Je-LKS

Journal of e-Learning and Knowledge Society

The Italian e-Learning Association Journal

SIe-L
Società Italiana di e-Learning

n. 3
2018
SEPTEMBER

Je-LKS
Journal of e-Learning
and Knowledge Society

www.sie-l.it
www.je-lks.org

The Journal is issued online three times per year.

Je-LKS is an Open Access Online publication. This means that everybody can free access online to abstracts and full lenght articles.

Libraries or researchers, can subscribe a Reprint Service Subscription. The Reprint Service Subscription is on a yearly basis and you can receive the three printed year issues for a 121€ annual fee (including taxes and shipping expenses).

In order to join SIe-L:

- segreteria@sie-l.it

- Tel. +39 052 2522521

For more information visit www.sie-l.it

Registration at the Rome Court in the pipeline.

eISSN: 1971 - 8829 (online)

ISSN: 1826 - 6223 (paper)

Resp. dir. Aurelio Simone

To the authors:

paper can be addressed to:
www.je-lks.org

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal
Vol. 14, n. 3, 2018

N. Villa
pag. 5 The issue

PEER REVIEWED PAPERS

A. Pierri
pag 7 From Practical to Theoretical Thinking: the Impact of the Role Play Activity

L. Pereira de Brito, M.H. Martinho
pag 17 Fostering Teachers' Adoption of Moodle: an Action-research framed on Evolutionary Game Theory

S. Fantinelli, V. Russo
pag 29 Community of Practice Online, the Importance of Technology for Learning: an Application of Social Network Analysis

R. Capone, F. Del Regno, F.S. Tortoriello
pag 41 E-Teaching in Mathematics Education: the Teacher's Role in Online Discussion

Y. Ghilay
pag 53 The Second Generation of Feedback-based Learning Model (FBL-2G) for Quantitative Courses in Higher Education

D. Keržič, A.Aristovnik, N. Tomaževič, L. Umek
pag 65 Evaluating the Impact of e-learning on Students' Perception of Acquired Competencies in an University Blended Learning Environment

L. Mich, D.M. Berry
pag 77 A Gentle Introduction to Computational Complexity through an Examination of Noodle Making

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal

THE ISSUE

VOL. 14, N.3, 2018

by Nicola Villa

The new issue of September 2018 includes a selection of multi-disciplinary works submitted by the authors and accepted after the review process.

The article by **Anna Pierri** (*From Practical to Theoretical Thinking: The Impact of the Role-Play Activity*) opens the issue. The paper concerns the analysis of the outcomes of a role-play activity aimed at fostering conceptual understanding of linear algebra for the first-year engineering students.

Luciana Pereira de Brito and **Maria Helena Martinho** (*Fostering Teachers' Adoption of Moodle: An Action-research framed on Evolutionary Game Theory*) discuss an action-research carried out in a Portuguese school, where it was intended to understand, from an Evolutionary Game Theory perspective, the survival and expansion of the using-Moodle behavior in a population of teachers.

Community of Practice Online, the Importance of Technology for Learning: an Application of Social Network Analysis is the paper prepared by **Stefania Fantinelli** and **Vanessa Russo** that describes an experience of blended learning education by four Italian Universities. The objective of the research was to implement the social network analysis technique in order to observe online interactions of students, thus describing the nodes that exert the most influence in the group and to evaluate if the online interactions can positively affect the learning process.

The paper by **Roberto Capone**, **Flora Del Regno** and **Francesco Saverio Tortoriello** (*E-Teaching in Mathematics Education: the Teacher's Role in Online Discussion*) describes the cross-referenced results of two educational experiments on the use of social platforms in the teaching and learning of mathematics. These were conducted over the course of two years in two mathematics courses at secondary schools and in two university's courses. It aimed to highlight the role that the teacher assumes in online discussion, revisiting their role as a transmitter of knowledge and taking on the role of facilitator in the acquisition of skills.

Yaron Ghilay in the article titled *The Second Generation of Feedback-based Learning Model (FBL-2G) for Quantitative Courses in Higher Education* examines the effectiveness of the second generation (2g) of Feedback-Based Learning model (FBL-2g) regarding quantitative courses in higher education. The intention was to examine students' views towards the model and check if there are differences between theoretical quantitative courses such as math or statistics and a computer course.

The article *Evaluating the Impact of e-learning on Students' Perception of Acquired Competencies in an University Blended Learning Environment* by **Damijana Keržič**, **Aleksander Aristovnik**, **Nina Tomaževič** and **Lan Umek** explores the correlations between selected aspects of e-learning in the blended learning environment and the competencies that students should acquire during their study.

Closes the issue the article by **Luisa Mich** and **Daniel M. Berry** (*A Gentle Introduction to Computational Complexity through an Examination of Noodle Making*) that describes several traditional algorithms for making Chinese and Italian noodles and classifies each according to its computational complexity.

The first number of 2019 will be edited by Letizia Cinganotto (INDIRE, Italy) and Kristina Lodding Cunningham (Senior Policy Officer, in charge of Multilingualism in the Directorate General for Education, Youth, Sport and Culture of the European Commission) with the focus **Embracing Language Awareness and Language Diversity in the 21st Century**.

It is also open the new call for paper for the number of May, edited by Veronica Rossano (University of Bari, Italy) and Rita Francese (University of Salerno, Italy) that will be dedicated to the theme **Educational Robotics: Research and Practices of Robots in Education**.

You can find all the information about the call's deadlines and all our news at www.je-lks.org or in our social media group on Facebook.

Nicola Villa
Managing Editor
Journal of e-Learning and Knowledge Society

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal
PEER REVIEWED PAPERS
Vol. 14, n.3, 2018
ISSN: 1826-6223 | eISSN: 1971-8829

FROM PRACTICAL TO THEORETICAL THINKING: THE IMPACT OF THE ROLE-PLAY ACTIVITY

Anna Pierri

Dept. of Information, Electrical Engineering and Applied Mathematics, University of Salerno, Italy

Keywords: Language, registers, written argumentations.

This paper concerns the analysis of the outcomes of a role-play activity aimed at fostering conceptual understanding of linear algebra for the first-year engineering students. The role of the teacher is considered in order to investigate about whether the designed role–play activity is able to affect the passage from practical to theoretical thinking. The analysis shows that, in spite of some difficulties related to the use of language, the students have improved their mastery of theoretical thinking.

for citations:
Pierri A. (2018), *From Practical to Theoretical Thinking: The Impact of the Role-Play Activity,* Journal of e-Learning and Knowledge Society, v.14, n.3, 7-15. ISSN: 1826-6223, e-ISSN:1971-8829 - *DOI: 10.20368/1971-8829/1375*

1 Introduction

The purpose of this paper is the analysis of the role-play activity; the outcomes of this analysis were already presented in our previous work (Albano & Pierri, 2014), in which the role was considered for investigating given competencies addressed by questions created by students.

Nevertheless, we now focus our attention on specific aspects of the students' reasoning in linear algebra. A number of students, indeed, tend to think by following practical rather than theoretical ways. "What is theoretical or practical is not thinking as such but *the relationship between thinking and its object"* (Sierpinska, 2005, p.120). From this point of view, this paper aims at analyzing undergraduate students' ways of thinking while playing the role of a teacher, who are required to pose some questions about specific topics of linear algebra.

In the framework of "Writing to Learn" (Morgan, 1998), as the role is played in an e-learning setting, it will be based on a written communication; hence the different forms of writing used by the students can be analyzed.

In the following sections, we are going to investigate the outcomes produced by the students and to discuss the subsequent findings with respect to the activity goal.

The questions addressed by the research are the following:

- How can the designed role–play activity affect the passage from practical to theoretical thinking?
- How can this kind of activity improve the students' writings going from abstract to algebraic-geometric language, the latter being characteristics of the language of mathematics? (Albano & Ferrari, 2013).

Finally, we try to draw some ideas for further works concerning the students' thinking.

2 Theoretical background

Linear algebra is an important field of study in mathematics, in particular for two principal reasons: on the one hand, it has a wide range of applications in different fields such as analysis, probability, etc.; on the other hand, it gives the students the opportunity for learning how to make mathematical abstractions. In particular, it provides them with instruments for graphical, numerical and symbolic representations that can be used in parallel or be chosen by the students according to their needs and/or personal preferences.

Notwithstanding its importance, teachers and students are aware of the fact that teaching and learning linear algebra is a difficult experience (Hillel, 2000).

Many are the researchers who conducted studies on linear algebra (Carlson, 1993; Nardi, 1997, Dorier, 2000, Pavlopoulou, 1993), and provided various theories in order to explain the reasons underlying the student's difficulties in understanding linear algebra issues and to present some suggestions about possible teaching methods.

Precisely referring to this persistent problem when teaching and learning linear algebra, Sierpinska (2000, p. 211) stated that

> "*We understood that for all the innovations that we made in presenting the theory to the students, we still wanted them to understand the same theory: the structural theory of linear algebra.... But the students in our experiments could not understand the theory because they appeared to want to grasp it with a 'practical' rather than a 'theoretical' mind*".

Sierpinska (*Ibidem*) assumed that in spite of a number of implementations for improving the teaching, some students continued having difficulties in understanding concepts in linear algebra. She claimed that this result depended on the inconsistency between the nature of linear algebra issues and the student's modes of thinking. From this point of view, this study aims at exploring undergraduate students' ways of thinking while solving specific tasks related to linear algebra topics, through a role-play activity.

Sierpinska (*Ibidem*) aims at identifying the characteristic of the students' way of thinking in linear algebra. Sierpinska reports three types of thinking modes: Synthetic-Geometric, Analytic-Arithmetic and Analytic-Structural, which derived from responses given by her students in linear algebra courses.

There are some fundamental differences among them, as the first one makes use of geometric representations, allowing the objects to be given readily (described through representations), but not to be defined, the two analytic modes instead, use numerical and algebraic representations. In these modes, the objects are defined through their definitions and properties.

This aspect is seen as strongly related to the diverse ways of representing objects in the linear algebra context. In parallel with the three modes of thinking identified by Sierpinska, Hillel (2000) three basic languages being used in linear algebra. A "geometric language" that refers to two and three spaces (points, lines, planes, directed line segments and geometric transformations), an "arithmetic language" that refers to n-tuples, matrices, rank, solutions of systems of equations and so on, "algebraic language" that refers to the general theory (vector spaces, subspaces, dimension, operators, kernels).

Basically, the theoretical framework of this research is twofold: Sierpinska's (*op. cit.*) modes of thinking and Hillel's (*op. cit.*) modes of describing and representing problems in the linear algebra context.

Several studies in Mathematics Education have shown that the difficulty for many students in studying mathematics can be due to their little ability to juggle between the everyday life meaning of a word and the formal use of the same word in mathematics (see for example Bardelle, 2010).

For such purpose, we planned to explore undergraduate students' ways of thinking during the role-play activity (Albano & Pierri, 2014), and to continue the work started in our initial research with the aim of showing how this kind of activity would engage the students with more "advanced" thinking (Morgan, 1998).

3 Experiment Setting and Methodology

If it is true, as Borba (2009, p. 463) claims, that schools *"seem to be resistant to technology"*, it is also true that "the online education has become a common feature" (Rosa & Lerman 2011, p. 69) at the university level. This is probably because higher education institutions aim to provide access to students with specific (for example distance, work or childcare related) needs.

Therefore, the use of technology in education may help reduce the gap between students' out-of-school and educational experience. The e-learning modalities may offer the possibility to personalize individual paths as well as activities involving a form of collaboration among students but also between students and teachers. For the purpose of our experiment, a group of voluntary freshman engineering students, involved in two intensive trimester-based modules in mathematics, was taken as a study sample. Indeed, our research was focused on the second module, which concerns topics covering linear algebra and calculus. The Linear Algebra course was composed of 60 hours, (5 per week), split into 3 hours of theoretical lecture and 2 hours of practice session. The Exam session consisted of two parts: the first one that included a written test having a compulsory nature for accessing the second part, and an oral exam (discussion); and the second part, where the student was required to master definitions and theorems (including understanding of the proofs). The final mark was the result of both written and oral tests.

In the context of the Linear Algebra course, we created and followed up a blended course delivered by a learning platform. The course was piloted with the voluntary group, composed of almost 70 first year engineering students.

The students, enrolled in the blended course from the beginning, could familiarize with the learning platform and the activities available on it, as part of their first attended lesson. They were also acquainted with the use of these activities to practice mathematics, though stating that they were not compulsory. They finally had access to a common area for them to exchange ideas, comments and questions about the activities in the platform. As regards the functionalities offered by the e-learning platform, we exploited a specific feature dealing with open-ended questions (tasks – "compito a casa"), suitably temporized. The temporization of this activity usually induces the students to carry out the assigned task in a fixed set time though, at the same time, gives them the possibility to choose when and where to complete the task. Precisely through this functionality, we could create the role-play activity, starting with assigning three different topics to each student taking part in the game, by playing a specific role. In other words, before starting with the experimentation we prepared a list of topics covering the Linear Algebra programme, for example Cramer's Theorem, Rouchè-Capelli Theorem.

The students had to run a specified role (teacher, student, and teacher) for three days so that each cycle lasted nine days, three per role. For the first role, the student acted as a teacher requested to evaluate the level of knowledge of a topic through the formulation of questions referred to the same topic. In the second role, the student had to answer a question formulated by his/her colleague. Finally, for the third role, the student, still acting as a teacher, was asked to check the correctness of the work delivered in the previous phases.

After having distributed specific topics to each student playing the first role, the teacher assigned a web task, as in the following example:

> *"Formulate at least four questions that you think are useful to verify that a student has understood the statement and proof of Theorem X, as if you were a teacher who wants to evaluate the learning of the specified topic".*

4 Analysis of Written Argumentation

In the following section, the work performed by the students regarding the first role is analyzed in the light of Sierpinska's modes of thinking.

Let us consider a few protocols.

In the first iteration cycle, some students formulated the following questions, by using an Abstract language

> Q1: "Taking into account the various algebraic structures (G; σ), that we know, which of them can be defined as groups?"
> Q2:" "*Extension*" of groups in rings and fields"
> Q3: "Given a matrix A (m, n) and A' its minor of order p, how many ways do exist for fringing with the lines of A?"
> Q4: "What elements define a row echelon matrix"?
> Q5: "Which of the two Laplace's theorems states that the sum of the products of the elements in a row or column is always null"?

As we can observe, the formulation of the questions remains at a superficial and generic level. In fact, although it has required a verification of the statement and a proof of the assigned Theorem, what really appears is the inability of the student to enter into the details of the proof.

The above questions are expressed using specific descriptions of different objects but give no definitions; for example, this is true for "*what's the meaning of "algebraic structures?"* in question Q1, and "*Extension*" in question Q2.

In other cases, the questions are formulated by exclusively using symbols, that is without giving a definition of terms, as seen in "A(m,n)" in Q3.

Indeed, this even caused some difficulties when it came to formulate four simple questions, as highlighted by the students themselves.

In other situations, we can also find some student's attempts to copy the requested definition from their textbook. For example, in question Q5, the student affirms: *"the sum of the products of the elements in a row or column is always null",* though leaving out some details related to the matrix.

However, another aspect that specifically emerged from this activity is that during the individual tutoring sessions, it gave rise to a form of 'competition' among the students, who felt encouraged to do always better.

The following protocols show examples of their use of the Algebraic language

> Q6: "Solve the following linear system with the help of Cramer's rule"
> Q7: "Reduce the following matrix in row-echelon form S and calculate the rank"
> Q8: "Fixed a row-echelon matrix, what does the number of non-null rows correspond to?

We can observe an algebraic (operational) rather than abstract approach.

