sharples, 2000) and worked to develop some of the first theories of mobile learning (Sharples et al. 2005) which proposed that mobility and communication were essential for learning. They proposed a framework that complimented existing theories related to infants, classroom, workplace and informal learning in the tradition of activity theory. They proposed a technological layer which is where the learner engages with technology, such as a phone and a semiotic layer where learning is a system in which the learners' actions are mediated by tools and signs. It was proposed that the technological layer allowed for design of the technology and the semiotic layer allowed for discussion by educational theorists to analyse learning in the mobile age.

ISSUES AND FUTURE DIRECTIONS: MOBILITY AND MOBILE DEVICES

As with the collaborative design space (see above *collaboration and group interactions*) the range of design possibilities are vast and often researchers spend considerable effort and resources implementing studies into very specific technologies and platforms that rapidly become obsolete. As a result many of the findings from the research studies are linked very specifically to technologies, methods, mediums and media that have become superseded as digital technologies advanced.

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THEORETICAL APPROACHES TO LEARNING DESIGN

The use of theory within the field of learning design is quite varied, being often a hybrid of traditional information systems design (Chen, 1976; Davis & Olson, 1985), intelligent systems (Ashby, 1952), mathematics (Brousseau, 1970; Artigue & Perrin-Glorian, 1991), human computer interaction (Carroll, 1997) , psychology (Chomsky, 1968 ; Piaget, 1970; Jung, 1971 ; Jones & Nisbett, 1971) , educational theory (Krumboltz, 1965 ; Johnson, 1981; Chevallard, 1988; Bransford, Brown, & Cocking, 1999) and more broad social cultural perspectives from the social sciences (Glaser & Strauss, 1967) and humanities (Vygotsky, 1978).

There is no one single theoretical approach that has predominated in the field of Learning Design (Hoyles, 2002 & 2004; Conole et al, 2004 & 2008; Doering, 2006 & 2008) but a close reading of the material shows some geographical preferences. Such that Cognitive approaches and Constructivism are often favoured by researchers from the United States, Socio-Cultural approaches are often favoured by Europeans and more mathematical modelling approaches are often favoured by Asian researchers. Obviously there are exceptions to this generalisation and the other strong influence on researchers is the theoretical approaches that predominated in their own education and graduate work.

ISSUES AND FUTURE DIRECTIONS: THEORETICAL APPROACHES

In many scientific disciplines theory strongly directs the patterns of research activity. In such scientific paradigms theory determines if a body of work will be considered a success or a failure. That is not the case in the field of designing digital learning. This is both a strength and a weakness of the body of work we have reviewed, and reflects the diverse sources that inspire and inform the design of digital learning systems.

What the field lacks are common units of measurement that will allow valid and reliable comparison between learners, educators, learning scenarios, approaches, experimental conditions and outcomes. Given the complexity of the human learner and educator it is unlikely that such common units will ever be developed. Human beings are complex, ever changing and evolving in their mental states, cultures and societies. It is this dynamic of human nature that makes objective measurement of any key characteristic almost impossible. It is also the very thing that makes education an extremely rewarding field, as it is filled with the infinite potential of the human mind.

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CONCLUSIONS CHAPTER

METHODOLOGICAL OBSERVATIONS

Subjective bias is unavoidable in reviews since they rely on the human researcher to filter and synthesize the work within a field. However these biases can be reduced by systematic controls on the various elements and processes involved in the review. By using two separate literature sources with independent citation and relevance prioritization methods and a single, independently selected, set of search terms we have made every effort to minimise selection bias with our sources and their selection. In the process we have devoted considerable effort to understanding the literature sources available to modern researchers using digital resources.

MONOPOLY ON SOURCES

We are concerned about the degree of influence held by the two major literature sources Thomson Reuters and Google. Their search, citation and impact processes are subject to potential manipulation and both have powerful agendas to maximise their exclusive control over the mechanisms that are essential to free enquiry within science.

AUTHORS AWARENESS OF TAGGING

We have also noted that authors are exceptionally poor at tagging their work effectively with keywords. When published works are increasingly accessed by digital means inefficient tagging of papers threatens the effective scaffolding of knowledge within science.

We strongly recommend that focused and coordinated training is provided to scientists and authors about the effective use of tagging when publishing and to increase awareness of the strong likelihood that researchers are not finding all relevant works when searching using digital tools due to poor tagging of previous works.

EU PROJECT INFORMATION

While we commend the work of CORDIS in listing details of all of the funded research projects and networks over the period, we note that the scientific value of the research that is being performed is to some extent negated by the lack of continuing support for the documentation of projects after their funding period has ceased. Whereas several hundred million euros of state funding has been utilised in the numerous framework calls it is regrettable that a large proportion of the projects websites no longer exist after the project has terminated. This is especially noticeable for projects more than three years old. There is also a lack of linkages between the various projects so it is virtually impossible for a researcher to do any kind of scaffolding for the findings produced by these initiatives over a decade and a half of time.

