Editorial

Charalampos Karagiannidis and Sabine Graf

Welcome to the Bulletin of the IEEE Technical Committee on Learning Technology, Volume 15, Number 2, April 2013 issue.

This issue includes articles related to the theme of ***Learning Analytics***. Johri & Teo discuss how data analytics can be used to examine informal learning in online learning communities, through examples from the authors' studies over a large set of data. Pham & Klamma discuss how data warehousing techniques can be used in Life-long Learning Analytics to improve our personal knowledge, skills, and competences during our professional life. McCormick discusses how a learning analytics tool can be used to improve discussion design and facilitation with the use of visual aids and an interview/discussion process. Finally, Ebner & Schön discuss how learning analytics can be used to get a better insight of the students performance in primary education.

The issue also includes a section with regular articles (i.e. articles that are not related to the special theme), where Sierra, Ariza & Fernandez discuss how the problem-based learning methodology is applied to the subject of Programming in Engineering in the University of Seville, Spain.

We sincerely hope that the issue will help in keeping you abreast of the current research and developments in Learning Technology. We also would like to take the opportunity to invite you to contribute your own work (e.g. work in progress, project reports, dissertation abstracts, case studies, event announcements) in this Bulletin, if you are involved in research and/or implementation of any aspect of advanced learning technology. For more details, please refer to the author guidelines at http://www.ieeetclt.org/content/authors-guidelines.

Special theme of the next issue: **School of the Future and Future Classrooms**

Deadline for submission of articles: **June 30, 2013**

Articles that are not in the area of the special theme are most welcome as well and will be published in the regular article section.

Using Data Analytics to Examine Expert/Novice Behavior in Informal Online Communities

Aditya Johri & Hon Jie Teo, *Virginia Tech*

***Abstract*—We present an overview of how data analytics can be used to examine informal learning in online communities and demonstrate the viability of the approach through examples from studies of online communities of engineering enthusiasts. First, we discuss the analysis of social network structure of online communities to discover the existence of a core group of community leaders. Next, we adopt network motif analysis to examine the micro-level interactions in triads and discuss how these network building blocks contribute to a better understanding of the quality of interaction in the community. Lastly, we demonstrate how a temporal analysis coupled with statistical tests can be useful for uncovering environmental factors that contribute to changes in newcomer participation. Our three approaches coalesce into one common purpose – to gain deeper insights into the interactional and participation dynamics of online communities.**

***Index Terms*— Engineering Education, Informal Learning, Learning Analytics, Online Communities**

I. Introduction

In this paper we present an overview of how data analytics can be applied to examine informal learning in online communities. We use the term "informal learning" [1] to refer to a wide array of mechanisms for learning including "lifelong learning" [2], "non-formal education" [3], and "self-directed learning" [4]. Informal learning constitutes a multitude of activities that are "predominately unstructured, experiential, and non-institutional" [5] and are likely to take place outside the classroom (such as science museums [6]). Other characteristics associated with informal learning include unplanned and incidental cognition which occurs in daily routines or intentional cognition with a particular emphasis on collaborative knowledge building. In the domain of science education research is directed towards investigation of interest-driven learning of science in out-of-school settings museums or out-of-school groups, science camp and enrichment programs [1, 6]. The focus of informal science learning has benefited from the deemphasizing of science information in favor of engaging participants and the development of interest in free-choice environments [6]. Overall, there have been numerous attempts to characterize learning in informal settings by using a continuum encompassing dissected forms of learning described as informal, non-formal and formal learning [3, 7]. For the purposes of our research within the context of engineering learning we define informal learning as: Social and cognitive behavior change relevant to engineering practice that occurs in engineering students as an outcome of their participation in activities outside of core curricular requirements (where teaching occurs at specific, institutionally dictated times, primarily in classrooms or in laboratories, under close supervision). Informal engineering learning is non-didactic and learner-centered and emphasizes participation in a community of practice.

II. Online Communities

Online communities that form around common interests have existed since the dawn of the Internet [9] but have proliferated as an increasing proportion of the population has gained access to the Internet. They are a modern incarnation of 'list-serv' discussion groups initiated by academic scholars in the early days of the Internet. Online communities allow participants to acquire information, skills, and other resources relevant to their work interests [10]. Scholars have studied online communities to understand motivation issues, issues of social cohesion and lack of social involvement, and have suggested ways to design online communities for sustained participation [11]. Online communities are increasingly regarded as important venues for promoting learning across the boundaries of time, space, and formal organization [12].

III. Online Communities of Engineering Enthusiasts

One critical avenue for technology-driven informal engineering learning is online communities of engineering enthusiasts (OCEE). These communities have formed around a range of engineering topics and tools – such as microelectronics, rapid prototyping, open source software – and bring together engineering practitioners, hobbyists, and students, to engage in information sharing and product development (e.g. Do-It-Yourself or DIY projects). Although

Manuscript received March 30, 2013. This work was supported in part by the U.S. National Science Foundation under Grants EEC-0935143 & EEC-0954034.

Aditya Johri is Assistant Professor at Virginia Tech, Blacksburg, VA 24061 USA (phone: 540-231-0653; fax: 540-231-6555; e-mail: ajohri@vt.edu).

Hon Jie Teo is a doctoral candidate in Engineering Education at Virginia Tech, Blacksburg, VA 24061 USA. (e-mail: hjteo@vt.edu).

most of these communities do not start with the intent to educate others, it is one critical function that they serve. We believe it is important to examine OCEEs given their increased prominence in the field of engineering and because they attract Net Generation students. These communities have accumulated rich sources of materials and user data and can form the backbone to understand and implement technology-based informal engineering learning. Their examination can lead to an understanding of what works and how to accelerate innovations in cyber-enabled learning within engineering education. OCEEs are specifically appropriate for studying informal engineering learning for several reasons. First, they are informal in the manner in which they are structured and rather than being hierarchical based on age or tenure the hierarchy is informally established over time based primarily on expertise. Second, people participate in these communities due to their affinity [13] with the topic of the community and form "communities of interest" or, in many cases, communities of practice [14]. Finally, an important aspect of these communities, relevant to engineering education, is that people assemble here not only to discuss and share knowledge but to design knowledge-based products and services. Therefore, the ability to make and share expertise on making is critical for participation in these communities. As scholars who have applied constructivism to education have noted, building something for public exchange is often one of the strongest intrinsic motivations for learning [15]. We believe that these communities have a great potential for transforming engineering education particularly in this era where the engineering curriculum has become highly saturated with required courses and activities leaving little, if any, room to add new courses or activities.

IV. Findings from Studies of OCEEs

Over the past couple of years, we have conducted several studies of informal learning in OCEEs with specific focus on computer and software engineering communities. The studies analyze learning on these communities using online digital data. The data is collected through parsing of forums on which discussion takes place. As an example, one of the biggest datasets we have is from a forum "New to Java" which is a community for those interested in learning the programming language Java. We have collected participation data for over 10 years consisting of over 200,000 discussion messages. Using this data we have examined several questions which we discuss below (also see [16]-[17]).

A. Community Structure Using Social Network Analysis

The overall functioning of OCEE is supported by collaborative activities – where learners and experts work together to answer questions and pursue common interests. The importance of social interaction and learner collaboration lead us to social network analysis, whereby the emphasis is placed on examining ties between social units. This approach is particularly useful due to the existence of a massive amount of discussions on the OCEE can be characterized as social networks. A macro-level social network analysis approach can reveal the participation structure of the community of interest. This research approach is informed by advances in social network analysis and we leveraged Gephi for the visualization process [18].As demonstrated in Figure 1, we apply the Hu YiFan [19] force algorithm has been applied to the entire network and the visualization in Figure 2 indicates the presence of a small core group of help-givers with high degrees of interactions with other community members. Given the positions of these core help-givers, it suggests that the community is highly reliant on these individual for their expertise and voluntary efforts.

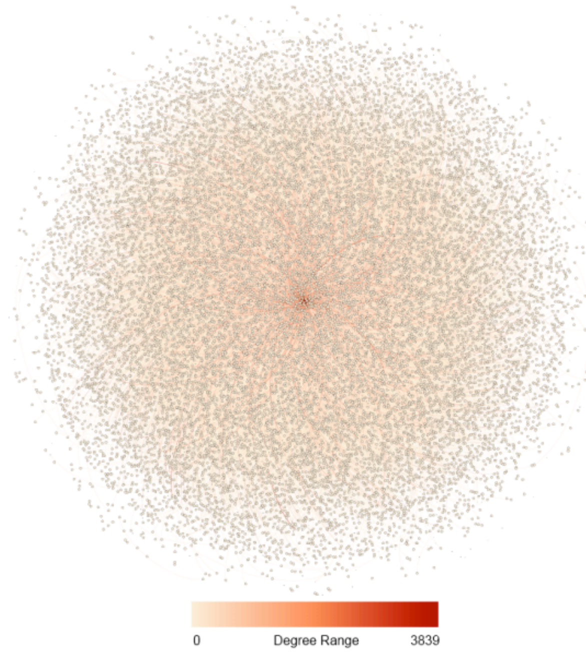

Figure 1: Network Visualization of Entire Community

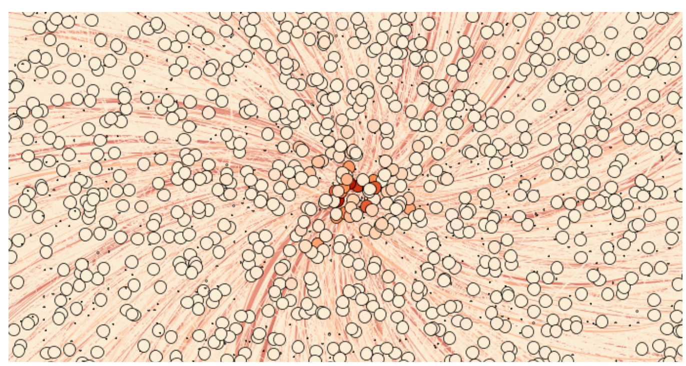

Figure 2: Close-up Visualization Showing Core Group of Help-givers

Table 1 describes the main network properties such as the total number of mean in/out degree and network diameter. There are a total of 21,509 nodes and 125,944 edges for this network. The average path length for the network is 3.253 where the clustering coefficient, which indicates how embedded the nodes are in their neighborhood, is at a relatively low value of 0.335 and indicate that the network has relatively sparse connections. These figures suggest that the social groups in this community are not tightly connected to each other which may be a consequence of deriving the social network from standalone discussion threads.

Table 1: Network Properties

Nodes	21509
Edges	125944
Mean Degree	5.981
Network Diameter	17
Average Path Length	3.253
Clustering Coefficient	0.335

B. *Motifs – Patterns of Community Sub-structures*

One formal – empirical and conceptual – avenue for understanding micro-level interactions in a community is "Network Motifs". Network motifs have been proposed by Milo and colleagues [20] as recurrent patterns of local inter-connections that occur in complex networks at frequencies that are significantly higher (reflected by the Z-score) than those occurring in randomized networks with equivalent number of nodes, in degree and out degree. Motifs can be small subgraphs of typically 3 to 7 nodes and represent the basic building blocks of most networks (to provide insights into the topology of complex networks [21]). While its use in social network analysis has been limited, we adopt this approach to gain deeper insights to the micro-level interactions amongst individual grouped into triads. More specifically, we explored if certain types of motifs make up a significant portion of interactions in the OCEE.