This approach can be regarded as a formal system designed to fulfill specific purposes, among which the opportunity of performing computations/procedures correctly and effectively.

However, also in this case, any form of theoretical thinking is absent.

During the last iteration cycle, we analyzed the protocols written by the students who had already formulated the questions from Q1 to Q5. A hint of a more complex language, probably associated to an analytic-structural way of thinking, is observed. See the following protocols:

> Q9: "According to the statement in the Gram-Schmidt's Theorem, what is the imposed condition on the dimension of the Euclidean space? And why?"
> Q10: "How can we use Steinitz' Lemma in the proof of the Base Theorem".

Q11: "What is the relationship between scalar product and vector norm?"

From the feedback received by both the tutor and the students, we can see how - despite some difficulties with the use of the language and the formalism for describing specific concepts still persist - it is possible to highlight a greater acquisition of theoretical thinking by the students.

This analysis allows us to draw some conclusions that are supported by:

- Feedback from students, after the numerous interactions between them and the tutor, both in a synchronous and asynchronous way.
- Progress made by clever students at the exams, observable at the end of each exam session.

As a result, the role-play activity has allowed the students to understand their educational goals compared with the operational ones, also improving their conceptual approach.

A possible reason for this achievement, could be found in the fact that this kind of activity has given the students a guidance for an in-depth analysis of the course topics; in particular, they tried to go into the details of the theorems' proof by overcoming the superficiality of the initial approach.

Indeed, as also claimed by some students during individual tutoring sessions, they adopted a critical attitude when posing a question, due, on the one hand, to the unicity of the method, and, on the other hand, to the its requirement to formulate at least four nonrepeating questions, helping them to study all the aspects of a given theorem.

It is also worth mentioning that some students used the teacher role for clarifying topics or particular steps of the proof for a specific theorem.

In brief, from the analysis of the protocols, it seems that the design of the role-play activity can help the students develop concepts and a more abstract ways of thinking. Indeed, looking at the questions made by the same students during the different cycles, we can observe a passage from the functional thinking to the set-theoretical thinking, where the utilization of the many functions passes from processes to objects.

Our analysis suggests the existence of theoretical thinking signals that find their expression through texts. Consequently, semiotic representation systems become themselves an object of reflection and analysis. Actually, as clearly pointed out by Sierpinska, acting at a meta-theoretical level constitutes the very essence of a theoretical perspective:

> […] Theoretical thinking is not about techniques or procedure for well-defined actions, […] theoretical thinking is reflective in that it does not take such techniques for granted but considers them always open to questioning and change.

> […] Theoretical thinking asks not only, is this statement true? But also what is the validity of our methods of verifying that it is true? Thus theoretical thinking always takes a distance towards its own results. […] theoretical thinking is thinking where thought and its object belong to distinct planes of action. (Sierpinska, 2005, pp. 121-23)

In the school context, the complexity of this meta-theoretical level seems to be ignored. At a university level, the professor has the duty to put into practice all the activities useful to develop possible ways of advanced thinking.

Conclusions and Future Work

In this paper, we have reported a work of outcomes analysis based on a role-play activity experimented by a number of first year engineering students, and aimed at fostering their conceptual understanding of mathematics. The activity has shown that introducing the students to theoretical thinking about mathematics is not such an easy task, in that it requires a long-term effort and has to take into account a great variety of contexts in which mathematics is studied and/or applied.

The transition from colloquial to 'abstract' mathematical registers is not a simple one but requires major changes in the organization of texts.

Therefore, we plan to continue the analysis of the other roles, in order to stress and ameliorate the students' thinking way.

REFERENCES

Albano, G., Ferrari, P.L. (2013). Linguistic competence and mathematics learning: the tools of e-learning. *Journal of e-Learning and Knowledge Society (Je-LKS) (eISSN 1971-8829*), Vol. 9, No. 2, pp. 27-41.

Albano, G., Pierri, A. (2014). Mathematical competencies in a role-play activity. In Nicol,C.,Liljedhak, P., Oesterle, S.& Allan,D.(Eds.). *Proc. 38th Conf. of the Int. Group for the Psychology of Mathematics Education* (Vol.2, pp.17-24). Vancouver, Canada: PME.

Bardelle, C. (2010). Interpreting monotonicity of functions: a semiotic perspective, in Pinto M.F. & Kawasaki T.F., *Proc. 34th Conf. of the Int. Group for the Psychology of Mathematics Education* (Vol. 2, pp.177-184). Belo Horizonte, Brazil: PME.

Borba, M. C. (2009). Potential scenarios for Internet use in the mathematics classroom. *ZDM—The International Journal on Mathematics Education*, 41(4), 453–465.

Carlson, D. (1993). Teaching linear algebra: Must the fog always roll in?. The College *Mathematics Journal*, 24(1), 29–40.

Dorier, J.-L.(2000). *On the Teaching of Linear Algebra*. Dordrecht: Kluwer Academic.

Hillel, J. (2000). *Modes of description and the problem of representation in linear algebra*. In J.-L. Dorier (Ed.), On the teaching of linear algebra (pp. 191-207). Dordrecht: Kluwer Academic Publishers.

Hillel, J., Sierpinska, A. (1994). *On One Persistent Mistake in Linear Algebra.* In the Proceedings PME 18, University of Lisbon, Portugal, 65–72.

Nardi, E. (1997). The novice mathematician's encounter with mathematical abstraction: A concept image of spanning sets in vectorial analysis. *Educación Matemática*, 91(1), 47-60.

Morgan, C. (1998). *Writing Mathematically. The Discourse of Investigation*. London: Falmer Press.

Pavlopoulou, K. (1993). Un problème décisif pour l'apprentissage de l'algèbre linéaire: la coordination des registres de représentation. In R.Duval (Ed.), *Annales de didactique et de sciences cognitives,* vol.5, 67-93, IREM de Strasbourg

Rosa, M., & Lerman, S. (2011). Researching online mathematics education: opening a space for virtual learner identities. *Educational Studies in Mathematics*, 78(1), 69–90.

Sierpinska, A. (2000). On some aspects of students' thinking in linear algebra. In J.-L. Dorier (Ed.), *On the teaching of linear algebra*- Dordrecht: Kluwer Academic Publishers: pp.209-246.

Sierpinska, A. (2005). On practical and theoretical thinking and other false dichotomies in mathematics education. In *Activity and Sign* (pp. 117-135). Springer US.

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal
PEER REVIEWED PAPERS
Vol. 14, n.3, 2018
ISSN: 1826-6223 | eISSN: 1971-8829

FOSTERING TEACHERS' ADOPTION OF MOODLE: AN ACTION-RESEARCH FRAMED ON EVOLUTIONARY GAME THEORY

Luciana Pereira de Brito
Maria Helena Martinho

University of Minho, Centre of Research in Education, Portugal

Keywords: Moodle, teacher, Game Theory.

Despite several studies' conclusions about the great potential of Learning Management Systems like Moodle for educational and professional practices in schools, many authors find a reduced use of this tool in school's pedagogical and organizational contexts. This article presents an action-research carried out in a Portuguese school, where it was intended to understand, from an Evolutionary Game Theory perspective, the survival and expansion of the using-Moodle behavior in a population of teachers. Some mechanisms studied in this theory influenced the actions negotiated with school leadership and implemented throughout the investigation, and the analysis of their impact. School leadership use of Moodle forums and the frequent interactions between Moodle users proved to be catalysts of the desired change, suggesting the importance of social reinforcement for the adoption of this tool.

for citations:
Pereira de Brito L., Martinho M.H. (2018), *Fostering Teachers' Adoption of Moodle: An Action-research framed on Evolutionary Game Theory,* Journal of e-Learning and Knowledge Society, v.14, n.3, 17-28. ISSN: 1826-6223, e-ISSN:1971-8829 - *DOI: 10.20368/1971-8829/1443*

1 Introduction

Moodle is an online learning management system, created by Martin Dougiamas and aimed to educational and collaborative environments management (Lisbôa *et al.*, 2009). In such platforms, teachers are exposed to a wide range of resources, ideas and perspectives, which helps them to understand the instructional value available and to expand their knowledge about opportunities to change or improve, thereby contributing to their professional development (Harasim *et al.*, 1995). Fernandes (2008), understanding the potential of Moodle's tools, suggests a wide range of uses for other school practices at the organizational level. Thus, it is possible to understand Moodle as a Public Good, in which school leaders and teachers can enjoy and learn – and contribute to school development – by sharing resources and experiences.

However, despite the adoption of Moodle by a large number of Portuguese schools (Pedro *et al.*, 2008), its effective use is still limited for most schools and teachers, in number of users and quality of use (Pedro *et al.*, *op. cit.*, Lisbôa *et al.*, *op. cit.*). Brinkerhoff (2006) identifies four sources for the barriers that hinder the integration of technology into teacher practices: attitudes/motivations, training/experience, institutional/ administrative support, and resources. Perceived usefulness is an important component of teachers' motivation to use computers (Mueller *et al.*, 2008). Regarding teacher's motivation, Baek, Jung and Kim (2008) present an unexpected result: from the six factors most pointed by teachers as justifications - seen here as perceived benefits - for the inclusion of Information and Communication Technologies (ICT) in their practices, the "adaptation to external requests and other expectations" was the most mentioned one, especially by teachers with more professional experience, in contrast to the expected factor, the "use of improved technological tools", mentioned mostly by younger teachers and advocated by the first scholars of Educational Technology. In other words, regardless of the ICT potential for teaching, learning and professional practices, their effective adoption by teachers is due, according to these authors, to the convenience to attend to external requirements, whether they arise from legislation or from other actors' social pressures. These results point clearly to a social network dynamics, where behavior is conditioned by the reputation that comes from it.

Studying factors affecting technology uses in schools, Zhao and Frank (2003) highlight the need of an ecological perspective to address such problems:

> Just as in a biological ecosystem, the teaching ecosystem exhibits diversity that it contains many types of species, each having a different set in of characteristics and playing a different role (occupying a unique niche) in ecological terms. The

> species' characteristics and roles constantly affect one another, thereby constantly modifying their interrelationships (p. 812).

Within this theoretical framework and aiming to understand different technology uses and institutional factors that may affect technology use, Zhao and Frank (2003) collected data from school administrators/ technology staff interviews and surveys administered to all school staff, suggesting, in their final conclusions, that the approach to school change should be "evolutionary rather than revolutionary" (p.839).

In fact, and analysing the problem of teacher's adoption of Moodle from an Evolutionary Game Theory (EGT) perspective – being EGT a mathematical theory that studies the evolution of behaviors adoption in populations, when the resulting costs and benefits of such behaviors are formally defined – it seems appropriate to define an LMS like Moodle as a public good: all teachers can take advantage of it to share materials and experiences and develop their practices. Even the school leadership, according to Fernandes (2008), may take advantage of its potential for the development of organizational and professional practices, fomenting its use among teachers and improving school as a whole. Thus, the low use of Moodle problem in a school may mean that few individuals cooperate to maintain this public good, and the spread of this cooperative behavior does not occur in the population.

2 Evolutionary Game Theory

Game Theory is a powerful theoretical tool of social sciences (Axelrod, 1984), crucial to understand the evolution of social behavior in animals as well as the notion of altruism and justice among humans (Erickson, 2006). It studies various types of games, and some elements are needed to define them: a set of players, a set of strategies or behaviors, and, for each strategy, a set of payoffs received by each player. Some games characterize many social dilemmas, which reflect the conflict of interests between the welfare of a community and of each individual (Hauert, 2006). In this class of games lies the Prisoner's Dilemma, which is, according to Axelrod (*op. cit.*), the paradigm of formal game theory to analyse prosocial behaviors: it has inspired several lines of research in psychology about factors that promote/inhibit cooperative behavior, also serving as a diagnostic tool for social orientations such as individualism/ altruism, and cooperation/competition (Axelrod, Riolo & Cohen, 2002).

In a population of players, Game Theory gives rise to Evolutionary Game Theory: it studies the spread of strategies or behaviors within the population, known the mechanisms used by players in the decision to adopt a given strategy or behavior, like trial and error or the imitation of successful strategies. Keeping the same mathematical structure of the Prisoner's Dilemma, EGT studies the Public Goods dilemma, having demonstrated in this case the importance to the emergence and maintenance of cooperative behavior of changing the payoff, volunteering, communication, social reputation and clustering (Axelrod, 1984).

The adoption levels of a behavior increase when there's a high personal benefit obtained by that behavior, and a small benefit that comes from not adopting it (Kollock, 1998). For the emergence of cooperative behavior Axelrod (*op. cit.*) recommends to leaderships changing the payoff of cooperation, making it an attractive behavior. Sigmund (2010) also suggests that the payoff resulting from the adoption of a particular behavior depends on the percentage of the population of individuals who adopt it.

Changing game's feature from mandatory to volunteer brings gains for social welfare (Hauert, 2006): cooperators are the ones who respond positively to the announcement of a volunteer cooperative game, revealing more comfortable to play than the non-cooperative ones (Orbell & Dawes, 1993), which increases the probability of socially productive relations. The frequent interactions between cooperators reinforce their optimism, and the improvement of social welfare attracts new participants – loners – to the game (*Ibidem*).

Communication is a prerequisite for the evolution of cooperation, because the ability to communicate and meet other players' intentions allows the development of alliances and even a morality that transcends the individualism of the rational player (Axelrod, *op. cit.*). Access to a record of cooperation of each individual - the maintenance of a memory game - also allows the development of social reputation, another important mechanism for the evolution of cooperation. Centola (2010) investigated the spread of behaviors in an internet community and found out that social reinforcement resulting from the receipt of emails with notifications of "friends" behaviors resulted in a propensity to adopt those same behaviors.

Communication also allows the creation and reinforcement of a sense of group identity and ethical standards (Kollock, 1998; Kirschbaum & Iwai, 2011). In fact, in a population of local interactions (such as a neighbourhood) that faces the Public Goods dilemma, cooperation can emerge by the natural formation of clusters of cooperators, where individuals, by repeated interactions within these groups, show altruistic behavior (Kollock, *op. cit.*) and maintain the levels of cooperation. The interactions in which cooperative behaviors are adopted result in benefits for each of the individual agents, promoting a social welfare that results in the desire to repeat such interactions, forming and thus keeping the cluster of cooperators. Several studies (such as Axelrod, *op. cit.*; Alves *et al.*, 2004) suggest that organizational leadership must focus on the deliberate formation of such teams.

3 Methodology

To understand the educational phenomena underlying the identified problem, an action-research seemed to be an appropriate methodology, as it "can serve as an organizational strategy to aggregate people to actively deal with particular issues" (Bogdan & Biklen, 1994; p. 297) and can be seen as an adaptive-evolutionary process of change (Noffke & Somekh, 2009).

3.1 Context

Favourable to this desired change regarding ICT adoption in schools, the Portuguese Ministry of Education identified in 2011 the need to establish school structures to support a Technological Plan for Education (TPE), which could respond more objectively to the problems and needs of each school. Such a structure was called TPE team, constituted mostly by school teachers.

The research took place from July 2010 to March 2011 at the school where the researcher worked as a mathematics teacher. It was a public school, where about 90 teachers were working with 900 students between 10 and 15 years of age. The school leadership was constituted by a director, a vice-director and 3 other members, including the TEP Coordinator (TEPC), an ICT teacher. All of the 36 class-rooms had 1 computer for teacher use, and 2 classrooms were also equipped with 14 computers for students. In the school library 6 computers were available to any user, and teacher's room had 8 computers for their use.