Clearly this is extremely wasteful and one can only speculate at the knowledge that is being lost through any lack of cumulative analysis between the different projects, and any attempts at retrospectively understanding the projects is rendered impractical by the lack of documentation once the project websites cease to exist. Researchers are left with a large listing of projects and only, in some cases, a single paragraph to describe an initiative with a budget in excess of a million euros.

It is a recommendation of our work that future research initiatives by national or international funding bodies include some provision for the long term support for documenting said projects and for ensuring that there is a clear scaffolding of cumulative knowledge generation that is documented in the repository that should be supported by the research councils. It is further recommended that phd stipends and other significant project work that is likely to contribute to advancing new knowledge or understanding is also systematically included within such a repository coordinated by the research councils that are funding such work. Such a repository would be of enormous benefit to the scientific community of each respective jurisdiction and also to the research councils to better enable themselves to see the direct outputs and cumulative knowledge generation that results from their investments in research and development at national and international levels.

THEMATIC OBSERVATIONS

TEL is a vast and complex domain of enquiry**.** It is subject to rapid change as it seeks to reflect advances in the capabilities of the underlying technology. Studies are often driven by exploration of the technology as opposed to fundamental research questions related to design or learning.

It is a domain where funding agencies have a powerful guiding influence in selecting the topics that are addressed by the leading research teams.

NEED FOR TARGETED ACTIONS BY FUNDING AGENCIES

There is a clear need for longitudinal studies that systematically build on a planned set of targeted research actions that encourage scaffolding of understanding over time and between different research groups. Such a long term plan would assist researchers to plan how their work (and careers) will progress even if they are unsuccessful in getting funding.

Targeted work is needed in establishing standardized measures of communication, learning effectiveness and teaching effectiveness.

We also note a need for the development of ethical guidelines in the measurement and recording of student and educator behaviours and activities in digital environments.

Some themes were not strongly reflected in our corpus since they have only recently appeared in the literature and had little time to gather high numbers of citations

REAL WORLD IMPACT

Our corpus provides little evidence of a direct linkage between formal research outputs and real world innovations in practice. However informal and anecdotal evidence suggests the linkage may be through ideas brought by graduates who work on projects and then bring new ideas into organisations as agents of innovation. This possible linkage could be explored by surveying organisations to find their sources of innovation

FUTURE DIRECTIONS - PREDICTED GROWTH AREAS IN TEL

Based on some of the time sequence topic models that emerged from the paper machines analysis we predict the following themes will expand dramatically in coming years

DIGITAL GAMING

It is recommended that focused research be applied to more abstract studies that examine the conceptual limits of virtual objects and environments so that more general guidelines can be produced that would not be so closely linked to the technology of any period

PERSONAL LEARNING ENVIRONMENTS

There is a clear need to conduct well-structured longitudinal studies to objectively determine if learning styles do impact effective learning, if they can be measured and if they can, to give designers guidelines about how this field should be interpreted and applied

MOBILE LEARNING

The range of design possibilities utilizing mobile learning are vast and often researchers spend considerable effort and resources implementing studies into very specific technologies and platforms that rapidly become obsolete. As a result many of the findings from the research studies are linked very specifically to technologies, methods, mediums and media that have become superseded as digital technologies advanced.

What would be useful to this sub discipline would be to develop some fundamental and standardised measures of communication, interaction and learning that would be independent of the changes in technology, and respected enough to be universally adopted.

LARGE SCALE COLLABORATIVE ENVIRONMENTS

The goal of designing such large scale collaborative environments and pedagogy that supports interpersonal interactions and inter-subjective meaning making is not without challenge. The issues of scalability for collaboration, assessment and pedagogy have not been researched for massive cohorts numbering many thousands. The attrition rates of 90% for enrolled students and the passive nature of many participants provide enormous challenges to existing paradigms of formal education and urgent research is required to provide informed guidance in these areas.

EDUCATIONAL DATA MINING

We recommend that some targeted research actions are initiated to provide guidelines to assist researchers on understanding how to check the validity and reliability of the recommendations produced by Educational Data Mining methods.

A further research action would be to fund work to provide standardized rules for specific data usages and an ethical framework to prevent abuse of usage information from students, instructors and institutions.