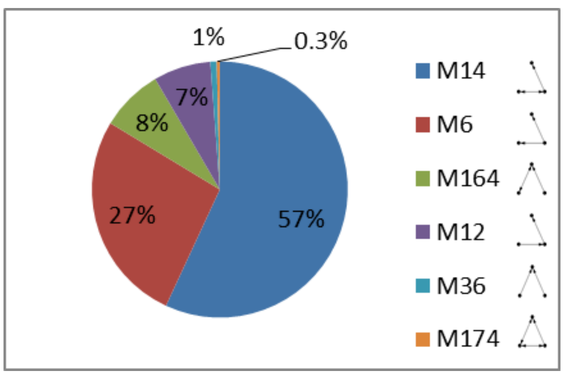

Figure 3: Frequency of occurrence of motifs

Referring to the motif network analysis (see Figure 3), we found that the "branch with one mutual dyad" motif (M14) and the branch motif (M6) make up approximately 63.5% of all recurrent patterns in this community. The network motif M14 represents an interaction triad that suggests that a learner is engaged in a bidirectional interaction with one helper and a unidirectional interaction with another. Specifically, the latter two actors are not interacting with each other in this triadic interaction and in contrast to the fully reciprocal motif (M174), the motif is not complete. M6, as the second most frequently occurring motif, can be inferred as learning system with one actor having two unidirectional interactions. This finding is not surprising considering that each help discussion will usually involve helpers engaging in unidirectional interactions with the learner to assist the help-seeker with the learning task at hand. The dominance of the two motifs M14 and M6 suggests that a large number of interactions are not complete in this help-seeking online community. On the other hand, highly connected motifs with more than 2 edges such as M36, M174, M238 and M46 occurred less frequently and this finding suggests that interactions between help-givers and help-seekers are seldom reciprocal in the help discussions.

C. *Effects of External Events on Newcomer Participation*

The attraction and retention of newcomers is a core concern to OCEEs as it reflects the much-needed community membership renewal. Researchers studying membership and persistence in organizations have argued that environmental factors rarely threaten well-designed organizations but can reveal how they react and adapt to them [22]. In one of our study, we drew from the concept of "environmental jolts" and conducted a temporal analysis of participation activities in a Java developer community triggered by two significant events: (1) open sourcing of Java by Sun (Nov. 19, 2006) and (2) acquisition of Sun (and consequently of Java) by Oracle (April 20, 2009). Both events represent a change either in the nature of product or in the ownership of the product and consequently the stewardship of the associated online community.

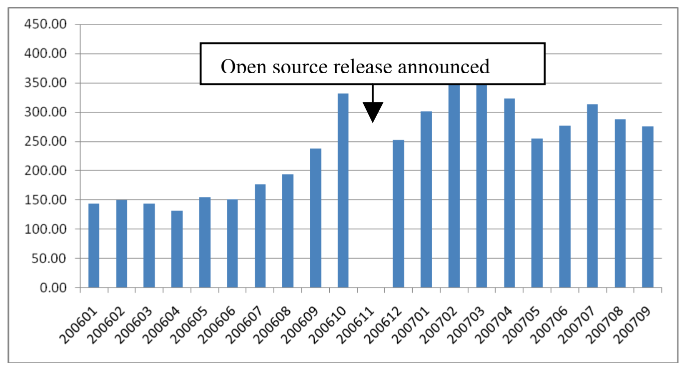

Figure 4: Participation change due to environmental change

We first captured a sizeable collection of archival data from Java developer community and parsed the data to capture the necessary user participation data with the goal of performing statistical tests on the four membership groups based on the amount of participation activity over time – bronze, silver, gold and platinum. The results of the quantitative analysis of forum participation before and after the announcement of open sourcing of Java by Sun reveal a significant difference in terms of both participation dimensions (see Figure 4): the average number of new forum users per day increased from 15.8 to 20.1 ($p<0.01$, Mann-Whitney test), the average number of discussion threads per day increased from 29.4 to 42.8 ($p<0.01$, Mann-Whitney test), and the average number of messages posted per day increased from 181.5 to 304.7 ($p<0.01$, Mann-Whitney test). The number of discussion threads and the number of messages posted were highly correlated ($r=0.96$ before the announcement; $r=0.92$ after the announcement). Activity broken down by user status indicated a sharp increase in the number of Bronze users (Average of 776.75 before the announcement to an average of 1020.65 after the announcement ($t= -3.10$, $P<.01$). The other groups of users also showed a steady and significant increase in number although the jump in numbers was not large (see Figure 5 on the next page).

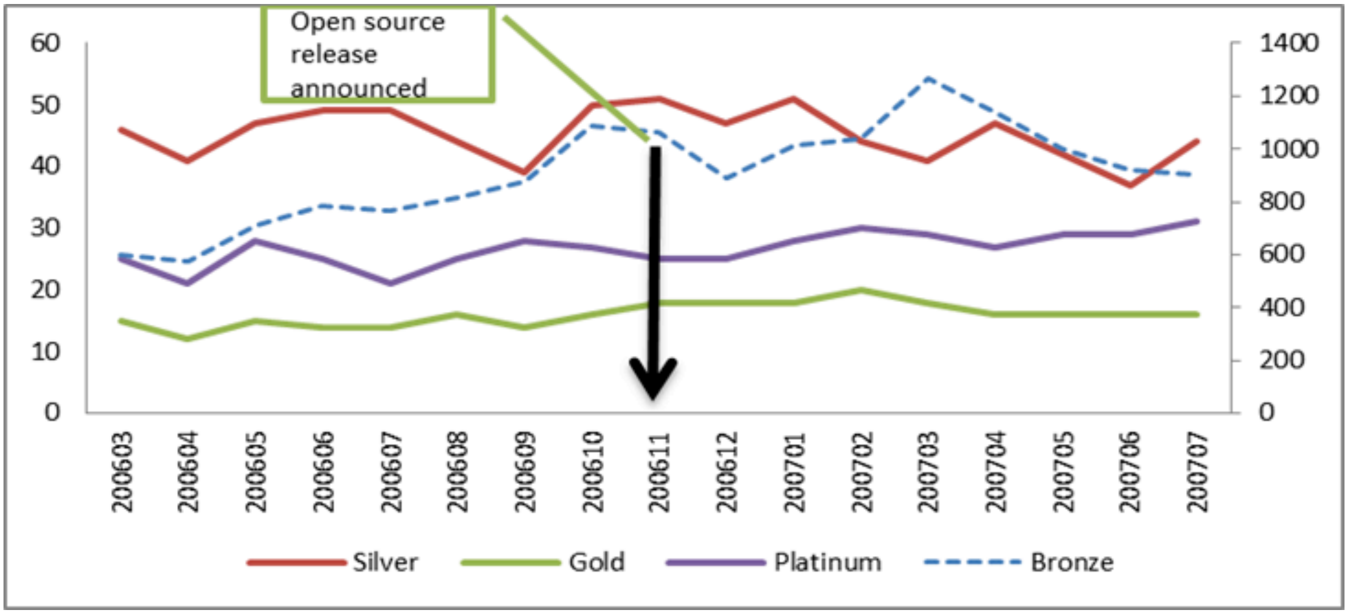

Figure 5: Differences in participation across four distinct membership groups

V. Discussion and Conclusion

In this paper, we describe three data analytics approaches: social network analysis, motif analysis and temporal analysis of participation. These analytics approaches can be extended to other platforms including formal online platforms complementing engineering coursework and MOOC. This is especially so considering that many engineering classes use course management software such as Blackboard that facilitates online discussion and learning. MOOC learning platforms on the other hand are supported with discussion forums to foster collaboration and knowledge sharing amongst learners and with instructors. Findings from our study show that by using data and analysis in novel ways we can uncover interactional and participation dimensions of learning communities that are not immediately representable and, and hence interpretable, to an education practitioner.

References

[1] P. Bell, B. Lewenstein, A.W. Shouse and M.A. Feder, *Learning Science in Informal. Environments: People, Places, and Pursuits,* The National Academy Press, 2009.

[2] Accreditation Board for Engineering and Technology (ABET). *Criteria for Evaluating Engineering Programs*, 2011.

[3] P. H. Coombs, P. H. and M. Ahmed, *Attacking Rural Poverty. How non-formal education can help.* Baltimore: John Hopkins University Press, 1974.

[4] M. Knowles, *The Modern Practice of Adult Education. From pedagogy to andragogy*. Englewood Cliffs: Prentice Hall/Cambridge, 1980.

[5] V. Marsick and M. Volpe. "The Nature of and Need for Informal Learning," in *Informal Learning on the Job,Advances in Developing Human Resources*, vol. 3, V. Marsick and M. Volpe, Eds. San Francisco: Berrett Koehler, 1999.

[6] J. Falk and L. Dierking, *Learning From Museums.* Walnut creek: Altamira Press, 2000

[7] Eraut, M. "Non-formal learning, implicit learning and tacit knowledge," in *The Necessity of Informal Learning,* F. Coffield, Ed. Bristol: Policy Press, 2000.

[8] European Commission, *A memorandum on lifelong learning.* Brussels: SEC , 2000

[9] M. Smith and P Kollock, *Communities in Cyberspace.* London: Routledge, 1999.

[10] L. Lakhani, and E. von Hippel. "How Open Source Software Works: "Free" User-to-User Assistance," *Research Policy*, vol. 32, no. 6, pp. 923–943, June 2003.

[11] R. Kraut, M. Patterson, V. Lundmark, S. Kiesler, T. Mukopadhyay and W. Scherlis. "Internet paradox: A social technology that reduces social involvement and psychological wellbeing?" *American Psychologist*, vol. 53, no. 9, pp. 1017-1031, 1998.

[12] M. Ahuja and K. Carley, "Network structure in virtual organizations," *Organization Science*, vol. 10, pp. 741-757, 1999.

[13] J. Gee, "Semiotic Social Spaces and Affinity Spaces: From The Age of Mythology to Today's Schools," in *Beyond communities of practice: Language, power and social context,* D. Barton and K. Tusting, Eds, Cambridge: Cambridge University Press, 2005, pp. 214–232.

[14] J. Lave and E. Wenger, *Situated Learning. Legitimate peripheral participation*, Cambridge: University of Cambridge Press, 1991.

[15] S. Papert. *Mindstorms: Children, computers and powerful ideas.* New York, New York: Basic Books, 1980.

[16] Teo, H. J., Johri, A. & Mitra, R. (2013). Visualizing and Analyzing Productive Structures and Patterns in Online Communities Using Multilevel Social Network Analysis. Proceedings of CSCL 2013, Wisconsin, MI, USA.

[17] Johri, A., Nov, O. & Mitra, R. (2011). "Cool" or "Monster"? Company Takeovers and Their Effect on Open Source Community Participation. Proceedings of iConference 2011, Feb. 8-11, Seattle, USA.

[18] M. Bastian, S. Heymann and M. Jacomy, "Gephi: an open source software for exploring and manipulating networks." In *Proc. International AAAI Conference on Weblogs and Social Media,* San Jose, CA, 2009.

[19] Y. F. Hu., "Efficient and high quality force-directed graph drawing," *The Mathematica Journal,* vol. 10, pp. 37-71, 2005.

[20] R. Milo, S. Shen-Orr, S. Itzkovitz, N. Kashtan, D. Chklovskii and U. Alon. "Network motifs: simple building blocks of complex networks," *Science*, vol. 298, pp. 824–827, 2002.

[21] K. Juszczyszyn, P. Kazienko, and K. Musia, "Local topology of social network based on motif analysis," *Knowledge-Based Intelligent Information and Engineering Systems*, pp. 97–105, 2008.

[22] A. D. Meyer, V. Gaba, and K. A. Colwell, K. A. "Organizing far from equilibrium: Nonlinear change in organizational fields," *Organization Science*, vol. 16, no. 5, pp. 456–473, 2005.

Data Warehousing for Lifelong Learning Analytics

M. C. Pham and R. Klamma

Abstract— **Lifelong learning aims at improving our personal knowledge, skills, and competences during our professional life. Traces or historical data of our lifelong learning processes are stored in a number of distributed portfolios. Lifelong learning analytics (LLA) involves harnessing these portfolios. However, data management of heterogeneous learning portfolios can become cumbersome and therefore limiting LLA, if done manually. Data warehousing is a data management technology ideally suited for automatic extraction, transformation and loading (ETL) of LLA data from heterogeneous portfolios making it perfectly suitable to be employed as a backend for visual LLA. A case study on teacher networks in Europe is demonstrating the feasibility of our data warehouse approach. We employed the data warehouse to analyze the interaction between teachers using social network analysis (SNA) for competence management and assessment of teachers' performance via measuring social capital of teachers in the networks over time. Since all core ETL processes are running automatically, only little maintenance effort is needed to run the LLA processes.**

***Index Terms*—Lifelong learning, learning analytics, data warehouse, social learning.**

I. Introduction

Learning analytics is recently attracting significant attention from research communities in learning technology, education, information science and computer science. The *First International Conference on Learning Analytics & Knowledge* (LAK 2011) defined learning analytics as the measurement, collection, analysis and reporting of data about learners and their context, for purposes of understanding and optimizing learning and the environments in which it occurs. Previously, learning analytics mainly focuses on supporting learning adminostrators, funders, departments, education authorities in decision-making. Currently, there is a shift from an institutional perspective to the concerns of learners and teachers, which are more personalized.