Through a brief exploratory case-study grounded in semi-structured interviews it was possible to understand that in September 2008 the TEPC conceived a strategic design to foster Moodle adoption and its dissemination, implemented in the scholar years of 2008/2009 and 2009/2010. It relied on the constitution of a PTE collaborating teachers team, whose 16 members belonged to various curricular departments, benefiting from a reduction of 1 hour of weekly working time to serve as hubs among their peers, spreading practices of using Moodle. Selecting PTE collaborators had been first conditioned by service requirements, and motivations and skills in using ICT were secondary conditions. Between September 2008 and June 2010, the TEPC provided these teachers with some sessions of formal technical training to use Moodle, and some moments of informal training by individual requests. This strategy showed to be unfruitful, for there was no significant increase in the number of accesses, resources, activities, disciplines or users of Moodle, according to some PTE collaborators.

3.2 Data Collection

The methods/tools used in this study to collect data were (i) a questionnaire, (ii) reports and statistics generated by Moodle, (iii) a diary and (iv) two semi-structured interviews.

The questionnaire was meant to deepen the knowledge about teachers' motivations and feelings, to better define the first actions to implement in that school. Diary data was collected from informal and natural conversations with various teachers, including PTE collaborators and leadership members. Two structured interviews were carried out, aiming to understand perceptions of the TEPC and a collaborating professor about the actions undertaken and their impact.

Given the naturalistic condition of the investigation, data analysis was done throughout the investigation.

Given that the researcher developed her professional career at that same school, interactions with teachers occurred perhaps daily in informal meetings, during breaks between classes and other encounters.

4 1st cycle of Action Research

It was designed and applied to school teachers in July 2010 a questionnaire with a Likert-type scale (1 – low; 4 – high) in order to understand frequencies of some ICT practices in teaching, and also feelings (at ease and enthusiasm) about ICT integration in teaching practices in general. There were no significant differences between the two groups with regard to ICT practices in teaching (Figure 1); however, and regarding their feelings, Figure 2 shows that PTE collaborators revealed, on average, values slightly lower than those revealed by the other teachers' group.

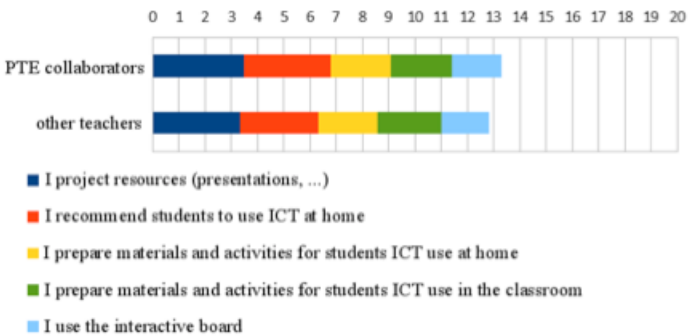

Fig. 1 - Frequency of different ICT teaching practices.

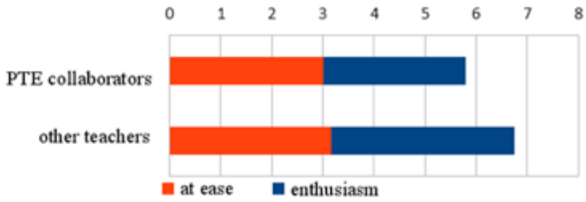

Fig. 2 - Feelings about ICT pedagogical use.

After collecting and analyzing data, some actions were negotiated with the school board and implemented at the start of the academic year 2010/2011:

- The researcher became Moodle's administrator, with six hours of work per week for this purpose;
- To promote frequent interactions with the researcher and PTE collaborators, their working time at school contemplated a weekly moment common to all, to provide informal training moments of using Moodle.

The researcher also performed some changes in Moodle's site configuration:

- Manual enrollment of all school teachers, and most of the students;
- Creating disciplines specifically to teachers with forced subscription to Forums, such as "Department of [...]" – to be managed by PTE collaborators along with their curricular department coordinators – and "Teachers Room" – a forum type discipline, to be boosted mainly by the school leadership, working as a "virtual bulletin board".
- Making available on the main page of Moodle's site the resources "contacts" (with the identification of 16 PTE collaborators) and the sideblock "active users".
- All school computers had their browser's homepage set to Moodle's site.

4.1 Results

Figure 3 shows the evolution of the use of Moodle in the population studied, since the Moodle instance was created in September 2008 until the end of the investigation, March 2011. The increase of accesses during the action-research study is quite significant, observed the black line which refers to all users' accesses. The researcher and the PTEC were the only users assigned with the administrator profile.

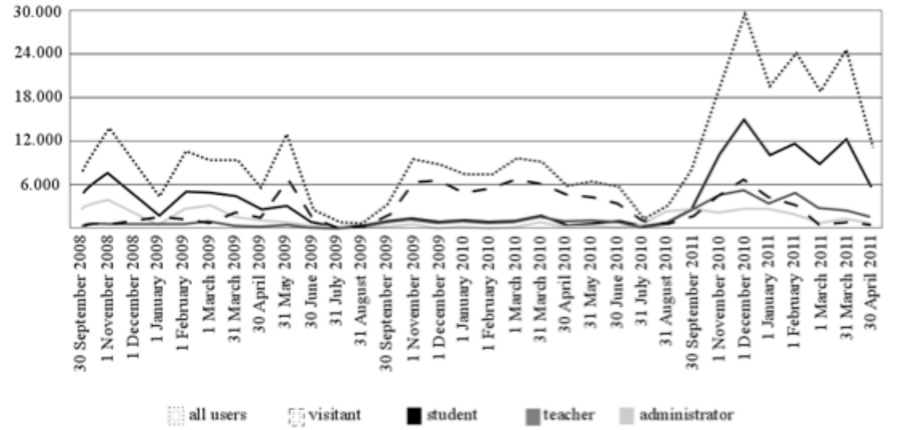

Fig. 3 - Evolution of the accesses to school Moodle's site from September 2008 to March 2011.

The dynamic nature of the action research methodology implies a strategic and intentional temporal sequence of data collection, being the reporting and interpretation crucial stages of the reflexive process that characterizes this methodology. Therefore, data will be presented in their chronological order of collection, followed by the interpretations that led to the new actions.

The first cycle of research was characterized by Moodle's administrative work (to configure and manage the platform) and also by several moments of technical support to its users, mostly new Moodle users. Also, and permanently, in formal and informal meetings at school, the researcher focused on showing the potential of Moodle to improve school practices.

Some PTE collaborators were less assiduous to weekly meetings with the researcher. For many participants, the existence of these weekly meetings functioned as a kind of "policing", making it mandatory for many to work for the platform at that time. The TEPC stressed the organizational constraints in forming such a team: "The most important qualities of a PTE collaborator are autonomy, technical skill and creativity. Not all colleagues reveal them, but the preparation of teachers working schedules involves so much ... Many became PTE collaborators because they had time available ... It's not me who chooses them, their working schedules do. [...] Some people may have the suitable profile but do not have time to be a PTE collaborator: they have to spend time giving support to this student, or in this coordination" (TEPC).

During those weekly meetings participants accessed Moodle site and expressed their concerns or raised questions aloud, and others intervened sharing knowledge or raising other questions. Excepting for one PTE collaborator, all the others – including Anna – had clearly defined a considerable distance between their ICT skills and those revealed by the researcher, perceiving her as a trainer. The researcher promptly attended requests, in an informal and collaborative way, suggesting activities which could promote efficient and effective Moodle use. Nevertheless, the greater interest of PTE collaborators during the first cycle of action research was to master the technique required to add resources to their Moodle disciplines.

Some PTE collaborators were Moodle enthusiasts; others showed increased interest and motivation when realized that technical problems and concerns were addressed and solved in every session. "For years and years and years I rejected the idea of computers, and then, for a moment, I realized: maybe it is interesting... Now I could not live without my computer! One can implement strategies to make lessons more enjoyable. [...] In my [Moodle] discipline there is a clear change from last year to this one. [...] The 45 weekly minutes? I was with you, but every Friday I was with my colleague [from the same Curricular Department] and we stayed in school working on the platform."(Anna)

Other school teachers showed interest in using Moodle, requesting technical support: "This [Moodle] is very interesting ... [...] Can you create a discipline for me? [...] Are you here at this hour every week? [...] Can you help me? "(5th grade teacher).

Curricular Department's coordinators showed little interest in adopting Moodle to develop their practices in Moodle's Curricular Department's disciplines, since its adoption was defined by school leadership as volunteer.

"An area [Moodle discipline] for teachers to share and collaborate? They won't go there. First, because we are increasingly required to do many things, many roles in school... There's no time. [...] We have to take it easy ... I value older people, because this is an absurd change for them... We must have patience and calm, they are slowly joining. We cannot be so demanding. But that doesn't mean we have to stop there: let's sow the seeds, this will eventually bear fruit" (Anna).

It was always difficult to meet with school leadership members to show Moodle's potential to develop organizational practices. Only at the end of October the school director began to use 'Teachers' Room' discipline, posting in a Forum information, notices and other scholar resources, which were, in turn and automatically, sent to all teachers by e-mail. This leadership use of Moodle proved to be catalyst for the desired change: after receiving the first email, many teachers approached the researcher requesting username and password to access platform, and also expressing technical constraints in accessing it, which was perceived as necessary and inevitable given the school director use of Moodle. "The school direction, by using Moodle, sets the example and shows that it is a good tool to quickly access and share information" (TEPC)". The coordinators of other leadership structures – being among these one particular teacher always very reticent to scholar ICT adoption – requested the creation of disciplines on the platform similar to 'Teachers' Room' in their capability to communicate with teachers through emails. The attention and interest of other teachers in the school Moodle site increased substantially since that time: there was a significant increase of requests for the creation of disciplines to work with students and for support in accessing and browsing the platform. During this cycle the platform underwent a major restructuring in its categories and disciplines.

Despite the success of the actions implemented from September to December 2010, some refinements were negotiated with the TEPC in order to improve Moodle's adoption, conducting to a 2nd cycle of action research: to raise awareness among school leadership members of Moodle's potential for the development of professional practices, seeking the increase of that use and, therefore, frequent interactions of school leadership with all teachers through Moodle itself.

In this 2nd cycle, leadership members gradually understood the potential of Moodle to the development of their practices, especially in collecting information through Moodle's questionnaires, which could allow them to save paper and systematically collect and process data. Nevertheless, despite the interest shown by these participants, their lack of time availability to develop technical skills to use the Moodle was frequent, which is confirmed by the TEPC: "we still need to improve a lot, but there are also many resources that we have not, there are many obstacles ... Too much work, for example."

5 Discussion

In general all disciplines managed by PTE collaborators had a major increase in students' accesses.

The school director clearly functioned as a hub of interactions with all school teachers, signaling his Moodle-use behavior through frequent emails sent through "Teachers Room". The initial assumption that PTE collaborators would be responsible for the dissemination of Moodle was quickly supplanted by the dynamics of a social network, where, for many teachers, the behavior of using Moodle was acquired by imitation of that single hub: though, in theory, each PTE collaborator had a strategic position in the population - at least one belonged to each curricular department - the reality had shown that these participants did not functioned exactly as hubs, for their positions didn't necessarily meant interactions with their peers.

The variable most privileged in this study and which effect had a most visible impact was communication. It seemed crucial to focus on that process to transcend Moodle adoption barriers, aiming to understand teachers' professional interests in ICT and raising awareness of the benefits of using Moodle. Through one of the most interesting Moodle's features, communication between participants was also established via email, where each post in a forum was automatically sent by email to subscribed users. Regardless of the different perceptions of Moodle adoption's benefits, knowledge about the actual state of the spread of use of the platform in the school population seemed to have some impact on the population of teachers as a social network.

Exposure and visibility of PTE collaborators work resulted in some cases into a greater commitment to its realization, which resulted in an increase in their use of Moodle. By forcing the creation and maintenance of social reputation, they could validate their PTE team membership and their acceptance in the community as using Moodle hubs.

Conclusion

One of Game Theory's main result is the importance of the 'shadow of the future' in the emergence of cooperative behavior: the perception of the possibility of future interactions allows the emergence and sustainability of cooperation in a "selfish individuals" population. In this particular study, involving the professional and educational use of ICT, the evolution of technology itself and of its integration in school practices do provide a future where ICT will be most certainly present in the school, hence facilitating school leadership and teachers decisions to adopt exploratory behaviors and accept technology, even with some individual and/or group resistances. As pointed out by Zhao and Frank (2003, p.3), schools are "said to have a structure that prevents wide spread uses of computers"; nevertheless, and integrating the fact that effective adoption of ICT can only be visible after some years of dedication (Balanskat, Blamire & Kefala, 2006) reinforces the need to develop in the whole school community this prospect of future with ICT and for ICT, stressing the need, as refers Axelrod (1984), to establish frequent and lasting interactions between individuals, which allow the emergence of cooperation around the use of ICT, particularly the use of an LMS such as Moodle.

Acknowledgments

This work is funded by the CIEd - Centre for Research in Education, projects UID/CED/1661/2013 and UID/CED/1661/2016, Institute of Education, University of Minho, through national funds from FCT / MCTES-PT.

REFERENCES

Alves, M., Kimura, H., Basso, L., & Krauter, E., (2004), O altruísmo nas organizações: interacção e selecção natural, in: Proceedings of XXXII Encontro Brasileiro de Economia, João Pessoa, ANPEC.

Axelrod, R. (1984), The Evolution of Cooperation, New York, Basic Books.

Axelrod, R., Riolo, R., & Cohen, M. (2002), Beyond Geography: Cooperation with persistent links in the absence of clustered neighborhoods, Personality and Social Psychology Review, 6(4), 341-346.

Baek, Y., Jung, J. & Kim, B. (2008), What makes teachers use technology in the classroom? Exploring the factors affecting facilitation of technology with a Korean sample, Computers & Education, 50(1), 224-234.

Balanskat, A., Blamire, R. & Kefala, S. (2006), The ICT Impact Report: A review of studies of ICT impact on schools in Europe, Brussels, European Schoolnet.

Bogdan, R. & Biklen, S. (1994), Investigação Qualitativa em Educação: Uma Introdução à Teoria e aos Métodos, Porto, Porto Editora.

Centola, D. (2010), The spread of behavior in an online social network experimente, Science, 329(5996), 1194-1197.

Fernandes, J. (2008), Moodle nas escolas portuguesas - números, oportunidades, ideias, in: Caldas Moodle' 2008, Caldas da Rainha: EDUCOM – Associação Portuguesa de Telemática Educativa. URL:http://hdl.handle.net/10362/1643 (accessed on 15th October 2010)

Harasim, L., Hiltz, S., Teles, L. & Turoff, M. (1995), Learning Networks: A Field Guide to Teaching and Learning Online, Cambridge, MA, MIT Press.

Hauert, C. (2006), Cooperation, collectives' formation and specialization, Advanced Complex Systems, 9, 315–335.

Kirschbaum, C. & Iwai, T. (2011), Teoria dos Jogos e Micro-Sociologia: Avenidas de Colaboração, Revista de Administração Contemporânea, 15(1), 138-157.

Kollock, P. (1998), Social dilemmas: The anatomy of cooperation, Annual Review of Sociology, 24, 183–214.

Lisbôa, E., Jesus, A., Varela, A., Teixeira, G., & Coutinho, C. (2009), LMS em Contexto Escolar: estudo sobre o uso da Moodle pelos docentes de duas escolas do Norte de Portugal, Educação, Formação & Tecnologias, 2(1), 44-57.

Mueller, J., Wood, E., Willoughby, T., Ross, C. & Specht, J. (2008), Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration, Computers & Education, 51(4), 1523-1537.

Noffke, S.E. & Somekh, B. (2009), The SAGE Handbook of Educational Action Research, London, Sage.