STRATEGIES AND TECHNOLOGIES TO IMPROVE CLASSROOM TEACHING

School based research is time-consuming and disruptive to on-going teaching practice, so it is necessary to find teachers and school leaders that are willing to invest the time and resources needed to participate with researchers. One problem is that research funding (e.g., especially European funding) can often not be spent on buying teacher time for involvement in projects. This is a large hindrance, especially for DBR approaches, as it is necessary to have the daily practitioner involved, and the support from school leadership. Funds have to be made available for such research efforts.

THE EUROPEAN STELLAR NETWORK OF EXCELLENCE'S WORK ON GRAND CHALLENGES

Finally we note that the three primary research themes that our review has identified within the field, *Learning Design*, *Collaborative Systems* and *Intelligent Systems* respectively, match quite elegantly to the **Grand Challenge themes** of "Connecting Learners", "Orchestrating Learning" and "Contextualising Learning" identified by the Stellar Network of Excellence[4].

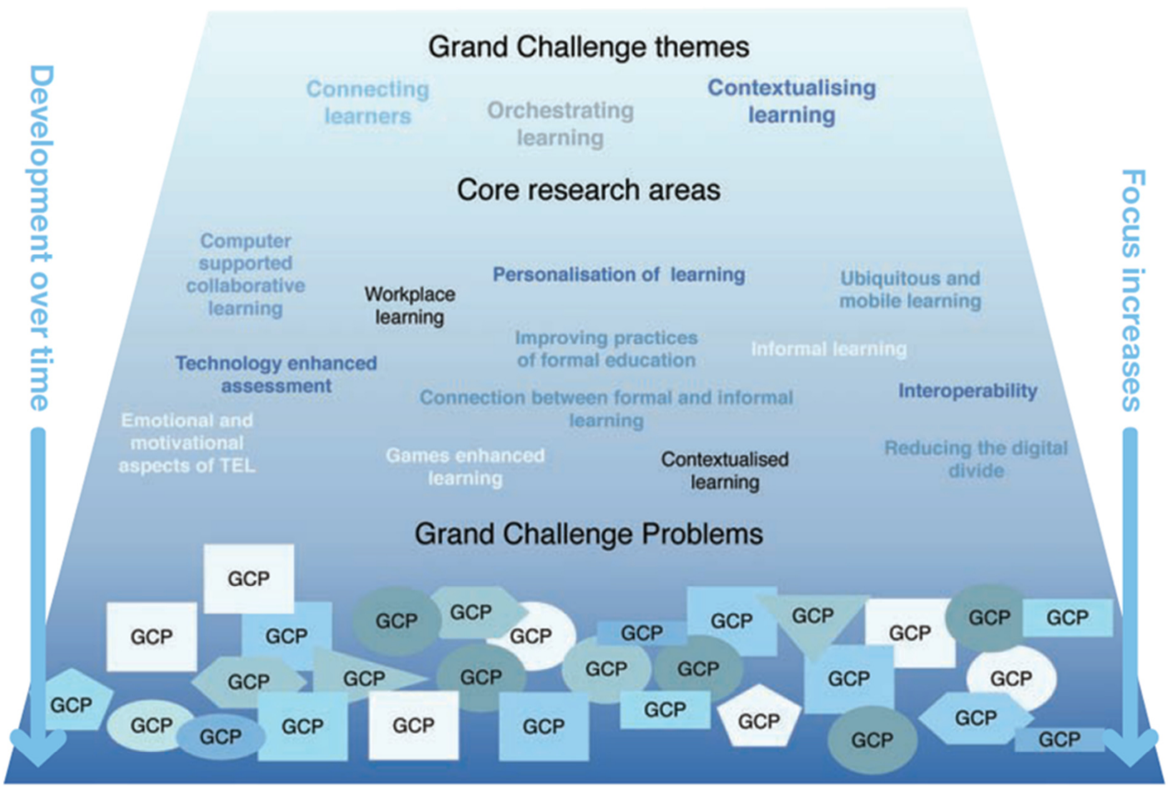

FIGURE 52 GRAND CHALLENGE THEMES FROM STELLAR NOE

4 STELLAR NOE's ground work on identifying a number of Grand Challenge themes and Core research areas for the TEL field in Europe (Sutherland, Eagle & Joubert, 2012). Furthermore, the Kaleidoscope NoE's legacy, the yearly Alpine-Rendez-Vous (ARV), was continued by the STELLAR NOE. The ARV hosts a number of collaborative workshops where each workshop is expected to identify at least one Grand Challenge Problem.

FUTURE USES OF THIS MATERIAL

Although we have attempted to provide a comprehensive review of the field due to time constraints we have only been able to analyse small fragments of the rich data set that we gathered, collated and synthesized.

We therefore hope that students, educators and researchers will find useful applications of our work in terms of their own research.