Manuscript received April 08, 2013. This work was supported in part by the DFG-funded excellence cluster UMIC, EU FP7 ICT Tellnet project and EU FP7 ICT Integrated Project Learning Layers.

M. C. Pham and R. Klamma are with Information Systems and Databases, RWTH Aachen, Ahorn Str. 55, D52056, Aachen, Germany (email: {pham, klamma}@ dbis.rwth-aachen.de).

Lifelong learning (LLL) is all learning actvitity that is undertaken throughout learners' life, with the aim of improving personal knowledge, skills, and competences [5]. The main focus of LLA is on learners and learning communities, where analysis helps learners to adapt to the learning environment and improve outcomes. Unlike formal learning where learning activities take place in certain places (schools, classes) and in certain time periods, lifelong learning is informal, where learning activities take place from the daily interactions with others and with the environment in different contexts, e.g. home schooling, continuing education, professional development and personal learning environments. Long time period of lifelong learning activities and the diversity of learners' interactions raise a challenge for learning analytics in both data management (e.g. data quality management, data uncertainty) and analytical applications for competence management, learner progression analysis and social interactions.

The central of any LLA system is a data warehouse that integrates information from various learning sources for use in analytical applications. Although designing and implementing a data warehose depends on the applications, there are several key principles in design and implementation of a LLA data warehouse, which we want to discus in this paper. The paper is organized as follows. In section II, we discus about the data warehouse model for LLA. In section III, a case study on the teacher network in Europe is presented. The paper finishes with conclusions and outlook.

II. Data Warehouse for Lifelong Learning Analytics

The data warehouse model for LLL analytics is given in Fig. 1. First, data about learning activities from learning systems such as Content Management Systems (CMSs), Learning Management Systems (LMSs), Student Information Systems (SISs), Social Networking Sites (SNSs) and other sources, e.g. Personal Learning Environments (PLEs) needs to be integrated. Data from those sources can be available in different formats, e.g. relational data tables, flat files or XML. Those different sources might contain data of varying quality, or use inconsistent representations, codes and formats. Data integration process needs to check the quality of data, perform data cleaning, transform data sources and integrate them.

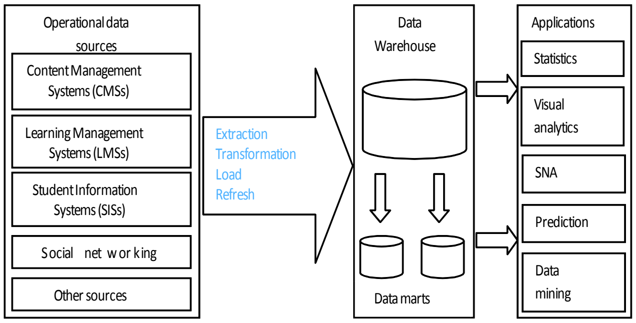

Fig. 1. Data warehouse for LLL analytics.

Since data warehouses are targeted for decision support, historical, summarized and consolidate data is more important than individual records in operational systems. For example, student performance in each subject over semesters, or social interaction of learners over time might be more important than the current data. Since a data warehouse contains consilidated data from several databases over long time periods, it should be seperated from operational learning systems to ease the data management and to allow complex queries and analysis to take place without disrupting or slowing learning systems.

After data integration, the resulting data is processed ETL standard steps. For automatic data proccessing, back end tools and utilities are implemented for data extraction, cleaning, transformation, loading and refreshing. Those tools connect to the data warehouse via standard interfaces, such as JDBC, Oracle Open Connect, etc. After extracting, cleaning and transforming, large amount of data is loaded into the warehouse. Then analytical applications such as visual analytics, SNA, recommendations or other data mining applications can be built on top of the data warehouse. Refreshing updates the warehouse (data and derived measures) based on the updates in operational databases.

To store information in a data warehouse, a data schema needs to be designed based on a *multidimensional* data model which views data in the form of a data cube and is commonly modeled within a relational databse management system (RDBMS). In this model, there is a set of measures that are derived from operational data. Each measure is associated with a set of dimensions, which give the context for the measure. For example, the dimensions associated with the average grade of students can be subject, semester and programm. Normally, the data schema is modeled using a *star schema* where a fact table (to store measures) is linked to dimension tables [6]. In the following, we present a case study on teacher network in Europe to give an example of the design of a data warehouse for a particular LLA application.

III. A CASE STUDY WITH TEACHER NETWORK IN EUROPE

eTwinning[1] is the community for schools in Europe, which creates a professional development network for European school teachers. It aims to promote European teachers' collaboration through the use of Information and Communication Technologies (ICT). The Teachers' Lifelong Learning Network (Tellnet) project aims to provide a learning analytics framework to analyze eTwinning community. The framework targets several stakeholder groups, including:

- **Decision-makers** pursue a better future for European school education and for European teachers' professional development and lifelong learning, which influence school education. They may be interested in different aspects of eTwinning community, especially how it develops over time, interactions between schools, regions and countries.
- **The Central Support Service** (CSS) i.e. learning network management staff. They are interested in questions like "What is the relationship between eTwinning and professional development? How do they influence each other and how do they support each other? "
- **The National Support Service** (NSS) promotes eTwinning by providing training and support, organizing meetings and national competitions, and managing public relationships based in each country. They may be more interested in the interaction of eTwinners in their country and, the interaction between their countries with other countries.
- **School management staff** is interested in teachers' activities in eTwinning, especially regarding the development of teachers' ICT skills and project cooperation. The interaction between teachers in the school with teachers in the same other schools is of special interest.
- **Teachers** (eTwinners) from pre-school, primary, secondary and upper schools can all participate in eTwinning to exchange and collaborate, as well as to learn new ICT skills, communication skills, teaching skills, and interdisciplinary working skills. They are interested in their own performance in eTwinning as well as their communities.

To answer the questions raised by different stakeholder groups, we employ data warehouse technology and social network analysis to analyze the interaction between teachers.

A. *eTwinning Data Warehouse Model*

The eTwinning data warehouse model is given in Fig. 2. eTwinning data is provided by European SchoolNet in CSV files. The data set consists of all teachers registered in eTwinning portal, their intitutions (schools), regions and countries. The interactions between teachers are reflected via several communitication mechanisms provided by the systems, including project collaboration, messages (posting messages on the profile wall of each other), contact lists and blogs. Other information includes prizes and awards of teachers and projects. Data also records time information of teachers' activities.

Before performing standard ETL steps, data is checked for consistency, e.g. missing values, wrong references, etc. When we have identified errors, appropriate data cleaning methods can be applied to correct them. For example, depending on the role of the missing values, they can be ignored, be filled by default values, or be deleted.

Based on the cleaned data, we extract several social networks at different levels as well as other objects such as teacher, institution, project, blog and message. Those networks include: *teacher networks* where nodes are teachers and connections between denote the interactions, e.g. project collaboration, contact list, commenting on blog posts, posting on the profile wall of each other; institution networks, region

[1] www.etwinning.net

network and contry networks where nodes are institutions, regions and countries and connections between them are aggregated from teacher networks based on teacher-institution relationship and the information about location of institutions.

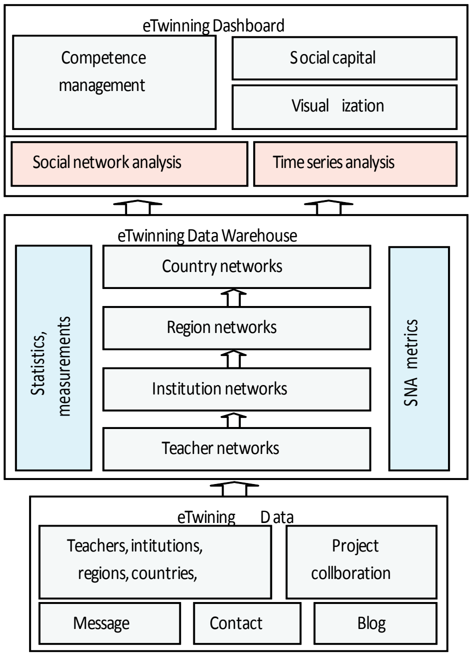

Fig. 2. eTwinning data warehouse model.

We develop a data model to store the above networks together with time information and network measures over time. For each time point, we store a snapshot of the each network and for each snapshot we computed a set of network parameters, including numbers of nodes and edges, network and node clustering coefficient and betweenness, node degree [1]. Together with other statistics, e.g. number of quality labels, prizes and projects, subjects, etc., this data allows us to analyze the development of the networks, assessing social capital of teachers and their professionnal development via the interactions with each other in eTwinning. eTwinning dashboard can be customized to serve different stakeholder groups according to their information needs. In the follows, we focus on three applications of this data warehouse: visualization of the networks provides an overview of teachers' interactions; comptetent management helps teachers to monitor their own performance in eTwinning network; and social capital assessment identifies the form of social capital in eTwinning, which can be used to make personalized recommendations to teachers.

B. *Network Visualizations*

Visualizations are useful for understanding teachers' interactions at different levels. Networks can be visualized directly from eTwining data warehouse. By combining the ranking of nodes in the networks by SNA measures, the visualizations can show the structure of the networks (e.g. communities) as well as the important of the nodes. The visualizations are especially useful for decision-makers, central support service, national support service and school management staffs, who are interested in an overview of teachers' interaction at Europe, country and school levels.

Fig. 3. Institution project collaboration network (geo layout).

For example, Fig. 3 shows the visualization of the institution collaboration network where nodes are institutions and are place on the map according to their coordination, and the color of nodes and edges denote the community that they belong to. One can see that eTwinning members come from schools which cover almost all countries in Europe. The collaboration is also very international, where members collaborate across geographical boundaries, not only within local members. eTwinning dashboard can visualize teacher networks at all level (i.e. teacher, institution, region and country levels) to provide different fine-grained views.

C. *Competence Management*

The term competence is defined as "The knowledge, skills, traits, attitudes, self-concepts, values, or motives directly related to job performance or important life outcomes and shown to differentiate between superior and average performers" [7]. eTwinning dashboard provides tools for learner self-monitoring and reflection. In competence management, competence assessment plays a central role. We consider three types of teacher competences and define indicators to assess them:

- *Professional competence*: involves all abilities or skills of teachers, which are necessary for performing professional tasks in eTwinning. For example, sufficient knowledge of a subject and a language are essential for organizing a successful consortium that focuses on the subject. We define *project performance* indicator to measure how a teacher performs in project by the number of projects she participated in and the number of quality labels/awards sh received.

- *Social competence*: considers the interactions of a teacher with others and with communities via different communication mechanisms, e.g. project collboration, messaging, blog posting and commenting. SNA measures on the networks formed by teachers' interactions can be used as indicators to assess social competences.

- *Meta-competence*: considers the self-monitoring ability of teachers, which describes teachers' ability to take advantage of monitoring their activities in the eTwinning network. It depends on various features, such as basic knowledge about SNA, understanding about graphs, charts, observation ability or abstract thinking ability etc.

eTwinning dashboard helps teachers to monitor their competences through plots of indicators. It also provides tools to monitor community (e.g. school, project) competences, i.e. teachers' competences in a particular communitys.