Orbell, J. & Dawes, R. (1993), Social welfare, cooperators' advantage, and the option of not playing the game, American Sociological Review, 58, 787-800.

Pedro, N., Soares, F., Matos, J. & Santos, M. (2008), Utilização de Plataformas de Gestão de Aprendizagem em Contexto Escolar-Estudo Nacional, Lisboa, DGIDC.

Zhao, Y. & Frank, K. A. (2003), Factors affecting technology uses in schools: An ecological perspective, American Educational Research Journal, 40, 807–840.

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal
PEER REVIEWED PAPERS
Vol. 14, n.3, 2018
ISSN: 1826-6223 | eISSN: 1971-8829

COMMUNITY OF PRACTICE ONLINE, THE IMPORTANCE OF TECHNOLOGY FOR LEARNING: AN APPLICATION OF SOCIAL NETWORK ANALYSIS

Stefania Fantinelli
Vanessa Russo

University G. d'Annunzio Chieti - Pescara, Italy

Keywords: community of practice online, blended learning, social network analysis

The pervasiveness of technology is affecting also the education field, so it is possible to evaluate whether technology can foster collaboration among students or improve the learning outcomes.
A community of practice online is the subject of the present study, it represents a kind of blended learning which is defined as the integration of classroom face-to-face learning with online learning experiences with the objective to increase students' engagement and motivation.
A recent experience of blended learning education has been carried out by four Italian Universities and in the present research study we have implemented social network analysis technique in order to observe online interactions of students, thus describing the nodes that exert the most influence in the group and to evaluate if the online interactions can positively affect the learning process.
As result we can state that the outcomes of social network analysis are

for citations:
Fantinelli S., Russo V. (2018), *Community of Practice Online, the Importance of Technology for Learning: an Application of Social Network Analysis,* Journal of e-Learning and Knowledge Society, v.14, n.3, 29-39. ISSN: 1826-6223, e-ISSN:1971-8829 - *DOI: 10.20368/1971-8829/1545*

valuable information for teachers and tutors in order to facilitate participation and collaboration, that in turn promote an effective learning process.

1 Introduction

In order to better frame this work it could be useful to first provide a definition of learning, there are many definitions in literature and we have tried to collect the most meaningful.

According to Kara (2009) there have been several definitions of learning across past years, it can be a better adaptation of the response to the situation and this concept is similar to Stern' intelligence definition which is: a general mental adaptability to new problems and conditions of life. Also Köhler formulated a definition of learning as a consequence or a result, according to the author, learning is the outcome deriving from personal interactions with the environment. Köhler was a Gestalt theorist who defined the concept of *insight learning*, so that learning can be a restructuring or a rearrangement of various elements involved in the situation rather than a simple result of trials and errors.

In 1936 Washburne stated that learning is «an increase, through experience, of ability to gain goals in spite of obstacles» (p. 603) and a sort of balance between goals and obstacles is needed. Boyd and Apps elaborated for the first time, in 1980, a double definition of learning as an act or as a process: learning is the act or process by which behavioural change, knowledge, skills and attitudes are acquired (Hammad, Odeh & Khan, 2017). But nowadays in the most of school systems, learning is approached as a product: activities such as copy a text from the blackboard or doing a dictation, are aimed at evaluating student's performance measured through the outcome of the task, so the process is not evaluated.

Later on Bandura defined learning as «an information processing activity in which information about the structure of behaviour and about environmental events is transformed into symbolic representations that serve as guides for action» (p. 51); according to the *social cognitive theory* (Bandura, 2012) there are three major factors that interacting each other can determine human behaviour and learning: environment, person characteristics and behaviours. Learning can occur either *actively* through actual doing or *vicariously* by observing models perform (live, symbolic, portrayed electronically), so from this moment we can assume that learning is a social process where learners interact with peers or models, as well as with situations.

Humanism scholars describe learning as a human centred activity, a personal act to fulfil potential, for the first time it is expressed the idea of a collaborative and supportive environment in order to facilitate learning, just as it is in an asynchronous environment (Duret *et al.*, 2018). This view is the best fitted in the contest of new technology supporting education and it is the definition of learning which can introduce our objective study.

The aim of our project is to observe a community of practice online where a sort of collaborative learning is involved, so that individuals are active creators of the knowledge building process. As stated by Wenger and colleagues (2002) a community of practice is «a group of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis» (Wenger, McDermott & Snyder, 2002, p. 4). The mix of face to face interactions with technology mediated communication can determine a community of practice, objective of the present project is to determine the relational dimension of a virtual learning community, by applying mathematical models typical of Social Network Analysis (SNA).

2 E-learning

The term "e-learning" has only been in existence since 1999, when the word was first utilized at a *CBT systems seminar*.

E-learning can be defined as «technology-based learning in which learning materials are delivered electronically to remote learners via a computer network» (Zhang *et al*., 2004, p. 76). We can say that distance education is a sort of precursor of modern e-learning, the first distance education course was done in 1840, by letters correspondence. So, we can say that nothing has changed except of tools. In 1972 Moore coined the term *distance education*. He elaborated the theory of Transactional Distance, stating that the education process is essentially based on the relation between the teacher and the learner and it concerns three main issues: environment, persons, behaviours (Beldarrain, 2006). In a distance education – which is also called transaction – communication misunderstanding can easily happen, due to the communication and psychological gap created by the distance. This space is called transactional distance, it is a subjective and variable concept that will change from one person to another; another assumption is that as the level of interaction between teacher and learner decreases, learner autonomy should increase. There are three kinds of interactions in learning activities: students with teachers, students with materials, students with students (*Ibidem*). We see as in an e-learning education the strongest and frequent interaction is the one between students and materials.

E-learning completely changes the traditional world of education: in classroom is the teacher to define time, subjects order and way of information providing. With e-learning the education become student-centred. This approach reflects the constructivist principle of learning as an active process conducted in a self-directed way; in this sense e-learning provides many opportunities by supporting a learning method rich in resources, student-centred and interactive (Zhang *et al*., 2004).

2.1 Blended learning

Technologies designed for education can be described as a continuum, where we can find different levels of technology adoption and where e-learning is in the middle, one step behind we find blended learning.

Blended learning is defined as the attentive combination of classroom face-to-face learning experiences with online learning activities (Dziuban *et al.*, 2018) and it is very close to what happen in a community of practice online.

It could represent one way to tackle those limits of e-learning that we mentioned before; in fact the three interactions described by Beldarrain are all present in this case, in different degrees there will be relations between students and material, teacher and other students.

The main objective of blended education is to redesign the teaching and learning relationship adopting new available technologies, but as some scholars said: it is not enough to deliver old content in a new medium (Dziuban *et al.*, 2018). It means for example that some traditional practice can be reversed: students can attend an online lecture at home instead of in the classroom and then discuss it face to face or do some work together about what learned at home. Another objective is to increase students' engagement and motivation as well.

There has been a sort of prejudice concerning the preference of technology based learning only by young students, but some scholars demonstrated that both young and adult students regard technology as an essential part of their learning experience (Richardson & Jelf, 2013). Moreover recent works have explored the persuasive power that information and entertainment can play in the use of mobile technologies, these features can also enrich the education environment (Fantinelli & Cortini, 2018).

3 Social Network Analysis for Communities of practice online

The use of computer mediated communication (CMC) tools has contributed to the creation of communities of practice and learning online, where individuals work together to create and share knowledge. The evolution of a synchronous and an asynchronous communication (mailing lists, chat, forum, etc.) allows the interaction between social actors and the development of informal roles, in an environment of online education.

At the structural level, the peculiarity of these social groups resides in relational mutation, which develops during the learning process. Communities of practice, in fact, were born as graph structured elements and connections clearly defined, that in the course of their evolution acquire weak ties, informal and unexpected that can get to transform completely the structure, the connotation of roles and the relations trend.

The learning derives from a self-managed, complex and interactive process, that is configured at the structural level as a Sociogram displayed by a graph consisting of nodes and connections among them. At the structural level, the peculiarity of these social groups lies in the alteration of relationships among individuals, that can develop during the learning process.

The SNA is a theoretical and methodological perspective that analyses the social reality from its lattice structure. This implies that the social relationship has to be considered as a minimum unit of observation at the expense of individual attributes (eg, gender, age, education, status, socioeconomic etc.), that are not excluded from the analysis, but traced to one of three possible levels of interdependence of social phenomena: the actors, the connecting relations and the networks that make up the overall structure (Scott, 2018).

The SNA has a fundamental objective: to analyse the complex system of interdependencies and multiple interconnections within society. In particular, the SNA is interested in explaining the dynamics of contamination of interdependencies between systems and social behaviour of individual actors.

The group, in essence, is meant as a complex web of relationships variously structured, preferably readable in a structural and relational key. The networks of relationships, in turn, are seen as dynamic relational systems that provide the context with social action of the actors. The actors are not always driven by an utilitarian or an instrumental motivation, which to varying degrees are influenced in their choices by the rules of the reticular system, but at the same time they are agents of change of the system itself.

4 Method

Objective of the project is to determine the relational dimension of a virtual learning community, by applying mathematical models typical of Social Network Analysis. Through the analysis of formal and informal interactions between users that are part of a community of online learning[1], there are signs of building links in the group. The SNA thus becomes a useful tool for teachers and tutors to identify and compensate for problems in a community of online learning in order to facilitate the participation and collaboration among the students themselves.

In particular, the research objectives are:1. Locate the influx of students from

[1] The learning community detected is part of the project Master "Koinè. Professione formatore per la didattica della comunicazione" (Koinè. Profession trainer for teaching communication) with the Scientific Coordination and Teaching of Prof. Giselda Antonelli.

the Master to the online community; 2. Reconstruct the relational dimension in order to detect nodes that have most influenced the network; 3. Evaluate the effective compliance of the conversations to the topic of search; 4. Assess whether, in this case, the online interactive processes were useful for the education process.

4.1 Stages of Research and methodology

This field of research methodologically borrows an application from the ethnographic method. The ethnographic approach is a non-standard methodology that allows the researcher to analyse the culture and the interactions of social actors in a given context. It is based on three basic actions of the human being: observe, question and read that are accomplished through a set of tools based on direct observation of the phenomenon, in-depth interviews and use of documents (Alinejad, 2018).

The cyberspace as field of research is suitable for the application of ethnographic technique. In fact, it consists of virtual social interactions that unfold through different tools and different networks but which, in fact, generate communication structures, representations of identity and culture which is real and shared (Murthy, 2008; Russo, 2017).

In ethnographic method the stages of research are not strictly defined but they must be designed ad hoc time after time. The stages of research, in this case, are divided into five phases: 1. Observation of the field; hidden observation, individuals in the community are observed and the researcher is not actively involved in the relationship dynamics of the network, this type of observation is also called passive lurking; 2. crawling of the content; a computer process by which it is possible to download the contents of a computer database; 3. content Analysis of "the traces of growth" produced by users and connections; 4. reconstruction of the network interactions and Social Network Analysis; using open source software Gephi it is possible to rebuild the network of relationships and analyse its contents; 5. Identification, users of the Master and classification of influencers this step is important in order to identify the social formal and informal rules.

5 Analysis and observation

The forums are virtual discussions already existent at the time of Web 1.0 and they are constituted of a general topic divided by topics of conversation. These networks are operated by administrator users (Admin) which define procedure rules and, in connection with them, the administrators control the content of the discussions and the users' behaviour.

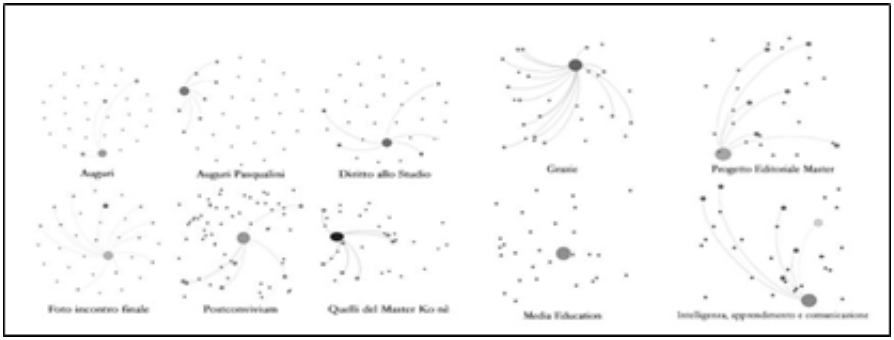

Fig. 1- Network mapping of Forum Cafè

The research started from “Forum Café” (Fig. 1) because we were interested in giving more importance to informal relationships among network users.

The “Forum Caffè” is an informal space into the master forum designed for the development of informal interactions among social actors of the master and it consists of ten rooms of conversation. In all cases the detected threads were consistent with the topic of the room: *Foto Incontro Finale; Auguri Pasqualini; Auguri; Diritto allo Studio; Grazie; Intelligenza Apprendimento e comunicazione educativa; Media Education; Postconvivium; Progetto editoriale Master; Quelli del Master Koinè.*

In order to ensure anonymity of social actors the name were replaced by number labels for students and letters for master’s tutors.

The activities in Forum Caffé were divided in active partecipation and passive partecipation. Active partecipation was for example the creation of contents and discussions into the forum, instead passive partecipation was just the answer to posts.

Ten topics of relations were indentified into Forum Caffè and the structures of network were analized for everyone, in relation to *density graph* and *average connections.*

The *density graph* measures efficiency in the exchange of information and utility for individuals. A smaller graph (as forum topics) with greater density represents a very structured community and it may be less useful than “weak-band networks”, as the latter are more flexible, thus providing a better exchange of ideas and opportunities *Average connection* is a parameter that indicates the extent to which the nodes of a graph tend to be connected to each other. A network with a high average connection shows a social community with a well-defined structure.

The analysis of affinity network in “Forum Caffè” points out a community with a communication system very strong. In fact, the structures of graph and label types are defined and structured.

Furthermore, the communication into Forum Caffè, at an informal level, is managed by a clique of users in an oligarchic mode.

5.1 The Clique and informal rules

The remark made through the reports graphs has highlighted the development of a clique of informal relations. The subgroup is made of 12 students and two tutors who interact with each other based on the arguments typical of the Master topic (Fig. 2).

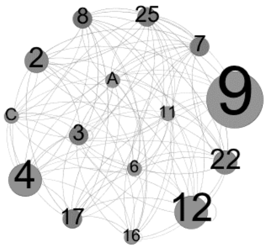

Fig. 2- Informal clique of Forum Caffè

In particular, it must be highlighted the activities of 9, 4, 12 and 22.

Number 9, among all members of the clique, is the most interesting element: it is a real hub in the network of Forum Caffè because he is linked with all members of community. The behaviour of n.9 is compatible with roles of informal teacher; in fact, his content post deals with a clarification and an explanation of the lessons themes.

If number 9 is an informal leader, number 4 is an informal "antagonist leader"; he usually is argumentative and critical of the topics discussed in the forum but he doesn't have the same influence as number 9.

Finally, it is important to underline the roles of numbers 12 and 22. These are two social actors labeled as "debaters" because they usually insist on discussions about lesson's themes.

6 Results

The turnout at the Web Forum by students is very high (75%) but only about the comments to posts. While the active creation of chat rooms concerns only about 21.8% of users of the Forum.

The study of the relational dimension has noted the existence of a clique of relations. The subgroup is dominant within the Network but puts in place behaviours in favour of the process of learning lessons.

The flow of communication within the rooms of the research was always consistent with the topic of reference.

Specifically, in this case study, it was found that the development of a CMC online proved to be functional to the communication process, which is in turn functional to learning.

The SNA thus becomes a useful tool for teachers and tutors to identify and address the problems within a community of online learning, in order to facilitate the participation and collaboration among the students.