SUMMARY OF REPORT

In this State of the Field study our goal was to conduct an objective and comprehensive review of the field of *ICT in Education.*

ACHIEVEMENTS

We have minimised subjective literature selection by using two independent sources and influence ranking mechanisms combined with an independently created lists of domain terms.

We have summarised the field by three independent techniques Paper machines, Tags, Thematic Analysis. And as a result of these three techniques we have identified the primary research themes that have emerged within the field; Learning Design, Collaborative Systems and Intelligent Systems.

By reading the literature within our corpus and tracing its origins we have provided an understanding as to why these themes have emerged. We have reviewed their background and historical development by means of identifying the key source texts.

In addition we have provided perspectives on contemporary work by analysing the EU Projects and Norwegian PhDs that emerged during our reference period of 2000 to 2013. We have summarised the principal activities and findings from these research actions and produced systematic reviews of three primary research themes.

Finally we have identified future strategic research actions that will strengthen not only each theme but also the entire field of ICT in Education and suggested targeted research actions within each theme and sub theme.

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FREQUENTLY ASKED QUESTIONS

WHY NOT JUST CITE WHATEVER AND WHOEVER YOU WANTED IN ORDER TO SUMMARISE AND UNDERSTAND THE FIELD?

The traditional approach for conducting literature reviews requires considerable subjective judgement with respect to selecting search terms when accessing publication databases, deciding which works to include, which to ignore and the relative importance to be assigned to specific contributions in comparison to other contributions. The potential for bias in self-selecting materials, either consciously or unconsciously, is considerable as is the manner in which contributions are evaluated.

In an effort to provide a degree of impartiality in our work we used a predetermined set of search terms (the TEL Dictionary terms) for the literature database searches and citation as the primary means of selecting publications. Our Corpus of source literature was therefore as free from personal selective bias as we could reasonably manage.

WHY ISN'T FAMOUS HIGHLY CITED PAPER X IN THE CORPUS?

Since we used a pre-existing set of search terms (the TEL Dictionary items) we only gathered papers that had been tagged using that search term or had included the term within its text. This means that authors who did not provide relevant keywords or tags for their papers were likely to be excluded from our searches. We believe this highlights a problem with author tagging of papers that will extend beyond the field of digital learning.

WHY DOESN'T "FAMOUS" SCIENTIST X APPEAR IN THE CORPUS?

The most likely reasons that a specific author does not appear within our corpus is that they published prior to the start date of our search (2000) or that their papers were not tagged with terms that matched our predetermined search terms or that their papers were not highly cited enough to be included.

Scientists are generally "famous" within their given domain or more frequently within a specific group of researchers who share an interest. There are some exceptions but they are relatively rare. As we have already noticed the manner in which traditional literature reviews are conducted are subject to considerable degrees of subjectivity and selection bias. Under such circumstances scientists can become famous because they have been consistently working in a field but have not produced highly cited publications.

HOW ON EARTH DID AUTHOR X GET INTO THE CORPUS?

Our research methodology precluded any opportunities for us to selectively include or exclude specific authors. If an author appears in the Corpus then they published materials that had key words or tags that matched our predetermined search terms (the TEL Dictionary) and were among the most highly cited publications detected by searches through WoS or Google Scholar. Under such a strict methodology a reaction as to whether a specific author deserved to be included is a subjective value judgement.

WHY DO SOME OF THE REFERENCES IN THE CORPUS HAVE ZERO CITATIONS?

Some of the predetermined search terms in the TEL Dictionary were very specific. If relatively few authors had written in such a very specific domain, or (more likely) had not tagged their papers using the specific search terms then those few papers that did exactly match the search criteria would have been included into the Corpus, even though they had no citations.

WHY DIDN'T YOU ADD SEARCH TERM "X" TO THE TEL DICTIONARY TERMS AS IT IS CLEARLY AN IMPORTANT AREA?

As has already been stated we wanted to take every reasonable precaution against personal bias influencing the search terms. As such we decided to use the TEL Dictionary as it had been developed by a large group of leading researchers in the field as a definitive list of terms used in the field. If we had then decided to add or remove specific terms from this list we would have been at risk of introducing more subjectivity into the process as it is not obvious how one would select which terms to add or remove.

FORMAL STATEMENTS

PRISMA

Throughout the project we attempted to comply with the PRISMA 2009 guidelines

http://www.prisma-statement.org/2.1.2%20-%20PRISMA%202009%20Checklist.pdf

GENDER AND AGE

Throughout the study great care was taken to avoid and be sensitive to gender and age discrimination.

ANIMALS

No animals were harmed in the process of conducting this research.

HEALTH AND SAFETY REGULATIONS

We confirm that all relevant Health and Safety principles were observed and respected throughout the project