D. Assessing Teacher Social Capital

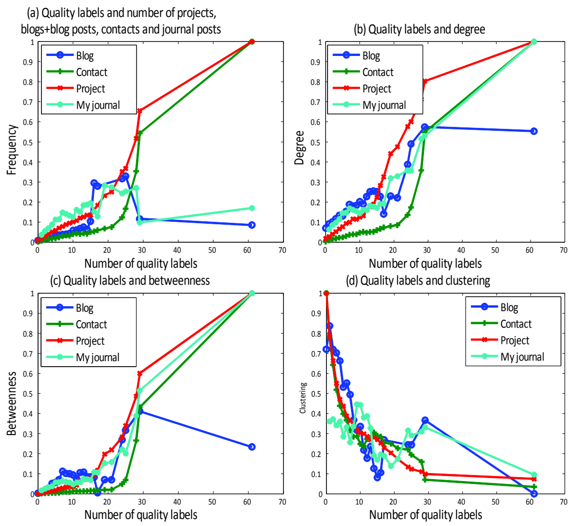

Fig. 4. Teachers' performance and network parameters.

Social capital stands for the ability of actors to derive benefits from the membership in social networks or other social structures [2]. In SNA, studies are concerned with the network structures that are the most effective factor for creating social capital. Two types are identified. Coleman [3] emphasizes the benefits of being embedded into densely connected groups, as regards to the confidence, trust and secured relationship in the community. This form of social capital is referred to as *closure*. On the other hand, Burt [4] discusses social capital as a tension between being embedded into communities and brokerage - the benefits arising from the ability to "broker" interactions at the interface between different groups. We call this form *structural hole*.

We analyze the correlation between teachers' performance (indicated by the quality labels and prizes) and their positions in eTwinning network to reveal the social capital form. *Closures* and *structural holes* can be differentiated by two network measures on nodes. *Local clustering coefficient* measures the extent to which a node is positioned in a densely-connected community. If a node is in a dense community, its local clustering coefficient is very high. *Node betweenness* measures the extent to which a particular node lies between the communities. Nodes connecting different communities together have very high betweenness. Therefore, closures are characterized by high local clustering coefficient, while nodes with high betweenness are structural holes.

The correlation between network parameters and teachers' performance (indicated by quality labels) is given in Fig. 4. It shows that teachers who are positioned at the interface between communities (i.e., *structural holes*) have a big advantage. Teachers with a high number of quality labels connect different communities together (high betweenness and low clustering coefficient), while teachers with low number of quality are clustered within communities (high clustering coefficient). The result is useful to make recommendations to teachers, e.g. suggesting projects and contacts, helping them to build their communities as well as selecting members for a particular project in the way that maximizes the social capital.

IV. CONCLUSION

In this paper, we discus about the application of data warehouse for LLA. The characteristics of lifelong learning such as the long time periods of learning activities and the heterogeneous interactions of learners raise a challenge for data management as well as analytical applications. Data warehouse is ideally suitable for LLA as a backend with automatic data extraction, transforming and load process. We present a case study on teacher network in Europe where we employed data ware house to deal with heterogeneous interactions between teacher and large-scale data derived from those interactions. The case study demonstrate the usefulness and efficiency of data warehouse for LLA.

REFERENCES

[1] S. Wasserman and K. Faust. Social Network Analysis: Methods and Applications. Cambridge University Press, New York, NY, 1994.

[2] Borgatti, S. Network measures of social capital. Wire, 21(2), 1998, pp. 27-36.

[3] Coleman, James S. Social Capital in the Creation of Human Capital. American Journal of Sociology Vol. 94, 1988, pp. 95-125, the University of Chicago Press.

[4] Burt, R. S. "Structural Holes versus Network Closure as Social Capital". In N. Lin, K. Cook and R. S. Burt: *Social Capital: Theory and Research.* Sociology and Economics: Controversy and Integration series. New York: Aldine de Gruyter, 2001, pp. 31-56

[5] Fischer, G. "Lifelong Learning—More Than Training". *Journal of Interactive Learning Research, 11*(3), 2000, pp. 265-294. Charlottesville, VA: AACE.

[6] Chaudhuri, S. and Dayal, U. "An overview of data warehousing and OLAP technology". *SIGMOD Rec.* 26, 1 (March 1997), pp. 65-74.

[7] McClelland, D.C. "Testing for competence rather than for intelligence". *American Psychologist* 20 (1973), pp. 321-333.

Manh Cuong Pham, born on September 7th 1977 in Thai Nguyen, Vietnam, received his master degree in Software Systems Engineering in Computer Science at RWTH Aachen University in Aachen, Germany in 2008. Currently, he is a researcher at Information Systems and Databases Institution, Department of Computer Science, RWTH Aachen, Germany. His main research areas include social network analysis, recommender systems, data mining, information retrieval and web science. He received BIT Research School scholarship for PhD study by University of Bonn and RWTH Aachen in 2008. He worked for Tellnet project funded by EU which deals with dynamic social network analysis on the teacher networks to study the interaction between teachers in Europe.

Ralf Klamma has diploma, doctoral and habilitation degrees in computer science from RWTH Aachen University. He leads the "Advanced Community Information Systems (ACIS)" research group at the information systems chair, RWTH Aachen University. He has worked in EU projects for Technology Enhanced Learning (PROLEARN, ROLE, TELMAP, GALA and Tellnet). He is on the editorial board of IEEE Transactions on Technology Enhanced Learning, International Journal on Technology Enhanced Learning (IJTEL) and Social Networks Analysis and Mining (SNAM). His research interests include community information systems, technology enhanced learning, data management, and social network analysis.

Visualizing Interaction: Pilot investigation of a discourse analytics tool for online discussion

John McCormick

Abstract— **Discussion boards are perhaps the most commonly used collaboration tool in online courses. However, native discussion tools in learning management systems are limited in their ability to show interaction patterns among learners. Tools that provide more robust visual representations of discussions can improve instructors' understanding of how students are interacting and, as a result, their ability to intervene when identifying suboptimal interaction patterns. This paper presents an exploratory investigation of one such tool, Social Networks Adapting Pedagogical Practice (SNAPP), examining its potential to help faculty understand and react to discussion patterns. Emerging learning analytics tools such as SNAPP can enhance the ability of course designers and facilitators of online discussions to make adjustments to their pedagogical approaches.**

***Index Terms*— Computer-supported collaborative learning, learning analytics, online course design, online discussion**

I. STATEMENT OF PROBLEM

Asynchronous online discussion plays a key role in computer supported collaborative learning in higher education. Instructors frequently use discussion to support collaborative knowledge-building and higher-order thinking, an important component of online learning [4]. Recent research has proposed theories and frameworks to guide the design and facilitation of online discussion [6, 12]. Design features providing structure such as protocols and criteria to scaffold discussions can be particularly critical to the achievement of high-level discourse [1, 7, 9, 10,13]. However, educators often find the design of discussions challenging, while monitoring and getting a clear sense of the gestalt of discussion interactions can be difficult and time-consuming [11].

Discourse learning analytics tools have the potential to improve both design and facilitation of online discussion. By parsing text-based information into useful visual and numerical displays, these tools give educators real-time data, which can be used to improve discussion-based learning activities. Social Networks Adapting Pedagogical Practice (SNAPP) is a free browser plug-in that works with a range of open source and commercial learning management systems and that generates real-time visuals showing discussion interaction patterns. Figure 1 shows a comparison of visuals generated from Blackboard 9.1 and SNAPP.

Manuscript received March 29, 2013.
Author is the Senior Instructional Designer for Lesley University, Cambridge, MA.

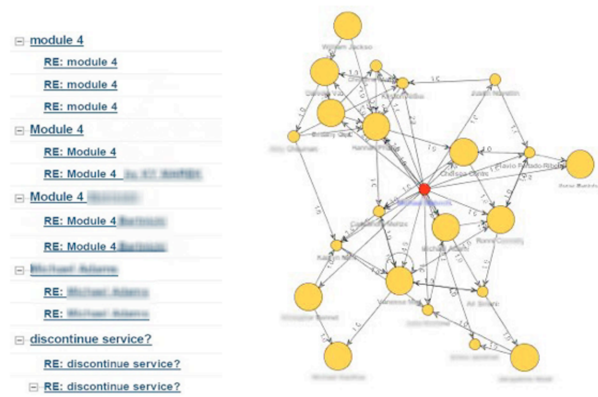

Fig. 1 Comparison of Blackboard 9.1 "tree view" vs. SNAPP-generated social network diagram.

Social network diagrams generated by SNAPP currently show only patterns and levels of interaction among discussion members; they do not include information related to the content of discussions. Therefore, one cannot discern the overall quality of discussions with the use of the SNAPP tool alone. However, SNAPP diagrams and metrics can illustrate certain characteristics of interaction, which can assist in design of interventions to improve discussions. For example, instructors can quickly determine students who are not actively involved and can identify poorly-developing discussion communities (Figure 2). Instructors can also see students who students who are centrally-located in discussions and correspond with many of their classmates. Early notification of this might lead an instructor to use such information to form more effective groups for later project work. Perhaps most importantly, the diagrams can prompt instructors to adjust design characteristics such as the question prompt or protocols, which can greatly improve resulting discussion quality.

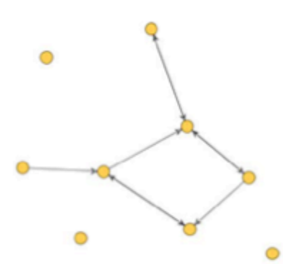

Fig. 2 Diagram showing poorly developing learning community, with students disconnected from the discussion.

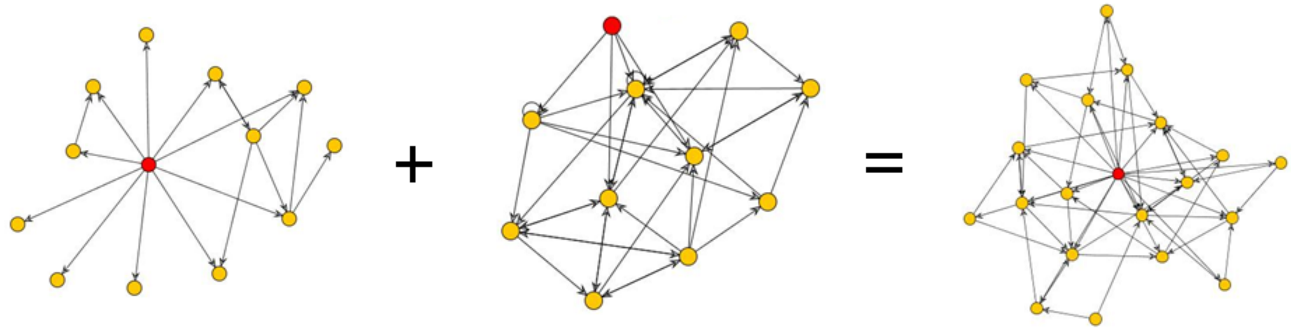

Fig. 3 Combining Instructor-Led (left) and Learning Community (middle) patterns yields Learning Community with Strong Instructor Presence pattern (right).

This paper presents a pilot investigation of a design aid and process intended to assist instructors in using social network diagrams to improve discussion design and facilitation.

II. Research Goals

This study focuses on two key challenges faculty encounter when using the SNAPP tool independently. Instructors have difficulty in interpreting social network diagrams and in designing interventions to improve the design or facilitation of discussions when suboptimal interaction patterns are identified. To investigate how to improve use of SNAPP, a process to address these two challenges was developed and piloted.

In a recent study focusing on the use of the SNAPP tool by instructors in higher education, Dawson et al [3] identified a need for professional development in the interpretation of social network diagrams, the design of interventions when problematic patterns emerge, and the redesign of collaborative learning activities. Their work also showed that instructors used the diagrams in a primarily reflective manner, looking back on discussion interaction after courses have ended, rather than using it to adjust learning activities while they were occurring.

III. Defining the Visual taxonomy

A visual taxonomy of social network diagrams for online discussions should aid faculty in identifying interaction patterns through comparison of their courses' discussion patterns to a set of standard patterns. In order to define a visual taxonomy, fifteen courses were reviewed at random to determine if specific patterns could be identified. Those patterns were then compared to patterns identified by Dawson [3]. Three of the patterns were in agreement with those findings and two additional, unique patterns were identified. Several patterns were combinations of other patterns, resulting in a total of six.