Conclusions and future perspectives

Some past studies evaluated student's activity on Facebook as a blended learning environment: McCarthy (2010) found that course engagement increased and students could socialize more easily with peers. It seems that the social dimension is one of the most appreciated by students, indeed results from another study (Irwin *et al.,* 2012) showed that students were more engaged in learning activities thanks to the social interactions offered by the social network platform.

In addition, some variables can influence the effectiveness of Facebook as a learning system: the role of the teacher, the discussion subject, the timing and the order of posts (Lim & Ismail, 2010).

In line with previous researches our results report that online interactions are essential for an effective education; also confirming the assumptions of social cognitive theory (Bandura, 2012).

Communities of practice online through a computer mediated communication can foster interactions and collaborations among students, as already stated by Sun (2014) communication and social interactions are precious elements for an effective learning process.

Indeed, the result of the current study leads to the conclusion that the communication process implemented by the community of practice online is functional to learning.

To conclude we see practical impact and insights deriving by the present study for what concern the planning and the design of online learning activities; furthermore, we suppose that more researches on this field are needed, as the human computer interaction is continuously changing and also the online learning process can be affected by latest innovations in the technological area.

For this reason, the future research perspectives will continue with the application of the presented analysis tool to other learning communities in order to define a multiple case study (Gustafsson, 2017).

The constitution of an analytic system of network applications will converge in a real time evaluation and monitoring model of the learning process in the Communities of practice online.

REFERENCES

Alinejad D. (2018*),* Digital Ethnography: Principles and practice*, Media & Society*, 20(1), 428-431.

Bandura, A. (2012), Social cognitive theory. *Handbook of theories of social psychology: Vol 1* (349-374).

Beldarrain Y. (2006), Distance education trends: Integrating new technologies to foster student interaction and collaboration, *Distance Education, 27*(2), 139-153.

Dziuban C., Graham C. R., Moskal P. D., Norberg A., & Sicilia N. (2018), Blended learning: The new normal and emerging technologies, *International Journal of Educational Technology in Higher Education*, 15(1).

Duret D., Christley R., Denny P., & Senior, A. (2018). Collaborative learning with peerwise, *Research in Learning Technology, 26*, 1-13

Gustafsson J. (2017), Single case studies vs. multiple case studies: A comparative study, http://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf

Fantinelli, S. & Cortini, M. (2018), Informational power and perceived collective benefit affecting the users' preference for a mobile technology: Evidences from a survey study, *Frontiers in Psychology, 9*(JUN).

Hammad R., Odeh M. & Khan Z. (2017), eLEM: A novel e-learner experience model, *International Arab Journal of Information Technology, 14*(4A, 586-597.

Irwin C., Ball L., Desbrow B. & Leveritt, M. (2012), Students' perception of using Facebook as an interactive learning resource at university, Australasian Journal of Educational Technology, 28(7), 1221-1232.

Kara A. (2009), The effect of a learning theories unit on students' attitudes toward learning. *Australian Journal of Teacher Education, 34*(3), 100-113.

Lim T. & Ismail J. T. (2010), The use of Facebook for online discussions among distance learners, Turkish Online Journal of Distance Education, 11(4), 72-81.

McCarthy J. (2010), Blended learning environments: Using social networking site to enhance the first year experience, Australasian Journal of Educational Technology, 26(6), 729-740.

Murthy D. (2008), Digital Ethnography: An Examination of the Use of New Technologies for Social Research, SAGE Publications BSA, Publications Ltd®, 42(5), 837–855.

Richardson J.T.E. & Jelfs A. (2013), Access and Attitudes to Digital Technologies Across the Adult Lifespan: Evidence from Distance Education. In L. Rosen, N. Cheever, L. Carrier (Eds.), *The Wiley handbook of Psychology, Technology and Society* (89-104). Wiley Blackwell.

Russo V. (2017), Digital Ethnography: Theories, Model and Case Studies, in S. Hoskova-Mayerova, F. Maturo, J. Kacprzyk, (Eds.) *Mathematical-Statistical Models and Qualitative Theories for Economic and Social Science*, Springer International Publishing.

Scott J. (2017), *Social Network Analysis*, Sage, London.

Sun S.Y.H. (2014). Learner perspectives on fully online language learning, *Distance Education, 35*(1), 18-42.

Wenger E., McDermott R. & Snyder W.M., (2002), *Cultivating communities of practice*, Boston, Harvard University Press.

Zhang D., Zhao J.L., Zhou L. & Nunamaker Jr., J.F. (2004), Can e-learning replace classroom learning? Communications of the ACM, 47(5), 75-79.

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal
PEER REVIEWED PAPERS
Vol. 14, n.3, 2018
ISSN: 1826-6223 | eISSN: 1971-8829

E-TEACHING IN MATHEMATICS EDUCATION: THE TEACHER'S ROLE IN ONLINE DISCUSSION

Roberto Capone
Flora Del Regno
Francesco Saverio Tortoriello

Department of Mathematics, University of Salerno, Italy

Keywords: E-teaching, Mathematics Education, Discussion, E-learning

This article describes the cross-referenced results of two educational experiments on the use of social platforms in the teaching and learning of mathematics. These were conducted over the course of two years in two mathematics courses at secondary schools in the Campania region of Southern Italy and in two courses of Calculus at University of Salerno, in the south of Italy. It aimed to highlight the role that the teacher assumes in online discussion, revisiting their role as a transmitter of knowledge and taking on the role of facilitator in the acquisition of skills. The qualitative results seem to point to significant benefits in the processes of evolution in the use and coordination of semiotic representation systems. Thanks partly to the help offered by the teacher, the peer comparison between enhanced the transition both from common to evolved language and from interpsychic to intrapsychic functions, i.e. the transition from forms of social activity to forms of entirely individual activity.

for citations:
Capone R., Del Regno F., Tortoriello F.S. (2018), *E-Teaching in Mathematics Education: The Teacher's Role in Online Discussion,* Journal of e-Learning and Knowledge Society, v.14, n.3, 41-51. ISSN: 1826-6223, e-ISSN:1971-8829 - *DOI: 10.20368/1971-8829/1538*

1 Introduction

All teachers build up their own teaching style, which may be based on many different factors, such as personality, principles, and cultural background. It may change over time but, in the absence of further stimuli, some features remain basically the same. The performance of a classroom activity involves the alternation of individual tasks and mathematical discussions. A mathematical discussion can be defined metaphorically as a polyphony of voices articulated on a mathematical object which constitutes one of the reasons for the teaching-learning activity (Bartolini Bussi & Boni, 1995). The educational scenarios of the 21st century are strongly influenced by factors originating outside the school which a teacher cannot ignore or neglect. New technologies enrich our knowledge and culture if they are properly employed and, if teaching is to become effective, it cannot disregard these tools with which our digital native students are so familiar. The novelty of the web lies in the interaction that takes place in real time between teachers and learners or, if the exchange is asynchronous, in the possibility to take advantage of the contents of the lessons at the time deemed most convenient by the student. Other advantages may be found; for example in multimedia, i.e. in the availability of audio, video or image files accompanying the text; in the opportunity to communicate with the teacher through a messaging system or to communicate with them via a webcam; in the possibility to check the progress made by each user (by monitoring the consultation of contents, the results of tests and the successful completion of each stage of the learning process). The research starts with an analysis of the evolution of e-learning up to the third-generation of distance education tools before describing the cross-referenced results of two educational experiments on the use of social platforms for teaching/learning mathematics over the course of two years in two mathematics courses at Secondary schools in the Campania region of Southern Italy, and in two courses of Calculus at University of Salerno, in the south of Italy. Particular attention is focused on the issue of conceptualization, which is justified whenever an item is mathematised, which may occur outside mathematics (mathematization of the real world) or within mathematics (function theory). Several experiments have led to the identification of a broad outline for conceptualisation discussions, which can be divided into separate phases: opening; expression of personal senses; constitution of meanings; cognitive dialectics; institutionalisation (Bartolini Bussi, 1995). The experimentation activity for secondary school students was organized online using a closed Facebook group of which a university lecturer, a researcher and students were members. This group helped to further students' understanding of some mathematical concepts by discussing them together. This activity did not have a fixed duration and each member intervened spontaneously on previous comments, as is usual in online groups. This made it possible to avoid authoritarian behaviour because the students were afforded considerable autonomy by the fact that the teacher acted as a participant and an observer of the quality of the discussion; it also allowed interventions to be carried out on the methodological level, enhancing the negotiation, sharing and stabilization of meanings. It also promoted a peer-to-peer relationship by fostering comparisons with the observations of classmates. The experimentation * involved about 200 students who used the Edmodo social platform during the Mathematics 1 and Mathematics 2 courses, integrated with *social network*, the *blogging,* and the *microblogging* (like Twitter) and the *podcasting* (Branchetti *et al.,* 2018).

These experiments, carried out using new communication strategies, made it possible to reformulate previously proposed concepts and produced clearer and more complete information for the reorganization of classroom activities. They also highlighted the difficulties facing the e-teacher who "is aware of the constant impact of ICT on education, school and society and is able to construct a personal vision/philosophy of learning and pedagogy suited to a knowledge society. This implies the achievement of a personal and intellectual maturity on the part of the teacher, which may take many years". The use of new technologies for teaching is thus an arduous task, but one that is necessary if we are to move properly in a constantly changing educational scenario. The results indicate that the use of social networks among students is widespread. In addition, students show a favourable attitude to those teachers who use social networks as a teaching resource. The frequency of use of social platforms turned out to be quite high among university students, while secondary school students seem to perceive social networks more as a pastime and participated in discussions only if so requested by the teacher. On the contrary, academic activities are frequently initiated by the students themselves. In both cases, the teacher's classroom activity seems to draw considerable advantages, especially in the teacher's perception of the difficulties encountered on some topics.

2 Theoretical framework

The term mathematical discussion was formally introduced into didactic research by Pirie & Schwarzenberger as "discourse focused on a mathematical topic in which there are original contributions from the students and interaction" (Pirie & Schwarzenberger, 1988). Examples of mathematical discussion can be found in the literature on the teaching of mathematics dating from the mid-1980s on. The kind of discourse in the discussion is predominantly of the following pattern: teacher's introduction – students' response – teacher's feedback.

The position of Richards (Bartolini Bussi *et.al,*,1995) also leaves the teacher's role unclear and, in the French scientific tradition, the teacher is assigned the role of moderator because attention is mainly focused on the role of socio-cognitive conflicts (Doise & Mugny 1981), i.e. conflicts that are generated in peer interaction when a strategy is explicitly contradicted by another person taking part in the discussion. Although these examples are different, they are united by the conception of the discussion as "a tool for building domains of consensus through class negotiation in which negotiation on a mathematical subject can take place. Can scientific concepts really be negotiated? Can students in a rich and stimulating situation reconstruct by themselves the quantity and variety of mathematical instruments developed by humanity over the centuries?" (*Ibidem*). The problem is twofold: on the one hand there is the consistency of the student's product with pre-existing knowledge and, on the other, the efficiency of the construction process. In this process the presence of an expert guide seems necessary but, in didactic research, the emphasis on the student's responsibility in learning is not counterbalanced by an emphasis on the teacher's responsibility in teaching (*Ibidem*). The approach to discussion, which aims to ensure that the expert teacher can provide a set of analysis and planning tools without reducing the students' responsibilities has gradually resulted in a distancing from the concepts of constructivist mathematical discussion like those mentioned above, where the teacher's role is unclear and in a search for inspiration from Vygotsky who, when speaking of internalisation, refers to interactions between subjects (teachers and students) who interpret different roles that must both be conserved and enhanced in the teaching-learning activity.

We can distinguish three different types of mathematical discussion:

The discussion of a problem seen as part of the overall problem-solving activity, in turn, presents two aspects: *solution discussion*, meaning the process of the whole class solving a problem expressed in words with the support of objects or images or visualized with application software; *balance discussion*, "meaning the process of information, analysis and evaluation of individual solutions proposed for a problem expressed in words with the possible support of objects or images or in the course of a discussion overseen by the teacher".

Conceptualization discussion is understood as the process of construction through the language of the links between past experiences and particular mathematical terms. This can be introduced by direct or indirect questions such as: "What is a number? What is a graph? Or why have many of you described this problem as a geometrical problem?" The conceptualisation discussion entails the interaction of the whole class overseen by the teacher and focussing on a word or a phrase in order to facilitate the expression of the personal sense given by the individual students to their experiences, to their products, to their processes (referred to by the word or the phrase in question) in meaning, just as it has been crystallized in its sensitive carrier (a word or an association of words) through the social experience of humanity. Several experiments have made it possible to define a broad outline for conceptualization discussions, divided into several phases:

Opening: in this phase the teacher introduces the discussion with questions such as "what do you mean? What does it mean?"

Expression of personal senses: this usually leads to the production of verbal texts perhaps accompanied by drawings or gestures that generally refer to previous experiences, all of which, the subject claims, are attributable to the word or phrase in question.

Constitution of meanings: this is guided by the teacher using the following technique: when a student clearly provides a relevant example that in itself contains the relationships between the fundamental features underlying the mathematical concept, the teacher generalizes the statement replacing the concrete determinations with more general expressions (object, thing instead of a concrete object...)

Cognitive dialectics between personal senses: this is achieved by the teacher explicitly inviting the students to produce statements that do not refer to particular cases (from sense to meaning) and to produce other examples of the same meaning (from meaning to a potential personal sense).

Institutionalisation: this is carried out by the teacher both by establishing (assessing) that certain links are pertinent and by explaining the meanings through their linguistic formulations, which are then recorded in writing on each student's notebook.

Meta-discussion: this is understood as "all those discussions that initially ask a question directly connected to metacognitive activity. It can be implemented by reconstructing the history of the class, often started by reading a passage taken from a previous discussion; discussions on the relationship between reality and mathematics; discussions on the method (what the sense of discussion is)." (Bartolini Bussi *et al.*, 1995).

Although these are different activities, in our experimentation they have been conceived as being ideally connected in a collective path.

3 Social learning and the Edmodo platform

In agreement with the fact that "every function of cultural development appears first on the social and then on the psychological level, firstly among people as an interpsychological category, then within the student as intrapsychological category" (Vygotskij, 1987, p.11), we tried to enhance peer comparison. For this purpose, we used the "Edmodo" social platform and a Facebook group of which all those enrolled in the course were members. Edmodo is a digital platform designed to work with groups of students in a protected environment.

Visually it has a central space where messages appear, enclosed between two service panels on the right and on the left, as in fig.1.

Fig. 1 – Homepage of Edmodo group of Calculus 1

Within the group, communication can be one-to-many (teacher to all, or a student to all) or discrete, (between teacher and student). In addition to dialoguing with the teacher, students can send attachments in the form of documents on which the teacher adds notes online and sends back to the sender (perhaps in one-to-one mode). Other useful tools that the platform offers are a shared library where documents, and images can be stored as well as a calendar reporting the deadlines for homework and test dates and the possibility to create quizzes and manage assessments while protecting privacy. The e-learning approach allowed the students to continuously interact with the teacher and the tutors and made it possible to activate and promote peer-education processes through a constant interaction between all members of the class group.

Students were provided with educational material through the Edmodo platform and simple exercises were proposed for class discussion. The learning material provided to the students and the related exercises aimed to encourage the students to engage in a discussion on the web in such a way that the teacher was able to understand the student's point of view on the topics to be discussed. The classroom lesson stemmed from the students' knowledge and was also oriented on the basis of the most common mistakes or any misconceptions documented and analysed in previous research arising during the debate.

We also tried to promote Self-Regulated Learning (SRL) defined as a "set of processes through which students personally activate and support cognition, emotion and behaviour systematically oriented towards their own objectives" (Zimmermann & Schunk, 2011, p.1). Interaction in a virtual community also proved useful because it facilitated a more natural transition from a colloquial linguistic register to a formal linguistic register.

As can be seen from Figure 2, even when dialogue between students used colloquial language it still allowed the teacher to identify difficulties in how students tackled the exercises.

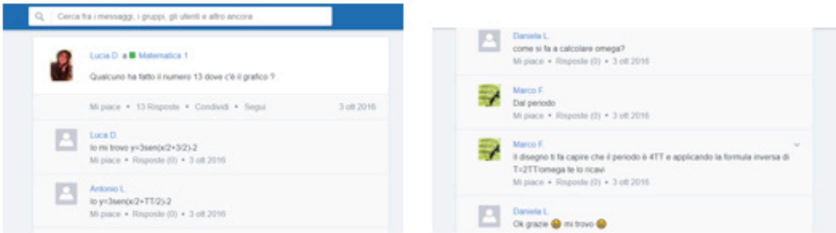

Fig. 2 – Some examples of student dialogue windows

The shared posts and comments left by the students made it possible to identify "Just in time" thematic groups to be studied in-depth and also to intervene on some misconceptions.

4 Experimentation using Facebook and Moodle

A first experiment used a closed Facebook group as a work environment, comprising students from 2 fifth-year (final year) classes of a *Liceo Scientifico* (secondary school focussing on scientific subjects). The topic for discussion was the concept of limit, which is fundamental in mathematical analysis but whose essence is not always understood by students, as emerged from the teaching/learning experiment. In a recent research article on the teaching of mathematics (Tall & Katz, 2014), one thing the authors often asked themselves was if the notion of dynamic change worked in Cauchy's lessons, why is the concept of limit today usually presented to students using definitions that are far beyond their experience? Moreover, the authors wondered if mathematical thinking can develop from the perception of a concept up to more sophisticated forms of reasoning. In looking for an answer, they referred to different theoretical perspectives and theories on the development of mathematical thought (Sfard,1991) which have focused on the way in which human beings perform mathematical operations, such as addition, division, calculation of the limit, derivation and integration. They concluded that, in each phase, a process takes place over time and produces a result that can also be conceived of as a mental entity, independent of time. Cornu (1991) then described how students think of the concept of limit as a process of reduction, as the production of an object that is arbitrarily small but not zero, defined as the *generic limit*.

The reading of the work Katz & Tall made us reflect on number of questions:

why is the concept of limit introduced to students with definitions that are far beyond their experience? Why is the concept of limit difficult to learn and to teach? The answer I have come up with is that very often the concept of limit is introduced in a "sophisticated" way. There is no right or wrong approach to helping the student understand this concept, but rather the "formal" and "non-formal" approach to the theory of limits depends on the context in which the students finds themselves. For this reason I tried to understand how to integrate the two aspects (formal and non-formal) and, while reflecting on this, I thought of tackling it in an environment with which students were familiar – Facebook – as I felt that continuing to teach our students ideas on limits that are implicitly based on a formal, axiomatic approach will give life to a series of generations transmitting ideas that fascinate few but confuse many in a society which has to serve a wider group of students to ensure wider participation within that group.

The decision to use Facebook was dictated by its ability to fill gaps in a timely manner and thus avoid a sense of defeat during the study of Mathematics, and also facilitate interaction with teachers and peers, thereby reducing workload and anxiety. This is made possible by the simplicity of the interface, the possibility of viewing the group on mobile devices and the straightforward feedback system: Facebook users can also easily enter comments or observations at any point of the discussion through a simple link and express their appreciation by clicking on "Like".

Before starting the online activity, a face-to-face meeting was held in order to introduce the activity and to allow me to better understand the students' relationship with mathematics, with respect to non-cognitive variables that influence the learning of mathematics (Di Martino & Zan, 2001). To this end, they were asked to write an essay entitled "In your opinion, what is mathematics?" in one hour. After this meeting, all interactions between students and between students and the researcher/teacher took place exclusively online, within the closed group "Noi e la Matematica" (Mathematics and Us), a name, chosen by the students themselves during the first meeting.

A second experiment was carried out using Moodle. This choice was dictated by the consideration that, unlike Facebook, Moodle is a purpose-built teaching tool that supports active learning, i.e. it makes it possible to build a topic, communicate it, collaborate on it and share it. It also offers a variety of ways to manage interactions through different types of forums and this allowed me to redesign the discussion activity using the Questions and Answers Forum, where each student could see the answers of others only after posting their own, and to add a new topic and reply to comments on the already active discussions. It was thus possible to rule out fake participation, in which a student merely shares the thoughts of others.

This activity took place with fourth-year students, again from a *Liceo*

Scientifico. It began with a face-to-face meeting during which a discussion was started on the concept of function, a topic that they were currently tackling with their class teacher. Subsequently, the activity continued on the platform. The topics covered were those that were taking place in the classroom with their regular teacher.

A third experiment again used the Facebook social network and was conducted on university undergraduates, specifically first-year engineering students who were attending a mathematics course. The experiment was open to all students who wanted to review some topics considered as key prerequisites for subsequent courses. However, particular attention was focussed on the planning of activities aimed at supporting students with educational debits (OFA). The course included 25 hours in class (5 hours a day for 5 consecutive days) and was supported by activities on Facebook, which continued after the end of classroom lessons, until the two tests were held. (about two months). The 63 students taking part in the course were enrolled in a closed Facebook group called "Precorso IngInf". Discussions were activated by posting entry test questions from previous years. In the test, multiple-choice questions were used, while in the group the questions required the candidate to justify the chosen answer:

"Post your answer explaining what reasoning or procedure you followed to reach your answer"

After the students had answered, especially in the case of a wrong answer and an incorrect procedure, they were asked further questions specifically created to stimulate the student to find the mistake made and to identify the correct procedure. After completing the activity, a questionnaire was posted in order to assess the students' feedback on their activity. The questionnaire was administered after the tests in order to make sure, as far as possible, that the responses were not somehow influenced by presumed with the recovery of OFA credits.

Conclusions

The experiments were conducted on 74 secondary school students and 212 university students divided into three groups who interacted with each other and with teachers on closed Facebook groups, through a MOODLE platform and Edmodo.

The activity involving secondary school students on Facebook was quite successful as regards both the active participation of students and the recovery and consolidation of mathematical skills. The students perceived Facebook as a virtual place in which to meet also with a view to discussing the studied topics.

The discussion on the Moodle platform had a greater educational success than that on Facebook because Moodle is a tool designed specifically for teaching. Moreover, thanks to the use of the questions and answers forum, it was possible to avoid answers like "I agree with...". The active participation of some students highlighted an evolution in their way of reasoning that led them from mere procedural execution to argumentation. There was also a blended use of the technologies when they started posting photos of exercises completed in exercise books or on the multimedia interactive whiteboard.

Discussion with university students on a closed Facebook group worked well. There was a very significant participation of those who did not need to recover an OFA debit but who took part because they considered this opportunity as something that would allow them to further investigate the issues in question. This produced a double positive effect: on the one hand, the comparison between peers led to improvements in the topics in question and, on the other, these students served as tutors for their weaker peers, thus providing an additional resource for the teacher, whose presence was widely appreciated for the interventions and the interactions within the group. The onset of discussion in the more advanced phases showed how students are in favour of participating in activities with an instrument that is familiar to them. Obviously, the evolution in the individual reasoning was not the same for everyone. The teacher's interventions never aimed to give the exact answers but were mainly intended to support critical thought, which led some students to enhance their reasoning process, moving from the procedures to the reasons underlying them and to the identification, understanding and recovery of any errors made by them or their peers. The teacher's interventions also resulted in an evolution in the use and coordination of several systems of semiotic representation: for example, some students began to complete exercises not only by using what they remembered but also by exploiting graphical representations. However, there were also interventions by students who, on the other hand, only posted work in which there were calculations. This seems to underline the beneficial effect of having a heterogeneous group, as it was at the beginning, in which there were students with different levels of learning, both people in difficulty and students who did not have any debits. The interaction between these learners seems to have been more fruitful, precisely as Vygotskji intended, because the stronger students represented a zone of proximal development for the weaker ones

REFERENCES

Bartolini Bussi Maria G., Boni M. Analisi dell'interazione verbale nella Discussione Matematica: un' approccio Vygotskiano, nell'Insegnamento della Matematica e delle Scienze Integrate vol 18,3 maggio 1995.

Bartolini' Bussi Maria G., Boni M. Ferri F. (1995). Interazione Sociale e conoscenza a scuola: la discussione matematica in Rapporto tecnico n.21 Nucleo di ricerca in Storia e Didattica della matematica. DMI Università degli Studi di Modena.

Branchetti, L., Capone, R., & Tortoriello, F. S. (2018). Un'esperienza didattica half-flipped in un ambiente di apprendimento SCALE-UP. *Annali online della Didattica e della Formazione Docente*, *9*(14), 355-371.

Cornu, B. (1991). Limits. In D. Tall (Ed.), Advanced mathematical thinking. (pp. 153-166). Dordrecht: Kluwer Academic Publishers.

Di Martino, P., & Zan, R. (2001). Attitude toward mathematics: Some theoretical issues. In M. van den Heuvel-Panhuizen (Ed.), *Proceedings of the 25th conference of the IGPME* (Vol. 3, pp. 351–358). Utrecht, The Netherlands.

Doise, W., & Mugny, G. (1981). *Le développement social de l'intelligence* (Vol. 1). Paris: InterEditions.

Pirie, S. E. B., & Schwarzenberger, R. L. E. (1988). Mathematical discussion and mathematical understanding. *Educational Studies in mathematics*, *19*(4), 459-470.

Sfard, A. (1991). On the Dual Nature of Mathematical Conceptions: Reflections on processes and objects as different sides of the same coin, *Educational Studies in Mathematics* **22**, 1–36

Tall D., Katz M.(2014). A cognitive analysis of Cauchy's conceptions of function, continuity, limit, and infinitesimal, with implications for teaching the calculus. Educational Studies in Mathematics, 86(1), 97-124

Vygotskij, L. (1987). Il processo cognitivo-Raccolta di scritti a cura di Michael Cole, Sylvia Scribner, Vera John-Steiner, Ellen Souberman. Ed. Bollati Boringhieri.

Zimmerman B. e Schunk D.H., (2011) Handbook of Self-Regulation of Learning and Performance, Taylor & Francis

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal
PEER REVIEWED PAPERS
Vol. 14, n.3, 2018
ISSN: 1826-6223 | eISSN: 1971-8829

THE SECOND GENERATION OF FEEEDBACK-BASED LEARNING MODEL (FBL-2G) FOR QUANTITATIVE COURSES IN HIGHER EDUCATION

Yaron Ghilay

The NB School of Design and Education, Haifa, Israel

Keywords: Quantitative course, FBL: Feedback Based Learning, Learning, Higher education, Course website

The aim of the study was to examine the effectiveness of the second generation (2g) of Feedback-Based Learning model (FBL-2g) regarding quantitative courses in higher education. The intention was to examine students' views towards the model and check if there are differences between theoretical quantitative courses such as math or statistics and a computer course. The research was based on three samples of students (n_1=28, n_2=25, n_3=19, n_{total}=72) who studied three quantitative courses based on the new model. All three course sites were prepared and managed by the same lecturer. Students were asked to fill out an online questionnaire to assess various characteristics of FBL-2g and its impact on their motivation and learning process.
The study findings show that according to students' attitudes, FBL-2g is perceived as very effective for learning quantitative courses. All characteristics were highly rated as follows: Diagnosis, prognosis, student

for citations:
Ghilay Y. (2018), *The Second Generation of Feeedback-based Learning Model (fbl-2g) for Quantitative Courses in Higher Education,* Journal of e-Learning and Knowledge Society, v.14, n.3, 53-64. ISSN: 1826-6223, e-ISSN:1971-8829 - *DOI: 10.20368/1971-8829/1521*

motivation and sense of belonging and the contribution to learning improvement. Therefore, it is recommended to support and train lecturers who teach quantitative courses in higher education so that they can use this model making a significant contribution to the students' motivation and learning.

1 Introduction

1.1 General Background

Academic studies in general are considered difficult and require students to face the challenge while making significant efforts. Learning quantitative courses in higher education is particularly difficult because students need to understand complex principles and procedures and acquire the ability to solve complicated problems. Moreover, the quantitative courses are based on a hierarchical knowledge structure, that is, new knowledge based on prior knowledge. Therefore, any gap that a student accumulates can make it very difficult to continue to understand and assimilate the course. To address the problem of growing gaps and promoting students, lecturers are required to conduct an ongoing diagnosis of the learners' situation in order to identify the weak points and intervene in real time. In order to achieve an effective diagnosis, comprehensive and appropriate feedback is needed.

Promoting student success in learning has become an issue of concern among educators all over the world (Elton & Johnston, 2002; Knight & Yorke, 2003; Race, 2005). Substantial numbers of students come into a class with all the appropriate prerequisites yet they are incapable of handling the course material (Wilson & Scalise, 2006). The usual explanation for student difficulties is that students do not study enough or they are not interested (Hesse, 1989). In light of the fact that communication between faculty and students is a critical element of higher education, effective feedback may be the missing component in successful outcomes (Felder & Brent, 2004). Higher education will not be significantly improved, Burksaitiene (2011) argues until the feedback system is changed.

Feedback can have different functions depending upon the learning environment, the needs of the learner, the purpose of the task, and the feedback paradigm adopted (Poulos & Mahony, 2008).

There is a substantial body of research reporting both university student and lecturer dissatisfaction with feedback (Ferguson, 2011). Most student complaints focus on: feedback content, organization of assessment activities, untimeliness of criticism, and lack of clarity about requirements or guidance as to how to use feedback to improve subsequent performance (Huxham, 2007). From the lecturers' perspective, complaints revolve around students not making use of or acting upon feedback in subsequent tasks and being concerned only with the mark (Spiller, 2009). Hence, both students and faculty deplore what is known as the feedback gap (Evans, 2013).

In order to be effective, feedback should close the gap between students' actual performance level and the level required by lecturers. Efficient feedback gives specifics regarding shortcomings (Hattie & Timperley, 2007): Does the information imparted in the critique help students close the gap between current knowledge and the program's desired outcomes (Croton, Willis III & Fish, 2014)? Providing such feedback is not an easy task.

Yet international research indicates that students respond very well to feedback delivered in digital form. A meta-analysis of more than 7,000 studies (Hattie & Timperley, 2007) reveals that multimedia feedback is one of the most effective ways to obtain positive results from feedback. While the term "feedback" refers to information provided to students to encourage them to improve their learning, information from students to lecturers may be just as transformative, assisting academic staff in changing their manner of teaching to better fit learners' needs. Often students are the first notice whether teaching is good or not. That said, too many institutions are not geared to accept student insights in an atmosphere that genuinely welcomes such feedback. Although requesting student feedback on their learning experience at the end of a semester has become common practice in many institutes, their views may not have any actual impact. Institutions of higher education need to create environments and mechanisms that allow student views, learning experiences, and performance to be taken into account (McAleese *et al.*, 2013).

The first generation of Feedback-Based Learning model (FBL-1g) confronts the challenge of getting institutions of higher education to appreciate the validity of students' learning experience (Ghilay, 2017; Ghilay & Ghilay, 2015). It provides immediate student responses to lecturers' practice via use of personal smartphones (or tablets/laptops) to online questionnaires concerning the delivery of the educational program. The model significantly improves student feedback to faculty. It informs lecturers how each subtopic has been understood and implemented by all students in the course. This enables instructors to respond in real time to student difficulties either by explaining topics over again or by discussing issues that are surrounded by lack of clarity. Depending upon the prevalence of the difficulty, a lecturer's response may involve a specific student or the whole class.