There are two basic patterns that can be conceptualized as either a continuum or a combination of patterns based on a few social network metrics. First, centralization is defined as the extent to which a network revolves around a single node, or in the case of online discourse, a single discussion participant. We termed a pattern in which a facilitator is clearly the most central person in a network, with little interaction among students *Instructor-Led*. Discussions that involve most or all participants have a relatively even distribution of participants interacting with one another, while the instructor is only peripherally involved. We termed this a *Learning Community*. When a discussion with a Learning Community pattern includes the instructor with the highest centrality of all participants, we have identified this pattern as a *Learning Community with Strong Instructor Presence*. Figure 3 shows how three patterns are related to the concept of centrality of the instructor or facilitator (instructor is in red).

A second pattern is delineated by the degree to which all participants are interacting with each other, which is manifested by the social network metric "average centrality." Lower average centrality is congruent with a more equal distribution of interaction (see Learning Community in Figure 4). In some discussions, learners are loosely connected or not connected at all to other students. For example, students who have posted but to whom others have not responded can be seen as disconnected nodes in the left-most diagram of Figure 4. The degree to which learners are interconnected can be seen as a continuum. In Figure 4, three visuals have been used to represent this continuum: *Weak Learning Community, Emerging Learning Community,* and *Learning Community.*

The Emerging Learning Community Pattern identified in this study (Figure 4) is supported by work in network analysis theory; Borgatti [2] originally formalized an intuitive, idealized "core-periphery" network pattern. Additional patterns identified in this study were combinations of Instructor-Led patterns and Learning Community and Emerging Learning Community patterns.

IV. Pilot Research design

Three instructors were selected for inclusion in a pilot study, and their permission was obtained to review discussion data from one or more of their courses. A visual report of patterns was also created for each discussion. For each discussion, the SNAPP diagram was juxtaposed against the associated question prompt, arguably the most important design component of a discussion. Both the visual patterns and the discussion content were also examined in detail, and several potential interventions for each instructor and course were

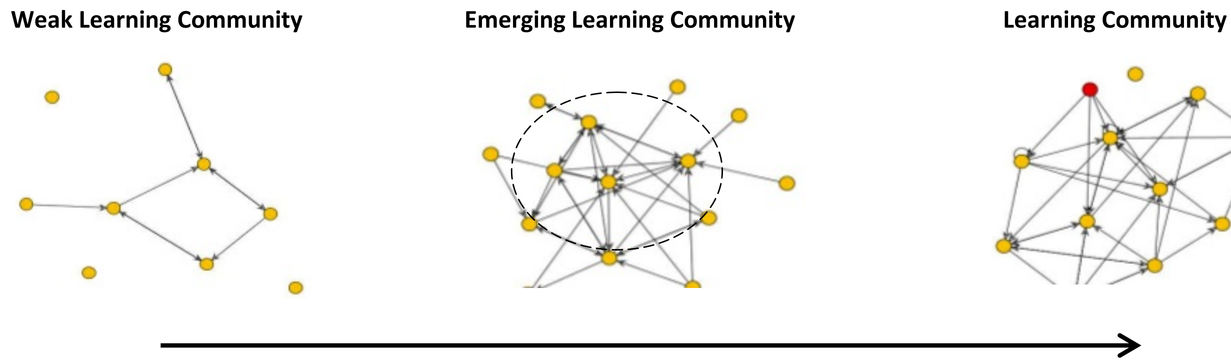

Fig. 4 Continuum showing degree to which participants are interacting.

devised. In addition, all design and facilitation features of all discussions were noted. Because question prompts were identified as the most important design feature, each was coded with one of the six levels of Bloom's cognitive levels to aid in potential intervention suggestions. Research has shown that question prompts at higher cognitive levels correlate with higher levels of discourse [8]. In a study examining the relationships among question types and students' subsequent interactions, Ertmer et al [5] used a similar approach to coding discussion prompts.

Instructors were then sent the visual key of patterns and the report showing patterns from each of their discussion boards juxtaposed with each respective question prompt. In discussions with each instructor, the SNAPP visual key of diagram patterns was explained in terms of what information from diagrams might reveal about learner interactions, and how such information could be used to improve discussion design. A brief set of questions that focused on instructors' goals, satisfaction levels, and challenges were used as a guide to the discussions. Finally, potential interventions for redesign of discussion activities were discussed. Intervention suggestions ranged from very simple organizational changes in discussion structure to more significant adjustments in discussion design or facilitation.

V. Results

The three instructors described below had extensive experience teaching online. Their names have been fictionalized and modified to protect identities.

Instructor Matson: Undergraduate business: Her discussions were focused on mini-scenarios at Bloom's cognitive level of application. Her facilitation consisted of brief postings including agreeing or disagreeing with students, redirecting, giving confirmation, and asking questions. Students rarely followed up on her queries. There was little to no feedback at the end of each discussion. Her postings comprised 25-30% of total number of posts. Course discussions were very consistent in terms of interaction pattern (Learning Community with Strong Instructor Presence) and numbers of posts by students and the instructor. The instructor noted the consistency of her social network diagrams and seemed pleased with this result, as well as the overall interaction pattern illustrating consistent involvement by all students. The key intervention suggestion centered on shifting to a less involved facilitation strategy during discussions and a more involved strategy after them (via a summary feedback announcement). We thought this would yield a benefit of reducing her workload while maintaining or even increasing student engagement. We also suggested increasing the level of difficulty of the scenarios, which might improve cognitive engagement with course concepts.

Instructor Hinson: Graduate education: His discussions covered a broad range of questions types, but most were on the lower cognitive level of Bloom's taxonomy. Student participation varied widely, depending upon the question type and topic. There was very low level of participation by the instructor, perhaps fitting with the facilitation philosophy of an instructor with a background in education. Feedback was primarily given after discussion completion. Discussion visual patterns also varied broadly. The instructor felt the SNAPP tool had great promise for helping with identification of participation patterns. He quickly determined that diagrams showing high levels of interaction did not necessarily indicate high-quality interaction. Nevertheless, he showed a strong interest in using the tool immediately for potential interventions. The diagrams showing weaker patterns particularly caught his interest and initiated a discussion that included ideas around alternative tools for some current discussions, as well as potential adjustments to discussion design features.

Instructor Paulson: Undergraduate business: His question prompts were at higher levels of Bloom's cognitive domain, and student participation was quite robust. Because his discussion activities were focused on simulations of negotiations (essentially role plays), followed by reflective discussions taking the form of self and peer assessment of those simulations, the format of the discussions was very clear and focused. The instructor's participation was minimal and occurred only in the reflective discussions, while feedback was primarily given after discussions. Discussion diagrams were primarily Learning Community patterns. The instructor felt that SNAPP could be particularly useful for identifying disengaged learners and students playing the role of Information broker early in the course. Given that his course used discussions for pair and group work, this function of SNAPP seems important for this course.

VI. Conclusion

This paper intended to show how a learning analytics tool can be used to improve discussion design and facilitation with the use of visual aids and an interview/discussion process. Two of the three instructors committed to using SNAPP in future teaching. For these instructors, the visual aids seemed to impact their view of the effectiveness of their discussions. However, instructor Matson seemed unlikely to adjust her design or facilitation. Her pedagogical philosophy was supported by the (instructor-centered) interaction patterns, which could prevent adjustments that may enhance her discussions. Future plans for use of visual aids described in this study include using them as part of a "post-facilitation" review process, which is an existing course design step that follows an instructor's first facilitation of a new online course. The purpose of this process is to review the design and facilitation of a course to determine how the course might be improved. The use of visuals at this juncture may prove the most potentially impactful point at which to focus attention on discussion design and facilitation.

References

[1] R. Aviv, "Network analysis of knowledge construction in asynchronous learning networks", *Journal of Asynchronous Learning Networks*, vol. 7, no. 3, Sept. 2003.

[2] S.Borgatti, and M. Everett, "Models of core/periphery structures," *Social Networks*, vol. 21, no. 4, pp. 375-395, Oct. 2000.

[3] S. Dawson, A. Bakharia, L. Lockyer, and E. Heathcote, "Seeing' Networks: Visualising and evaluating student learning networks," Australian Learning and Teaching Council, Canberra, Australia. 2011.

[4] B. De Wever, T. Schellens, M. Valeck, M., and H. Van Keer, "Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review," *Computers & Education*, vol. 46, pp. 6–28, Jan.2006.

[5] P. Ertmer, A. Sadaf, and D. Ertmer, "Student-content interactions in online courses: The role of question prompts in facilitating higher-level engagement with course content," *Journal of Computing in Higher Education*, vol. 23, no. 2-3, pp.157-186, Dec. 2011.

[6] F. Fischer, I. Kollar, K. Stegmann, and C. Wecker, "Toward a script theory of guidance in computer-supported collaborative learning," *Educational Psychologist*, vol. 48, no.1, pp.56-66, Jan. 2013.

[7] H. Kanuka, L. Rourke, and E. Laflamme, "The influence of instructional methods on the quality of online discussion," *British Journal of Educational Technology*, vol. 38, no.2, pp.260-271, June 2006.

[8] K. Meyer, "Evaluating online discussions: Four different frames of analysis," *Journal of Asynchronous Networks*, vol. 8, no.), pp. 101–114, 2004.

[9] J.L. Moore, R.M. Marra, "A comparative analysis of online discussion participation protocols," *Journal of Research on Technology in Education,* vol. 38, No. 2. p 191-212, Dec. 2005.

[10] J. C. Richardson, J. C. and P. Ice, "Investigation students' level of thinking across instructional strategies in online discussions," *Internet and Higher Education*, vol.13, no. 1-2, pp. 52–59, 2010.

[11] L. Rourke and T. Anderson, "Using peer teams to lead online discussions," *Journal of Interactive Media in Education*, vol.1, pp.1-21, 2002.

[12] A. Weinberger, I. Kollar, Y. Dimitriadis, K. Makitalo-Siegal, and F. Fischer, "Computer-supported collaboration scripts," in Scripting Computer-Supported Collaborative Learning, chapter 12, F. Fischer, I. Kollar, H. Mandl, and J. M. Haake, Eds., 2007.

[13] J. M. Zydney, A. deNoyelles, and K. Kyeong-Ju Seo, "Creating a community of inquiry in online environments: An exploratory study on the effect of a protocol on interactions within asynchronous discussions," *Computers & Education*, vol. 5, no.1, pp. 77–87, Jan. 2012

Why Learning Analytics for Primary Education Matters!

Martin Ebner and Martin Schön, *Social Learning, Graz University of Technology*

***Abstract*—The ubiquitous availability of applications enables us to offer students opportunities to test and train competences in almost every situation. At Graz University of Technolgy two apps for testing competences in multiplication are developed. They estimate the competence level of every user and adapt to their individual development in this domain. They collect a lot of data during a longer period, which could be used on further research. In the foreground they give feedback in a compact and clearly arranged way to the single student and the teachers of classes. But furthermore the analysis of the data during a longer term showed us, that the process of testing and giving feedback has also an positive effect on learning. We emphasize that this quality in supporting the students could not be achieved by human teachers. Information Technology and Learning Analytics gives them a wider radius to perceive specific behavior and establishes their capacity for storing and processing all the relevant data.**

***Index Terms*— Electronic learning, intelligent tutor, multiplication tables, Learning Analytics**

I. Introduction

LEARNING analytics is an increasing research topic in the field of Technology Enhanced Learning (TEL) and became international popular since the Horizon Report 2012 described it as a forthcoming trend [1]. Phil Long and George Siemens stated [2] that "the most dramatic factor shaping the future of higher education is something that we can't actually touch or see: big data and analytics". But even before the first Personal Computer (PC) had been introduced to classrooms, educational researchers attempted to realize an Intelligent Tutoring System (ITS) to assist children in their daily learning processes. This first attempts and all the further ongoing work is nowadays described as Educational Data Mining (EDM) which has a long research tradition [3]. Romero and Ventura [3] pointed out that Learning Analytics (LA) is a part of EDM whether this is not clear in the current debate. Nevertheless the most important research question in respect to LA seems to be: What exactly should be measured to get a deeper understanding of how learning takes place [4]?

LA depends on the growing possibilities to generate data about each single learner, to combine these date with learning activities in accordance with didactical instructions. With other words LA strongly relates to the context, to the so-called learning behavior. Lotze & Tatzal [5] mentioned that LA helps us to understand learning more deeply.