1.2 The second generation of Feedback-Based Learning model (FBL-2g)

The current research presents a second generation of the Feedback-Based Learning model (FBL-2g) designated mainly for quantitative courses. The new model is designed to overcome the specific difficulties of the quantitative courses mentioned above by two major activities, diagnosis and prognosis. It is quite clear that the diagnosis phase is critical because the prognosis depends on it. Moreover, in conjunction with any diagnostic activity, there must be appropriate prognostic activity that should produce a desired outcome.

While the previous model (Ghilay, 2017; Ghilay & Ghilay, 2015) uses only one diagnostic component (feedback questionnaires), the second generation is based on four main diagnostic modules. The two major phases of the model are the following:

Diagnosis

A lecturer's initiative:

1. *An online feedback questionnaire*: At the end of every main topic, each student answers an online questionnaire covering all subtopics of the main theme. Students are asked to evaluate the extent to which they understood and assimilated the subjects studied on each topic (1-very little, 2-little, 3-medium, 4-much, 5-very much). In addition, they can add verbal comments about the learning process of the subject, especially understanding and assimilation of the material. The questionnaire can be answered by a smartphone, tablet or PC connected to the Internet.
2. *Daily Monitoring of exercises' status*: All the course exercises and examinations are computerized and the instructor is supposed to supervise the progress of the students. It is possible to check who did not submit a certain exercise even though the date of submission was over, what grade was received, what questions the students had difficulty with, etc. The use of Computer Assisted Assessment (CAA) allows complete remote control of student progress, pointing out weaknesses and difficulties.
3. *Constant monitoring of student attendance (for face-to-face courses) or entries to the course website (for distance courses)*: Using the website tools, the lecturer can monitor the absence of students from the class or their entries to the site.

Students' initiative:

4. *Questions and requests forwarded to the lecturer by the students*: Student questions or requests are another important component of the diagnostic information that serves as the basis for the prognosis stage.

***Prognosis*:**

Difficulties can be solved by explaining unclear issues, adapting the rate of progress to students, and treating each student appropriately and individually. Help of any kind may be provided remotely through the various communication channels and in special cases also by connecting the lecturer to the student computer and providing personal guidance. The lecturer can help students solve exercises if necessary, delay the submission time or add response attempts. If students are missing or inactive, the lecturer can contact them and see if they need help. In cases where students ask a question or make a request, the lecturer must be attentive and respond as quickly as possible through one of the available communication channels. The best way is not to dwell on and give answers on the same day that the request was made. All this is done while creating an ongoing dialogue with the student.

1.3 Examining students' views toward FBL-2g

The study examined students' attitudes regarding various characteristics of FBL-2g model for quantitative courses in higher education. These characteristics were examined in various types of quantitative courses in higher education, both in face-to-face and distance learning: Mathematics, statistics and a computer course (PSPP).

Three groups of students who studied the following courses based on FBL-2g were examined:

1. Mathematics for business administration: first year students
2. Introduction to statistics: first year students.
3. Fundamentals of PSPP (statistical software equivalent to SPSS): third year students.

All students participated, studied in the Department of Management and Economics at the NB School of Design and Education, Haifa, Israel. The three courses included the following topics:

- *Mathematics for business administration:* Functions, linear inequalities, quadratic inequalities, exponents and roots, logarithms, arithmetic sequence, geometric sequence, derivative and integral.
- *Introduction to Statistics:* Introduction - basic terms, measurement scales, group data in tables, visualization of the distribution of frequencies, rules of summation (basic use of Sigma and Sigma rules), measures of central tendency (mode, midrange, median and mean), measures of dispersion, relative position of data (standard scores), distribution of standard scores and the standard normal curve.
- *Fundamentals of PSPP:* Introduction to PSPP, data editor, foundations of descriptive statistics, syntax, case selection, descriptive statistics – additional tools (Descriptives and Explore), means, computerized variables, sort files and data control, independent samples T-Test, paired samples T-Test and one sample T-Test, ANOVA (one way analysis of variance), correlations, crosstabs and chi square test, reliability (Cronbach's alpha including item analysis) and factor analysis.

2 Method

The study examined the students' attitudes towards FBL-2g, which are divided into two categories: Theoretical courses and computer courses. The same lecturer prepared all the course sites and conducted the three courses.

2.1 The research question

The research question intended to examine the characteristics and advantages of FBL-2g for quantitative courses in higher education. The following research question was worded:

> *Based on the learners' views, what are the characteristics and advantages of FBL-2g for learning quantitative courses?*

2.2 Population and Samples

Population: The research population addressed through the study included all those who studied quantitative courses, based on FBL-2g.

Samples: Three samples (Academic year: 2017-18) that have been examined are presented in table 1:

Table 1
THE STUDY SAMPLES

No.	Course	Way of learning	Sample size	Rate of response
1	Mathematics for Business Administration	Face-to-face	28	96.6% (28/29)
2	Introduction to Statistics	Face-to-face	25	92.6% (25/27)
3	Fundamentals of PSPP	Distance	19	100% (19/19)
	Overall		72	

2.3 Tools

Respondents were asked to answer an online five-point Likert scale questionnaire consisting of 19 items (1-strongly disagree, 2-mostly disagree, 3-moderately agree, 4-mostly agree, 5-strongly agree). At the end of the questionnaire, the following open ended question was added: Was the FBL-2g helpful for your studying during the course?

2.4 Data Analysis

The following factors divided into two main categories were examined:

Diagnosis and prognosis:
- Diagnosis: Identifying learning difficulties
- Prognosis: Handling problems.

Outcomes:
- Motivation and sense of belonging.
- The contribution of FBL-2g to learning improvement.

Table 2 summarizes the four factors, the items composing them and the reliability. For each factor, a mean score was calculated (including standard deviation). One Way ANOVA was conducted to examine significant differences among the three courses above. Paired Samples T-test was undertaken as well to check significant differences between pairs of factors ($\alpha \leq 0.05$).

3 Results

Table 3 presents the mean scores of the three samples.

Table 2
FACTORS AND RELIABILITY

Factors	Questionnaire's Questions
Diagnosis: Identifying learning difficulties (Alpha = 0.885)	FBL enables me to inform the lecturer as to topics I did not understand. FBL allows the lecturer to know what difficulties I have encountered. FBL allows the lecturer to know what subjects I am familiar with. FBL enables the lecturer to know my weaknesses and strengths.
Prognosis: Handling problems (Alpha = 0.946)	FBL allows the lecturer to explain unclear issues. FBL highlights the difficulties common to most students in the class. FBL allows for treating specific difficulties even if they are not common to most of the class. FBL allows the lecturer to address problematic issues in learning. The lecturer can adjust the pace of the lesson to students’ progress. FBL allows the lecturer to treat each student appropriately and individually. FBL enabled me to get responses to difficulties I faced.
Motivation and sense of belonging (Alpha = 0.809)	FBL gives me a feeling that the lecturer is interested in me. When the lecturer is interested in my learning, my motivation to study increases. It is important that the lecturer be interested in my learning. Following the FBL, I feel more comfortable in contacting the lecturer.
The contribution of FBL-2g to learning improvement (Alpha = 0.906)	FBL causes me to learn better. FBL causes me to be better prepared for the final exam. FBL enables me to better understand the material that was taught. FBL causes me to have meaningful learning.

Table 3
SAMPLES' MEAN SCORES

Category	Factor	Course	N	Mean	S.D
Diagnosis and prognosis	Diagnosis: Identifying learning difficulties	Math	28	4.61	.55
		Statistics	25	4.56	.76
		PSPP	19	4.64	.48
	Prognosis: Handling problems	Math	28	4.45	.73
		Statistics	25	4.54	.77
		PSPP	19	4.60	.49
Outcomes	Motivation and sense of belonging	Math	28	4.38	.70
		Statistics	25	4.45	.68
		PSPP	19	4.51	.56
	The contribution of FBL-2g to learning improvement	Math	28	4.35	.82
		Statistics	25	4.42	.60
		PSPP	19	4.55	.58

Below are One Way ANOVA ($\alpha \leq 0.05$)) results intended to find out if there are significant differences between the mean scores of all the samples, relating to the factors mentioned above:

1. Diagnosis: Identifying learning difficulties: $F_{(2,69)} = .104,\ p = .901$
2. Prognosis: Handling problems: $F_{(2,69)} = .273,\ p = .762$
3. Motivation and sense of belonging: $F_{(2,69)} = .222,\ p = .802$
4. The contribution to learning improvement: $F_{(2,69)} = .478,\ p = .622$

The above findings indicate that no significant differences were found between the means of all the samples, for all factors. Therefore, the mean factors for all these samples together are shown in Table 4.

Table 4
MEAN FACTORS: THREE SAMPLES TOGETHER

Category	Factor	N	Mean	S.D
Diagnosis and prognosis	Diagnosis: Identifying learning difficulties	72	4.60	.61
	Prognosis: Handling problems	72	4.52	.68
Outcomes	Motivation and sense of belonging	72	4.44	.65
	The contribution of FBL-2g to learning improvement	72	4.43	.68

The findings of Table 4 can be summarized as follows:

Regarding the diagnosis and prognosis, both factors have been very highly rated by learners for all the different courses or ways of learning: Diagnosis - identifying learning difficulties (4.60) and prognosis - handling problems (4.52). Based on Paired samples T-Tests, there was no significant difference between these two factors ($t_{(71)} = 1.691,\ p = .095$). This means that they are very highly and equally rated. In other words, according to students' perceptions, FBL-2g allows lecturers to make an effective continuous diagnosis for each student and to know regularly what problems learners have and what their weaknesses and strengths are. After mapping the difficulties, the lecturer successfully deals with the problems and resolve them for the entire group as well as for each individual student.

As for the outcomes, both factors have been also very highly rated for various courses and ways of learning: students' motivation and sense of belonging (4.44) and the contribution of FBL-2g to learning improvement (4.43). Findings show that there was no significant difference between these two factors ($t_{(71)} = .259,\ p = .797$), that is, they are highly and equally evaluated. The meaning of these findings is that FBL-2g gives students the sense that the lecturer is interested in them, and in their learning, which increases their motivation to learn and ask questions or requests. Besides, the model provides a significant contribution to improving the learning process. This is accomplished by causing students to better understand the material and have meaningful learning.

The open-ended question strengthens the closed items and gives them more validity as presented in the following quotations of respondents:

Mathematics for business administration:

> "*It is a great idea to know what my situation is in terms of understanding the material being studied. This allows the lecturer to assist me during the learning process".*
> "*The feedback method is interesting and allows me to progress in the material in a consistent and safe manner*".

Introduction to statistics:

> "*The method is very useful and allows to solve problems and difficulties before it gets worse.*"
> "*Thanks to the feedback method, all topics were clear and understandable*".

Fundamentals of PSPP:

> "*The feedback was very helpful for my learning process during the course.*"
> "*The lecturer's continuous follow-up of each student's learning process was excellent and helped to overcome problems quickly and efficiently.*"

The above quotes emphasize the high effectiveness of the FBL-2g model for learning quantitative courses in higher education. Because this type of course is difficult to understand and assimilate, such comprehensive feedback is perceived as very helpful to students' learning.

Conclusion

Studying quantitative courses in higher education is difficult because students need to understand and assimilate complex principles and procedures and face the challenge of dealing with difficult quantitative questions.

As mentioned earlier, a quantitative course is based on a hierarchical knowledge structure. Therefore, the accumulation of gaps that grow over time can be problematic and difficult to deal with as time passes. The FBL-2g model offers an effective solution to address this problem. It enables lecturers to continuously diagnose the situation of learners, identify weaknesses and intervene in real time. At first glance, it appears that it is difficult to conduct a quantitative academic course based on these principles. In fact, this is not the case. If the learning processes of all students are well managed from the beginning without accumulating gaps, the course is well advanced and the lecturer does not have to spend too much work later. On the other hand, in the traditional learning method in which the instructor examines the status of learners only at the end of the semester (if any), students can accumulate ever-increasing knowledge gaps until they lose control.

According to the study, the FBL-2g model may be the first step in improving the learning of quantitative courses in higher education. Thus, researchers are invited to examine the model for other quantitative courses and other samples in order to improve its validity.

The current findings indicate that the method should be used in higher education institutions, which teach courses of this type. Unfortunately, not all faculty members are familiar with the various issues of educational technology needed to implement the model. To do this in practice, training programs are needed so that lecturers will be familiar with the creation and analysis of online questionnaires, use Computer Assisted Assessment (CAA) to effectively handle online exercises and exams, and be proficient in effectively monitoring students' activity on the course site. Such knowledge can be purchased on the basis of the TMOC (Training for the Management of Online Courses) model (Ghilay, 2017; Ghilay & Ghilay, 2014).

REFERENCES

Burksaitiene, N. (2011), Promoting student learning through feedback in higher education. *Societal Studies*, 4(1), 33-46.

Croton, B., Willis III, J. E., & Fish, J, (2014). EDUCAUSE Review. URL: http://www.educause.edu/ero/article/passnote-feedback-tool-improving-student-success (accessed on 11th August 2015).

Elton, L., & Johnston, B. (2002), *Assessment in universities: A critical review of research*. York: Learning and Teaching Support Network Generic Centre.

Evans, C. (2013), Making sense of assessment feedback in higher education. *Review of Educational Research*, 83(1), 70-120. http://dx.doi.org/10.3102/0034654312474350

Felder, R. M., & Brent, R. (2004), The intellectual development of science and engineering students. Part 2: Teaching to Promote Growth. *Journal of Engineering Education*, 93(4), 280. http://dx.doi.org/10.1002/j.2168-9830.2004.tb00817.x

Ferguson, P. (2011), Student perceptions of quality feedback in teacher education. *Assessment & Evaluation in Higher Education*, 36(1), 51-62. http://dx.doi.org/10.1080/02602930903197883

Ghilay, Y. (2017), *Online Learning in Higher Education*. Nova Science Publishers-New-York.

Ghilay, Y. & Ghilay, R. (2015), FBL: Feedback Based Learning in Higher Education. *Higher Education Studies*, 5(5), 1-10. http://dx.doi.org/10.5539/hes.v5n5p1

Ghilay Y. & Ghilay R. (2014), TMOC: a Model for Lecturers' Training to Management of Online Courses in Higher-Education. *i-manager's Journal of Educational Technology*, 11(2), 6-16.

Hattie, J., & Timperley, H. (2007), The power of feedback. *Review of Educational Research*, 77(1), 81-112. http://dx.doi.org/10.3102/003465430298487

Hesse, J. (1989), *From naive to knowledgeable*. The Science Teacher.

Huxham, M. (2007). Fast and effective feedback: Are model answers the answer? *Assessment and Evaluation in Higher Education*, 32(6), 601-611. http://dx.doi.org/10.1080/02602930601116946

Knight, P. T., & Yorke, M. (2003), Employability and good learning in higher education. *Teaching in Higher Education*, 8(1), 3-16. http://dx.doi.org/10.1080/1356251032000052294

McAleese, M., Bladh, A., Berger, V., Bode, C., Muehlfeit, J., Petrin, T., Schiesaro, A., & Tsoukalis, L. (2013), *Report to the European commission on improving the quality of teaching and learning in Europe's higher education institutions. Luxembourg: Publications Office of the European Union*.

Poulos, A., & Mahony, M. J. (2008), Effectiveness of feedback: The students' perspective. *Assessment and Evaluation in Higher Education*, 33(2), 143-154.

http://dx.doi.org/10.1080/02602930601127869

Race, P. (2005), *Making learning happen: A guide for post-compulsory education*. London: Sage Publications.