George Siemens is looking for additional information through big learning data to predict learning success [6]. He also pointed out that not the models of analyses are important, but the whole process. LA is also related to interventions by teachers, the adaption of learning instructions, or the predication of learning success as well as social connections. LA can be differentiated from the primarily EDM due to the fact that LA is more than just interpreting data and related automatic processes. It is the assistance of instructors, teachers, and lecturers with appropriate data to enhance the learning behaviors of each single learner – individualized and personalized.

Schön et al. [7] defined LA as interpretation of big learning data to enhance the individual learning process.

Martin Ebner is with the department Social Learning at Computer and Information Services at Graz University of Technology, 8010 Graz Austria (corresponding author; phone: +43 316 8738540; e-mail: martin.ebner@ tugraz.at).

Martin Schön is with the department Social Learning at Computer and Information Services at Graz University of Technology, 8010 Graz Austria (e-mail: martin.schoen@tugraz.at).

II. Learning Math in Primary Schools

A. General Overview

In this publication we want to show that research work concerning LA is interesting and also already necessary for education in primary schools. Personal computers are available in most of our classrooms. Now we can recognize that more and more students have smartphones and pads/tablets to use internet based applications [8]. It seems obvious that the ubiquitous integration of mobile devices with stable Internet connection is just a matter of time. Therefore Graz University of Technology (TU Graz) began to take care about related research in the field of mobile learning and Learning Analytics especially for the youngest school children. The very first approach is about learning math due to the fact that the number of problems is limited.

The research question we address in this work is how can LA be helpful for learning math in primary education? In our case the implementation concentrated on learning the multiplication table and multi-digit multiplication.

B. Theoretical Background

Nowadays lot of effort is put on the development of software to improve practicing the multiplication tables for school children. As a result of our concept phase in the beginning of the project teachers characterize "learning the multiplication table" is an enduring core problem of the first school years. Furthermore, wrong calculations of single multiplications are often the cause to further problems in the next step of basic mathematics, for example, multi-digit multiplication.

After a first interview about the quantitative extent of the problem teachers were only able to give approximate and exemplary information about the skills of their pupils. One of the most announced phrases were: “There is one, who is very good .... and another ....”.

Learning the multiplication table seems to be a very simple problem in the beginning, because there are only 10 times 10 problems, which children have to memorize. The competence to produce results is finally not a general competence that delivers results with a random error. Due to the fact that the result of each problem has to be known, the training situation differs arbitrarily from those that are well researched using intelligent tutoring systems (ITS) and predictions of a certain level of knowledge. Furthermore, there is also a lack of knowledge about the way individuals learn the multiplication table best. Of course, there are different methods to solve the problem for each of us. Sometimes fingers play a role or similar other tricks. But the general recipe for learning the tables is still “drill & practice”.

It can be summarized that it is of high importance that every single of the hundred multiplications should be done by each learner reliable. From this perspective, it becomes an information-processing task for the teacher to attend them adequately. The teacher for example has to decide, whether the child meets the competence to begin with the multi-digit multiplication or the child may work as a reliable tutor for other students.

C. Pedagogical Approach

Multiplication tables seem to be mainly a problem of drill & practice. Considering current didactical knowledge about learning math it can be pointed out, that some of the basic knowledge about mathematics is acquired even before children start school. As one reason there are cultural differences, some obviously based on language implications [9]. Each child needs a general linguistic competence before starting to operate with numbers. Some publications point out that mathematic is even the first non-native language [10]. Understanding the expression “multiply” is implicit not only a mathematical problem but also a linguistic one. Many children who carry out the algorithms correctly do not really understand reasons for crucial aspects of the procedure [10].

From the perspective of special education it is well-researched that learning as well as teaching math only by memorizing results is problematic and leads to disorders and blockades on the learner side. According to current neurological oriented research results, but also based on a very old educational tradition, teaching should use tactile, optical and acoustic processing methods in every single case – even more intensive when we observe anomaly from the mainstream. It is important to allow math to be taught in a multisensory way to children with special educational needs. Kendall [11] offers some practical suggestions how to achieve this. But the daily experiences are dominated by pure “row learning” of the multiplication table [12].

Bearing in mind that the competence “perfect handling the multiplication table” differs arbitrarily from required learning time and learning effort; it seems obviously that the simple problems “learning the multiplication table” is not as trivial as it seems to be on the first glance. The goal of our research work was to develop a web based intelligent system for testing and perhaps training the multiplication table that is accessible from any web browser to assist learners as well as teachers.

Furthermore, it should provide teachers a quick overview about the current learning process of their pupils. Our research group, consisting of educators, e-learning experts, educational scientists, and IT-developers specified the requirements beforehand as follows:

- The system should estimate the competence grade of the learner
- The system should record and store data of all done exercises, test results and the current competence grade of the learner in order to prepare the next sessions in an adequate way. The goal is to generate a complete table to inform learners as well as teachers about their competence in every single task, actually about every single multiplication fact
- The system should provide appropriate tasks according to the competence grade of the learner.
- The system should ensure that already well-done exercises are repeated and practiced continuously. After succeeding a problem the probability for a repeated display should decrease in two levels as already suggested by the well-known “Leitner system”.
- In general the system should be motivating and show that learning can be fun. Nevertheless the tasks should tend to be challenging.
- Thereby it should unburden the teachers from any administrative tasks.
- From a technical perspective the system should run on the web and on many different clients. Therefore the script language PHP and a MYSQL database were chosen. Furthermore native applications for iOS devices (iPhone, iPad) and Android were developed.

III. Some Simple Examples

A. General Remarks

In respect to LA, web-based applications should be programmed in order to enhance the individual learning behavior of each single child. From a technical perspective this program (trainer) should be available from anywhere with any device. Therefore a web-based solution was chosen with a so-called API, which allows mobile devices to have access too. Furthermore, each single calculation is stored in the database for an individual evaluation of each learner.

B. Multiplication Table

First of all it is important to mention, that the web-based application works with an intelligent algorithm for choosing the next question; due to the fact that a too easy question bores learners and a too difficult one demotivates them to go on.

Therefore different categories or areas were introduced. A random number between 0 and 1 is chosen to decide which category is activated to generate the next multiplication problem. Three different possible cases are defined:

- Case 1: If the random number (x) is smaller or equal 0.05 than a well-known question marked with 2 is chosen.
- Case 2: The random number is 0.05 > x >= 0.15 than a known question marked with 1 is chosen.
- Case 3: The random number is x > 0.15 than a (unknown) question out of the extended and actual learning area is chosen.

The extended area follows the idea that not only items of the learning area are chosen, but also items exceeding the level of competence (0.15).

Finally data of already done calculations are used for adjusting the competence level from the estimation at the beginning.

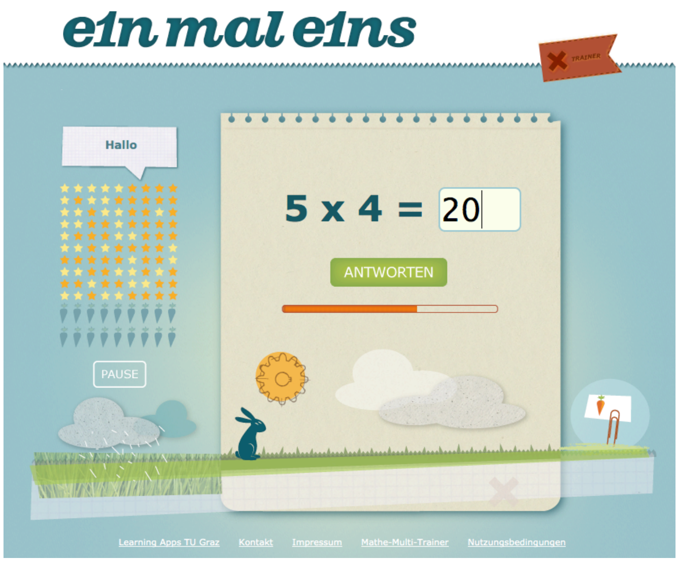

Fig. 1 Screenshot of the multiplication trainer (http://mathe.tugraz.at)

Fig. 1 shows the main screen of the trainer. A problem is presented which has to be solved within a defined time frame. On the left side each already correctly solved problem is shown (yellow = well known; orange = known).

Multi-digit Multiplication [14]

In a very similar way a web-based application has been built that should assist learning multi-digit multiplication:

1. an overall learning algorithm that sets the difficulty for multiplications adaptively and independently for each user,
2. the generation of multiplications of a specific category (of difficulty),
3. the analysis/evaluation of the results of the generated and displayed multiplications (= user inputs), categorization of the detailed results (multiplication, addition alignment).

In respect to EDM the learning application has to adapt to the current user's expertise in multi-digit multiplication knowledge. To do so, we defined a hierarchy of multiplication problems that differ in difficulty. Another main objective of the algorithm for generation multiplication problems is to offer a large variety of examples at the same time. On the basis of [13] we distinguished eight different problem groups of multi-digit multiplication. The overall domain of definition includes multiplicands (left factor) with 2 to 4 digits and multipliers (right factor) starting from 1 up to 3 digits in size. Beside these categories of difficulty, the concept of written addition and multiplication includes another dimension: the carry. In our application simple multiplications without carry and multiplications including a carry are separated.

Fig. 2 Main screen of the multi-digit trainer (http://mathe.tugraz.at)

Fig 2 shows a screenshot of the final trainer. A problem is presented and each learner has to fill in the given fields.

IV. Discussion

In order to analyze the data in respect to LA a user-management was introduced that not only allows children and teacher to register, but also to define schools and classes as well. This means that an instructor can see the results of a single child, the class or his/her school.

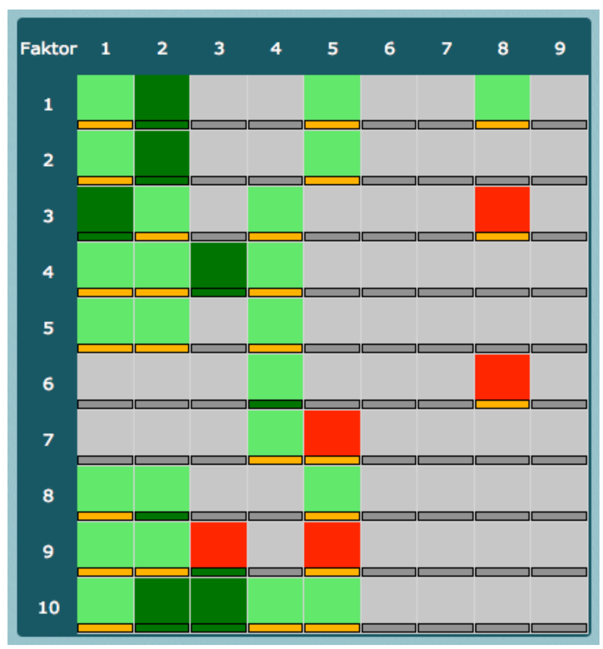

Fig. 3 Analyses of one single child (http://mathe.tugraz.at)

Due to the fact that each single calculation is stored in the database it is easy imaginable that the interpretation of the data of just one single child needs arbitrarily time. So there is an urgent need for a first fast overview, that enables teachers to decide quickly, whether they have to intervene or not. Therefore a simple visualization was chosen. A table of all calculations is visualized overlaid with four colors (see Fig 3). Dark green marks “well-known” calculations, light green marks “known”, red that is unknown and grey that the calculation was not done yet. With the help of this traffic light scheme teachers can see in seconds how well each child performs and which specific action of the teacher may be needed. With other words, for the first time it is possible to determine exactly for each child it´s problems with the multiplication tables.

During a longer period we can state for most of the cases an increase of the student´s competences. For some students these apps are not a real problem. They just are getting perfect by correcting some problems with single multiplications. For many others we observed a development – learning.

Fig. 4 shows for example the increasing learning rate of one single child. In the very first beginning only about the first 20% of the multiplication table are well-known. Following a longer time period with no real increasing success. Finally after about 300-presented examples the number of right solutions increased arbitrarily. So it can be assumed that a learning process occurred perhaps because a teacher gives important instructions to help this child.

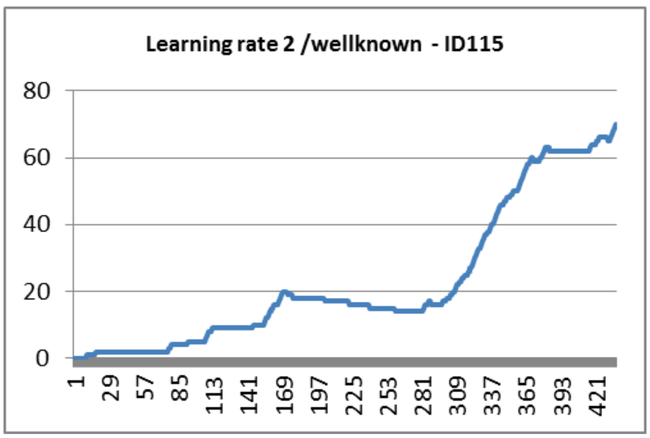

Fig. 4 Level of competence of one student along the test period

V. Conclusion

LA brings new insights into the classroom. For the first time we are able to observe in an economical way single steps and solutions of every child during a longer period. We started with the expectance to improve the diagnostic of some problems with the multiplication table and multi-digit multiplications. Our results show: automated precise testing and feedback can be seen as an individual assistance and an effort to an effective learning process.

It is remarkable that normal teachers don´t have enough capacity in perception and mind to realize a similar competence in classrooms. This is so to say a unique feature of this application for LA.

Our future works will not only focus on math, but also on first attempts in language education. For example, currently a trainer is implemented to measure the reading competences of school children. We see that behind the holistic perception of a child´s reading competence there are some simple partial competences which could be observed, measured and perhaps trained without appreciable investments – and without additional stresses and strains for the teachers.

Finally we like to summarize that Learning Analytics is an important step to give the learners precise feedback and shows how teaching of tomorrow can support and promote each individual learner exactly at the state needed.

References

[1] Johnson, L., Adams, S., and Cummins, M. (2012). The NMC Horizon Report: 2012 Higher Education Edition. Austin, Texas: The New Media Consortium. http://www.nmc.org/pdf/2012-horizon-report-HE.pdf (last accessed: March 2013)

[2] Long, P., Siemens, G. (2011). Penetrating the Fog: Analytics in Learning and Education. *EDUCAUSE Review Magazine.* Volume 46. 5. p. 31-40. http://www.educause.edu/EDUCAUSE+Review/EDUCAUSEReviewMagazineV olume46/PenetratingtheFogAnalyticsin Le/235017 (last accessed March 2013)

[3] Romero, C., Ventura, S. (2010). Educational Data Mining: A Review of the State of the Art. IEE Transactions on Systems, Man, and Cybernetics – Part C. Applications and Reviews. Vol 40. N. 6. P. 601-618

[4] Duval, E. (2010). Attention Please! Learning Analytics for Visualization and Recommendation. To appear in: Proceedings of LAK11: 1st International Conference on Learning Analytics and Knowledge 2011. https://lirias.kuleuven.be/bitstream/123456789/315113/1/la2.pdf (last accessed March 2013)

[5] T. Lotze A. Bader-Natal. Evolving a learning analytics platform. 1st International Conference on Learning Analytics and Knowledge 2011; The Technology Enhanced Knowledge Research Institute, Athabasca University, Canada. 1, 4, 5

[6] G. Siemens. What are Learning Analytics?, August 2010. http://www.elearnspace.org/blog/2010/08/25/what-are-learning-analytics/ (last accessed March 2013)

[7] Schön, M., Ebner, M., Kothmeier, G. (2012) It's Just About Learning the Multiplication Table, In Proceedings of the 2nd International Conference on Learning Analytics and Knowledge (LAK '12), Simon Buckingham Shum, Dragan Gasevic, and Rebecca Ferguson (Eds.). ACM, New York, NY, USA, 73-81

[8] Ebner, M., Nagler, W. & Schön, M. (2012). Have They Changed? Five Years of Survey on Academic Net-Generation. In *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2012* (pp. 343-353). Chesapeake, VA: AACE

[9] Fuson, K.C. (1990) Using a base-ten blocks learning/teaching approach for first- and second- grade- place-value and multidigit addition and subtraction . In: Journal for Research in Mathematics Education. 21, No. 3, 180-206 Northwestern University

[10] Gerster, H.D. (2009) Schwierigkeiten bei der Entwicklung arithmetischer Konzepte im Zahlenraum bis 100.- In: Rechenschwäche. Lernwege, Schwierigkeiten und Hilfen bei Dyskalkulie. Fritz, A., Ricken, G., Schmidt, S. (Ed.)- Weinheim, Basel, Berlin: Beltz, p 248–268.

[11] Kendall, J. (2008) Multisensory maths for teaching SEN, http://www.teachingexpertise.com/articles/multisensory-maths-teaching-sen-5209 (last accessed March 2013)

[12] Landerl, K., Butterworth, B., Lorenz, J.H., and Möderl, K. (2003) Rechenschwäche - Rechenstörung - Dyskalkulie: Erkennung - Prävention – Förderung, Leykam, Graz.

[13] Gerber, M. M., Semmel, D. S. and Semmel, M. I. Computer- Based Dynamic Assessment of Multidigit Multiplication. Exceptional Children 61 (1994). 114-125.

[14] Ebner, M., Schön, M., Taraghi, B., Steyrer, M. (2013) Teachers Little Helper: Multi-Math-Coach, IADIS International Conference e-Learning, Prague 2013, accepted, in print

PBL in Programming Subjects at Engineering

A. J. Sierra, T. Ariza, F. J. Fernández

***Abstract*—This paper presents the PBL learning methodology applied to the subject of Programming in Engineering. We show two different perspectives, teacher and student. First, the point of view of the teacher considers the design of the project, and secondly student that considers its implementation.**

***Index Terms*—Communication engineering education (Engineering education), Computer science education, Engineering students. Programming (Computers and information processing), Problem- and Project-based learning**

I. Introduction

SINCE 2010 the Department of Telematics Engineering in the University of Seville, subjects are taught in the new DTTE (Degree in Telecommunication Technology Engineering), to converge with the EHEA (European Higher Education Area) recommendations. This is an ambitious and complex plan launched to promote European convergence in education. The foundation of EHEA is based on student's work and laboratories are essential to develop theoretical content and implement abilities in a larger scale work.

Programming content is taught in two subjects in the first course: Fundamental of Programming I (FPI) and Fundamental of Programming II (FPII). The purpose of these subjects is to establish the principles of computer programming.

FPI is a term core subject at the first-year of DTTE. This subject consists of 6 ECTS (3 ECTS credits are lectures and 3 ECTS credits are practical classes).

FPII is a term core subject at the first-year of DTTE. This subject consists of 6 ECTS (1.5 ECTS credits lectures and 4.5 ECTS credits are practical classes). This subject has a high practical content. The methodologies used for the acquisition of knowledge are the following: lectures, laboratory practices, and Active use of e-learning technologies.

Every student must complete a course project that will consist of developing an application, that consist of developing an application, comprising the steps of understanding the problem, designing of the program, coding it in C and subsequent testing. Furthermore, every student must complete another course project that will consist of developing an application, comprising the steps of understanding the problem, designing of the program, coding it in Java and subsequent testing.

Manuscript received Mars 30, 2013. This work was supported in part by the Department of Telematics Engineering in the School of Engineering at University of Seville.

J. Sierra, T. Ariza and F. J. Fernández are with the Department of Telematics Engineering in the School of Engineering at University of Seville, C/ Camino de los descubrimientos s/n, 41092, Seville, Spain (phone: 349-448-7384; fax: 349-448-7385; e-mail: {antonio, teresa, fjfj}@ trajano.us.es).

Project and problem-based learning (PBL) are perhaps the most innovative instructional method conceived and implemented in education, and has been widely recognised as an active, collaborative, cumulative and integrative learning approach that engages learners, motivates team creativity and centers on practical education. It aims to enhance students' application of knowledge, problem solving skills, higher-order thinking, and self-directed learning skills.

This instructional method has been successfully applied in different educational disciplines. Hung[8] builds on the 3C3R problem design model, a 9-step problem design process. This model does not fit the design of projects in programming courses, due to the complexity associated with software project.

We propose a new model, based on the 9-step of the 3C3R model, to design the project for the programming in FPII.

This paper is organized as follows, first we present the PBL in programming labs, where we shows both, a review state in PBL, and the context in the programming's subject. Second, we present how to design the project. Then, we show the project implementation, and finally conclusions.

II. Project-Based Learning in Programming Labs

A. Review Stage in PBL

PBL was originally conceived and implemented in response to students' unsatisfactory clinical performance [3] resulting from the emphasis on memorization of fragmented biomedical knowledge in traditional health science education.

The widely adopted format of PBL was first developed in medical education at McMaster University in the 60s and 70s [3]. Since its first implementation, PBL has become a prominent instructional method in medical and health science education throughout the world.

With the positive results from implementing PBL in medical education, PBL has also been embraced by other disciplines in higher education, such as architecture [10], law schools [12], leadership education [5], nursing [4], and teacher education [9], science courses [1], biochemistry [11], calculus [14], chemistry [2], economics [7], geology [18], and psychology [13].

Hung[8] builds on the 3C3R problem design model, which is a systematic conceptual framework for guiding the design of effective and reliable problems for PBL. To help practitioners apply the 3C3R model, this model introduces a 9-step problem design process.

This model to design problems (in 9 steps 3c3r) proposed by Hung does not comply with design of projects in programming courses because of the complexity associated with software project. Our design model for the programming project is based on Hung. We have adapted the Hung's model to consider the specific characteristics of a software project.

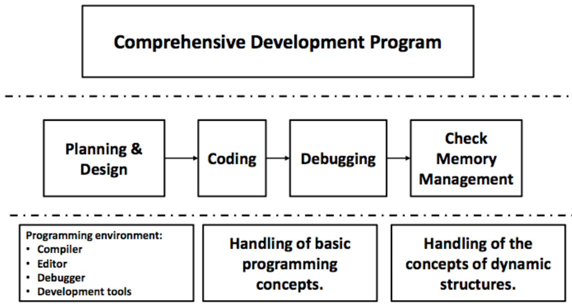

Fig. 1. Link content to project tasks

B. Context in the Programming's subject

The programming courses usually require practice and projects to assimilate knowledge by the student. Therefore, since many years, this course introduced the PBL model. The skill of this subject is taught through guided practice where the student has to deliver different types of exercises related. The practices involve training the skills required to develop a larger software project. A student must develop a software project that requires a series of tasks to perform (which has not faced ever). All possible implementations can be different and all potentially valid, but must meet certain requirements. Software engineering has made a series of development phases of a project. The proposed project develops the concepts and content of structured programming. The topic and structure must meet the following aspects:

- **Contextualized:** The topic must be in the telecommunication context.
- **Real-world:** The project should be a case taken from the real world.
- **Ill-structured:** The problem must be of adequate size so it can be broken down into parts where required design criteria.

Typically, students in their implementation can be found with the following problems:

- **Poor structuring.** There is usually a trend to approach the project as "a whole", coding is performed with a complete program without structure, without modules.
- **Without running tests**. No validation is performed, or is performed testing the modules implemented, until the final stage of the project.

The teacher's job is to design a project ill-structured, appropriate to the student's knowledge, and to tutor in order to guide students in their development to achieve carry it out properly. The statement of the project should be complete, well specified, self-contained, real-world, drafting and design requires a series of steps very carefully developed to serve as a standard specification or project design. These design steps shown in the next section.

II. Designing the Project

This section presents the steps required to design a project in a programming course.

Step 1: *Set objectives and goals.*

In this step the objectives and goals of the course are specified. Both the depth and breadth of content are set and also skills the student should acquire by developing the project. In FP2, the main goal is to learn the basics of programming in an imperative language, such as acquire the necessary skills to manage dynamic structures.

Step 2: *Link content to project tasks*.

In this step how to get the learning objectives set in step 1 are decided. The objectives are broken down into tasks.

The knowledge goals set in step 1 will be achieved through the development of a software project, where the student must use basic concepts of structured programming and dynamic structures. This idea is shows in the following Fig. 1.

Paso 3: *Specify the context*.

In this step the following context are specified:

A. **Real-world context:**

This context refers to the general topic of the project. In fp2 is the context of telecommunications, since the subject belongs to the DTTE.

B. **Work context:**

This context refers to whether the work is individual or collective, the location where the project is developed and the platform that is used for communication between teacher and student.

In the case of the subject of FPII,

- The work is performed individually.
- The physical placement where students perform the project is in the data center and classrooms electrified in the school. This development can also be done at home, using a similar environment.
- To communicate teacher and student, WebCT platform is used.

C. **Programming Environment**.

In this context the programming language, the tools used for development, and virtualized environments are specified.

In order to develop the project in fp2, the C programming language, the gcc compiler, emacs and gedit editors are used. Besides, a virtual machine environment for the development of the project is provided, so that a student can develop your project anywhere.

Step 4: *Select/generate PBL problem.*

Step 3 determines the context of the project, determining the theme, location and environment where the problem will be developed. In this step 4 a specific problem is selected for achieving the targets set in step 1.

We have been developed a list of project, within the topic of telecommunication engineering. These problems are:

1. NAT: Network address translation
2. Packet Forwarding System.
3. Calculating the shortest path in a packet network.

Step 5: *Project affordance analysis and calibration.*

This step is an analysis to determine whether the proposed project is affordable, and a calibration that allows adjusting the concepts and skills needed to develop the project. This task includes the following steps:

A. **Understanding the actual operation of the system proposed**: The teacher develops the subject of the project to propose a particular situation. The functionality of the system must be defined to make it affordable for the student

B. **General description of the project**: Once the general topic of the project has been decided, a statement is described corresponding to the knowledge of the students who must carry out the project. This general description should describe:

- Concepts used in solving the problem.
- Principles used in the solution of the problem.
- Procedures used in the solution of the problem.
- Factual information necessary to solve the problem.

C. **Valuate the student's knowledge to address the project**. Here, that the student has acquired the necessary knowledge is verified, otherwise it must be provided in the statement. That the student has the skills to develop the project should also be analyzed. In case of lack of skills, teachers should guide development in these skills. This represents a calibration of the concepts and skills of the student to adjust to the required skills to develop the project.

D. **Detailed Description**. At this point a detailed description of the inputs and outputs must be made as concretely as possible and real examples must be given. This detailed description should include the necessary documentation to guide students in those tasks that in the previous section has detected some lack.

E. **Project implementation by teachers.** At this point the proposed project is implemented by teachers to assess different aspects. These aspects are the difficulty of the project, the breadth and depth of content, errors in the statement. This implementation helps detect details that have not been specified in the first statement.

The result of this analysis is a statement of a project that is affordable for students. It also allows having a working implementation of the project.

Step 6: *Correspondence analysis.*

It is evaluated at this point if the proposed project includes all the knowledge and skills that have aimed at point 1.

Step 7: *Documentation.*

The documentation that the student must submit is determined in this step.

Step 8: *Construction of a test suite.* This step is to build a test suite that includes all possible cases in the project. This test suite allows checking the correct functionality of the project in all cases included in the statement.

In FP2, several configuration files and input files that are consistent with the statement are constructed. They define the situation in which the system generates some kind of error.

Step 9: Enabling a mechanism for discussion.

It is necessary to determine a form of communication between teacher-student and student-student to resolve any questions about the statement, design, implementation and testing of the project.

En fp2, a través de WebCT un foro específico para el proyecto es habilitado.

Step 10: *Establishment of a mechanism for validation of the project***.** In this section, the teacher should provide students with a way to validate the project independently. That provides information in malfunction of the project.

A validation tool that runs the project with a series of tests designed is provided. This tool checks the correct operation of the project both outputs, outputs errors and memory leaks.

III. Project Implementation

Once the project has been designed by the teacher, the teacher must make known this project to students.

In this section a number of general recommendations are given on how to deploy the project to help as a guide to their development. It also lists a series of steps the student should take to undertake the development and recommendations for code comments.

A. General recommendations

The work should be carried out in an incremental manner through successive refinement. The implementation of this project represents a different challenge because, for the first time, the development of a complex program is proposed. It must be designed and implemented individually; therefore, the solution is unique for each student.

The solution should be focused so as to follow these basic and interrelated principles:

- Simplicity: keep short, manageable programs.
- Clarity: it guarantees that are easy to understand for people.
- Generality: working well in a wide range of situations.

The following are general recommendations for addressing the problem solution:

- Review concepts already acquired of programming (control structures, files, data types, compilation and debugging tools, etc.).
- Start with the most basic.
- Follow a consistent style for indentation of the code and for naming variables and functions.
- Comment and document the code properly.
- Always choose the simplest solution.
- Be organized and structured.
- The better the code and documentation, more easily possible errors are detected and corrected.

B. Steps to develop the program that the student must perform

Following are a number of steps the student must follow to develop the project:

Step 1. *Understanding the problem to solve.* Understand the system to be implemented.

- Comprehensive reading of the statement and the problem proposed.
- Identification of the context and the different basic elements involved in the problem.

Step 2. *Problem analysis and decomposition into smaller parts (Divide and Conquer).*

Analysis and selection of the components needed to implement the solution:

- Data to be handled by the program.
- Tasks to be performed by the program.

Step 3. *Design of system components.*

In the next step, each of the features of the program has to be developed. To do this:

- In this step student makes a proposal estructures data that the program uses. The choice of these structures determine the remaining implementation.
- Perform the tasks in functions. Each function, determines a name, inputs and outputs.

- Documentation of the design. Student describe in this step it implementation.

Step 4. *Search for alternative solutions.*

Evaluate the alternatives in terms of simplicity, clarity and optimization of resources (memory, runtime).

Step 5. *Coding different parts.*

- Define the data structures in the programming language.
- Split code in files, organizing it coherently based on logic and functional grouping.
- Coding and independent verification of each part (function).

For each part to implement, perform the following steps:

- Coding.
- Documentation of the code.
- Evaluation of the complexity of the code.
- Test, independently, the correct operation of this part. Check borderline cases.
- Integration with the rest of the code.
- Test with the rest of the code.
- Reasoning of whether the implementation of the code can be improved.

Step 6. *Full System Test.*

Student should develop the tests needed to prove the satisfactory performance of the program implemented, including the limiting cases.

Step 7. *Project Report*.

Production of the report of the program, according to the rules.

C. Recommendations for code comments

The purpose of comments is to help the reader of a program. The best comments aid the understanding of a program with a brief indication of the important details, or offering a broader perspective on the code. The code comments should be written following these recommendations:

- Do not repeat what is already obvious.
- Discuss the functions and data types.
- Do not comment bad code. Rewrite it!
- Do not contradict the code.

Comments are usefull to understand parts of the program. The better you do the code, less comments are necessary.

IV. Conclusion

In this paper we are shown the PBL learning methodology applied to the subject of Programming in Engineering. Shown are two views, teacher and student. First, the point of view of the teacher considers the design of the project, and secondly student that considers its implementation.

Acknowledgment

The authors would like to thank to all teachers of the both courses (FPI and FPII) Rafael Bachiller Soler, Isabel Román Martínez, Antonio José Estepa Alonso, Rafael Estepa Alonso, José Manuel Fornés Rumbao, José Ángel Gómez Argudo, Fernando Cárdenas Fernández, Pablo Nebrera Herrera, Godofredo Fernández Requena, Juan Manuel Vozmediano Torres, Antonio Luis Delgado González, and Germán Madinabeitia Luque. These results would not have been possible without their dedication.

References

[1] Allen, D. E., Duch, B. J., & Groh, S. E. (1996). The power of problem-based learning in teaching introductory science course. In L. Wilkerson &W. H. Gijselaers (Eds.), Bringing problem-based learning into higher education: Theory and practice. San Francisco, CA: Jossey-Bass.

[2] Barak, M., & Dori, Y. J. (2005). Enhancing undergraduate students' chemistry understanding through project-based learning in an IT environment. Science Education, 89(1), 117–139.

[3] Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. New Direction for Teaching and Learning, 68, 3–12.

[4] Barnard, A., Nash, R., & O'Brien, M. (2005). Information literacy: Developing lifelong skills through nursing education. Journal of Nursing Education, 44(11), 505–510.

[5] Cunningham,W. G., & Cordeiro, P. A. (2003). Educational leadership: A problem-based approach. Boston, MA: Pearson Education.

[6] Fernández, F.J.; Sierra, A.J.; Ariza, T.; Madinabeitia, G.; Vozmediano J.M.; Virtualization Environment in Telematics Labs, Global Engineering Education Conference (EDUCON), 2013.

[7] Garland, N. J. (1995). Peer group support in economics: Innovations in problem-based learning. InW. Gijselaers, D. Tempelaar, P.Keizer, E. Bernard,&H. Kasper (Eds.), Educational innovation in economics and business administration: The case of problem-based learning (pp. 331–337). Dordrecht, The Netherlands: Kluwer.

[8] Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-based learning. In J. M. Spector, M. D. Merrill, J. van Merriënboer, & M. Driscoll (Eds.), Handbook of research on educational communications and technology (3rd ed., Vol. 1, pp. 485–506). New York: Erlbaum.

[9] Oberlander, J., & Talbert-Johnson, C. (2004). Using technology to support problem-based learning. Action in Teacher Education, 25(4), 48–57.

[10] Ostwald, M. J., Chen, S. E., Varnam, B., & McGeorge,W. D. (1992). The application of problem based learning to distance education (ERIC Document Reproduction Service No. ED 359 398).

[11] Osgood, M. P.,Mitchell, S. M., & Anderson,W. L. (2005). Teachers as learners in a cooperative learning biochemistry class. Biochemistry and Molecular Biology Education, 33(6), 394–398.

[12] Pletinckx, J., & Segers, M. (2001). Programme evaluation as an instrument for quality assurance in a student-oriented educational system. Studies in Educational Evaluation, 27, 355–372.

[13] Reynolds, F. (1997). Studying psychology at degree level:Would problem-based learning enhance students' experiences? Studies in Higher Education, 22(3), 263–275.

[14] Seltzer, S., Hilbert, S., Maceli, J., Robinson, E., & Schwartz, D. (1996). An active approach to calculus. In L. Wilkerson & W. H. Gijselaers (Eds.), Bringing Problem-based learning into higher education: Theory and practice (pp. 83–90). San Francisco, CA: Jossey-Bass.

[15] Sierra, A.J.; Ariza, T.; Fernandez, F.J., Establishment EHEA for telecommunication technologies engineering degree Global Engineering Education Conference (EDUCON), 2012 IEEE Digital Object Identifier: 10.1109/EDUCON.2012.6201158 Publication Year: 2012, Page(s): 1–6.

[16] Sierra, A.J.; Ariza, T.; Fernandez, F.J.; Madinabeitia, G., TVSP: A Tool for Validation Software Projects in programming labs Global Engineering Education Conference (EDUCON), 2012 IEEE Digital Object Identifier: 10.1109/EDUCON.2012.6201196 Publication Year: 2012 , Page(s): 1 – 6.

[17] Sierra, A.J.; Ariza, T.; Fernandez, F.J.; Madinabeitia, G., Tool for Validation Software Projects in Programming Labs, International Journal of Engineering Pedagogy (iJEP), Vol 2, No 2 (2012).

[18] Smith, D., & Hoersch, A. L. (1995). Problem-based learning in the undergraduate geology classroom. Journal of Geological Education, 43, 149–152.

A.J. Sierra is with the Department of Telematic Engineering at the School of Engineering of the University of Sevilla, Camino de los Descubrimientos S/N, 41092 Seville, Spain (e-mail: antonio@trajano.us.es).

T. Ariza is with the Department of Telematic Engineering at the School of Engineering of the University of Sevilla, Camino de los Descubrimientos S/N, 41092 Seville, Spain (e-mail: matere@trajano.us.es).

F.J. Fernández is with the Department of Telematic Engineering at the School of Engineering of the University of Sevilla, Camino de los Descubrimientos S/N, 41092 Seville, Spain (e-mail: fjfj@trajano.us.es).