Spiller, D. (2009). *Assessment: Feedback to promote learning*. The University of Waikato, New Zealand: Teaching Development Unit.

Wilson, M., & Scalise, K. (2006), Assessment to improve learning in higher education: The BEAR assessment system. *Higher Education*, 52(4), 635-663. http://dx.doi.org/10.1007/s10734-004-7263-y

Je-LKS
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal
PEER REVIEWED PAPERS
Vol. 14, n.3, 2018
ISSN: 1826-6223 | eISSN: 1971-8829

EVALUATING THE IMPACT OF E-LEARNING ON STUDENTS` PERCEPTION OF ACQUIRED COMPETENCIES IN AN UNIVERSITY BLENDED LEARNING ENVIRONMENT

Damijana Keržič
Aleksander Aristovnik
Nina Tomaževič
Lan Umek

Faculty of Administration, University of Ljubljana, Slovenia

Keywords: Blended learning, Student survey, Competencies, Higher education, Public administration program.

In the present study, the correlations between selected aspects of e-learning in the blended learning environment and the competencies students should acquire during their study are explored. The research was based on two different questionnaire-based surveys conducted among Faculty of Administration students. In the research 41 2nd year students of the university study programme were involved. We found that the problem-solving competency is highly correlated with the adequacy of e-learning. Our findings also suggest a high correlation between the computer skills competency and the usefulness of e-learning. The results could serve as a guide for the faculty management when further investigating how to enhance the students' competencies while employing modern solutions in the teaching process.

for citations:
Keržič D., Aristovnik A., Tomaževič N., Umek L. (2018), *Evaluating the Impact of e-learning on Students` Perception of Acquired Competencies in an University Blended Learning Environment,* Journal of e-Learning and Knowledge Society, v.14, n.3, 65-76. ISSN: 1826-6223, e-ISSN:1971-8829 - *DOI: 10.20368/1971-8829/1440*

1 Introduction

Development of information technologies indirectly called for the emergence of applications in various fields, such as e-commerce, e-banking, e-health, e-government and e-learning. E-learning systems are one of the most important online applications in the field of education, experiencing continuous and rapid development, and gaining an increasingly important place in public and private educational institutions, as well as in organizations offering education and training. Today, various stakeholders, such as students, trainers, academic staff and ICT staff, widely use web applications (Alsabawy*,* Cater-Steel & Soar, 2016; Islam, 2016).

Until now, there has not been so many free information sources available to anyone who wants to learn or supplement their knowledge in a particular subject. On the internet, the access is immediate and possibilities are infinite. Not only have interactions between learner and teacher become easier and more efficient, but the time and space limitations are also significantly mitigated. Nowadays, Internet access guarantees the possibility of a world-class education at minimal, if not zero, costs (Aparicio, Bacao & Oliveira, 2017).

Today's societies encounter globalization and modernization where everything is changing fast. Educational institutions face the challenge of educating their students to be well prepared to function in such varying and complex situations. Nowadays, mere mastery of knowledge is losing in importance while the skills learned by the individual and the competencies they acquire are ever more appreciated. The literature shows the terms "competence" and "competency" are sometimes synonyms while other times their meaning varies (Kennedy, Hyland & Ryan, 2009). In the article, competency refers to a person's individual combination of knowledge, skills, attitudes, thought patterns, and motives that when appropriately applied, singularly or in various combinations, result in successful performance for achieving preferred outcomes. Opposite, "competence" is a state of being able to do certain task.

The European Key Competences Reference Framework (European Council, 2009) defines eight core competencies and five of them are cross-curricular competencies: digital competency, learning to learn, social and civic competencies, sense of initiative and entrepreneurship, and cultural awareness and expression. In higher education, the Bologna reform foregrounds competency-based academic education highlighting learning objectives, learning outcomes and competencies, which allow comparability between studies from all over Europe as well as the mobility of students and teachers. But, this also requires a reorganization of examinations in higher education – measuring the level of competency acquired, which could be regarded the pending task in the European higher education area (e.g. Zawacki-Richter, Hanft & Bäcker2011).

The purpose of the paper is to identify possible relations between students' opinions on specific aspects of e-learning and their self-assessment regarding the level of competencies they have acquired. The paper presents the strength of that correlation and suggests induces how the results could be taken into account when thinking about potential improvements or significant changes in teaching methods at Faculty of Administration.

The paper is structured as follows: after the introduction, which includes a description of the problem and the paper's purpose, a brief literature review on different aspects of blended learning and competencies is presented, followed by the description of data, used methodology and obtained results of our empirical study. At the end, conclusions are offered based on the examined data, accompanied by the study's limitations and plans for our future research.

2 Literature Review

In the last 15 years, the focus in education has shifted from teaching itself towards learning and competencies on the students' side. In the European Higher Education Area (EHEA) students are placed at the heart of the education model and the concept of competency becomes one of the main elements of the learning process. Hence, previous learning model focused on content is transformed into a competence-focused model, which implies a radical change in the learning process. Students are expected to build their own knowledge by searching and processing information. The teacher no longer just spreads the knowledge as it takes up several roles and the process, such as instructor, moderator, coach, collaborator, and organizer (Donnelly, 2004; Fito-Bertran, Hernandez-Lara & Seradell-Lopez, *op. cit.*).

The new concept brought into classrooms is competency-based learning, ensuring students gain skills that seem important for their adult life and career. In this way, the academic world is coming closer to the professional world (Fito-Bertran, Hernandez-Lara & Seradell-Lopez, *op. cit.*). According to Gonzalez and Wagenaar (2003, p. 15), competencies are "…underlying characteristics of a person that are coincidentally related to good or excellent performance at work". Competencies can be divided into two types: specific and generic (Fito-Bertran, Hernandez-Lara, & Seradell-Lopez, *op. cit.*; Gonzalez & Wagenaar, *op. cit.*). Students in higher education acquire not only specific skills and particular knowledge of the field under study but also generic competencies which are common and comparable among different study programmes. Generic competencies are those not necessarily related to a specific subject, such us critical thinking, problem-solving, decision-making, teamwork, logical thinking, finding and managing information, effective communication in the mother and at least one foreign language. Since competencies are generally obtained during the educational process in different courses, they are related to the educational programme. Instead of credits-based education programmes, in the new competency-based concept obtained skills, abilities and knowledge – competencies – are measured. The Tuning final report on the educational structure in the EU stated that "Credits as such are not a sufficient indication of learning achievements. The only reliable way to compare pieces of learning and study programmes offered by (higher) education institutions is to look at learning outcomes/competencies" (Gonzalez & Wagenaar, 2003, p. 45).

The competency-based learning requires different learning approaches, where students become active stakeholders in the learning process, and not just passive learners, and where students independently develop new skills and knowledge (Dunning, 2014; Fito-Bertran, Hernandez-Lara & Seradell-Lopez, 2014). In general, faculties do not drastically change their teaching methods to follow the competency-based concept of learning where, ideally, every student has the opportunity to achieve knowledge and skills to be successful in a competitive society. In recent years, a noticeable change in higher education institutions is the integration of various learning management e-learning systems to support the educational process allowing students to learn at their own pace and facilitates without time or space constraints between teachers and colleagues. Dunning (*op. cit.*, p. 66) concludes that "the delivery of a course, usually by the same professor over many years and in the confines of a classroom, is being overtaken by online delivery of the same course by multiple professors".

Because of the important role of e-learning systems in education, industry, and society scientific studies about various aspects of e-learning systems were conducted recently. Several studies have focused on either factors influencing e-learning (e.g. Novo-Corti, Varela-Candamio & Ramil-Diaz, 2013; Upadhyaya & Mallik, 2013) or the consequences of e-learning, e.g. student performance (e.g. Fryer & Bovee, 2016; Joo, Joung & Son, 2014) or their satisfaction with e-learning (e.g. Novo-Corti, Varela-Candamio & Ramil-Diaz, *op. cit.*; Sun *et al.*, 2008), especially with its usefulness (e.g. Alsabawy, Cater-Steel & Soar, 2016). Recently, gamification is used as one of the ways in online learning environment. Among the researchers, the subject of surveys is also the acquisition of competencies in e-learning compared to face-to-face. For example, in their research, Fito-Bertran, Hernandez-Lara, and Seradell-Lopez (*op. cit.*) found that (generic and managerial specific) competencies acquired by students via a business game are assessed as higher when students learn online compared to face to face. Similar conclusions have been made in the field of medical and nursing studies (e.g. Reime *et al.*, 2008), where various software for virtual reality offers simulations, virtual patients and clinical scenarios, and immediate access to information and educational materials (for example clinical images, anatomical atlas...), which enables efficient and personalized learning to assess the clinical skills and reasoning of medical students. In the research, Galbis-Córdova, Martí-Parreño and Currás-Pérez (2017) found that students' attitude towards gamification is related to whether the game draws one's attention, the ability to change difficulty of the game according to one's abilities and, last but not least, one must perceive the importance of the game for acquiring competencies.

3 Empirical Study

The research presented here was conducted among students of the Faculty of Administration (FA), which is part of the University of Ljubljana, Slovenia. The FA educates students in the field of administrative science. The Faculty offers two undergraduate study programmes (1st cycle) – University Study Programme in Public Sector Governance and a Higher Education Professional Study Programme in Administration. Both programmes are provided in a combination of traditional face-to-face teaching and e-courses where LMS Moodle has been used for e-learning since 2009.

The present study aims to analyse two long-running surveys (students' evaluation of e-learning aspects and their evaluation of the competencies acquired) at the FA and to find links between them. Since both surveys depend on students' opinions, we added an objective performance measure, namely students' average grade. For each individual student who participated in our survey, we collected 7 opinions on e-learning, 25 opinions on the level of competencies acquired and the average grade for all exams a student had passed.

3.1 Data

Our data originate from two different questionnaires; one on competencies and the other on aspects of e-learning. The survey on competencies is based on a questionnaire initially intended for FA graduates. Part of this questionnaire comprises a list of 25 competencies students should acquire during their studies (Table 1).

Table 1
LIST OF COMPETENCIES INCLUDED (S – SPECIFIC, G – GENERIC)

Label		Description
C1	S	Professionalism and practical experience in the field of administration.
C2	S	Knowledge of and dealing with research methods and procedures in the field of social sciences.
C3	G	Ability to analyse, synthesize and anticipate solutions and consequences of a phenomenon.
C4	S	Ability to be critical or self-critical in social issues.
C5	G	Ability to obtain maximum results in negotiations.
C6	G	Ability to keep functioning effectively when under pressure.
C7	G	Ability to take advantage of an opportunity, being proactive.
C8	G	Ability to coordinate activities (in a team).
C9	G	Ability to efficiently use time.
C10	G	Ability to cooperate productively in a team.
C11	G	Ability to motivate people (and move toward a common goal).
C12	G	Ability to speak clearly and be easily understood.
C13	G	Ability to establish own authority.
C14	G	Skills in the use of information (from the Internet) and communications technologies.
C15	G	Capacity to generate new ideas and solutions.
C16	G	Ability to discuss values in approaches, ideas, and solutions of oneself and others.
C17	G	Ability to solve problems.
C18	G	Ability to make business decisions autonomously.
C19	G	Ability to present ideas, arguments, ideas, or reports clearly and concisely.
C20	S	Ability to write reports, records, and documents in the administration.
C21	G	Ability to communicate verbally and in writing in at least one foreign language.
C22	S	Professional knowledge of other countries in the fields of economics, society and the law.
C23	G	Knowledge of cultural differences.
C24	G	Ability to work with people from different cultural backgrounds.
C25	S	Ability to assess acts and practices in accordance with professional ethics in administration.

We asked students to express their opinions on the competencies they had acquired on a 6-level scale from 1 (“not acquired at all”) to 6 (“fully acquired”).

The second data source is a questionnaire-based survey started in 2014 at the FA (see Aristovnik, Tomaževič, Keržič & Umek, 2017). Once a semester we ask our students to evaluate several aspects of e-courses in which they are enrolled. In addition to questions about a specific e-course, the questionnaire includes several general statements about e-learning. This part of the questionnaire is therefore used for our survey. The list of these selected aspects is shown in Table 2.

Table 2
ASPECTS ABOUT E-LEARNING

Label	Description
A1	Working with computers for study purposes suits me.
A2	The Moodle e-learning system is easy to use.
A3	The Moodle system is reliable and stable (it does not crash, submitted tasks are not lost).
A4	I am satisfied with the support and assistance in the event of technical problems.
A5	Working with computers for study purposes is not difficult for me.
A6	E-learning contributes to higher student academic performance.
A7	E-learning is a quality replacement for traditional learning in the classroom.

The students expressed their opinions on the statements in Table 2 on a seven-point Likert scale from "completely disagree" (value 1) to "completely agree" (value 7). Students can also choose N ("do not know") or even to not respond at all since survey participation is not obligatory. Missing responses and the value of N in the survey analysis are considered as missing values and were excluded from the study.

During the 2016/17 academic year, 2nd year students of the university study programme were involved in the research. Our population of interest were 84 students, 51 (61%) of them participated in the survey on competencies and 45 (54%) in the survey of aspects of e-learning; 41 (49%) participated in both surveys. Student voluntarily participated in the survey, without any coercion or undue influence. Both questionnaires (on competencies and on aspects of e-learning) were carried out on-line. In both surveys, we ask them students for their student ID number to help us link the obtained results with various sources. Data from both questionnaires answered by 41 students were analysed. Basic demographic properties of our data set are:

- Gender: male 34%, female 66%;
- Region: Ljubljana 56%, outside Ljubljana 41%, abroad 2%;
- High school final grade: sufficient (2) 44%, good (3) 44%, very good (4) 7%, excellent (5) 5%.

3.2 Methodology and Empirical Results

We calculated 175 Spearman's correlation coefficients between 25 competencies (C1…C25) and 7 aspects (A1…A7) of e-learning and 32 correlations between the average grade (AG) and all competencies and aspects of e-learning. Altogether, we computed 207 Spearman's correlations and corresponding p-values. Due to the large number of hypotheses tested, we adjusted p-values using a False Discovery Rate (FDR) correction (Yoav &

Hochberg, 1995). For a FDR level of 0.2, we found 27 significant correlations (14% of all pairs we analysed).

Table 3 shows 27 significant correlations (Spearman's r) between analysed competencies (C1…C25), aspects of e-learning (A1…A7) and the average grade (AG) and corresponding significances (Sig.).

Table 3
SIGNIFICANT CORRELATIONS (R) BETWEEN ANALYSED COMPETENCIES (C1...C25), ASPECTS OF E-LEARNING (A1...A7), AND THE AVERAGE GRADE (AG)

Pair	r		Sig.	Pair	r		Sig.	Pair	r		Sig.
C21	AG	0.601	3.29E-05	A1	AG	0.440	0.004	C4	A1	0.396	0.010
C17	A1	0.584	6.06E-05	C16	A1	0.437	0.004	C7	A1	0.386	0.013
C14	A6	0.549	2.03E-04	C16	AG	0.435	0.004	C15	AG	0.380	0.014
C19	AG	0.541	2.59E-04	C18	A6	0.433	0.005	C5	A5	0.370	0.017
C21	A1	0.533	3.37E-04	C6	AG	0.431	0.005	C24	A1	0.365	0.019
C12	AG	0.517	0.001	C4	AG	0.422	0.006	C5	AG	0.361	0.021
C8	AG	0.479	0.002	C6	A1	0.413	0.007	C13	A6	0.359	0.021
C15	A1	0.474	0.002	C21	A2	0.412	0.007	C25	A3	-0.356	0.023
C15	A6	0.454	0.003	C25	A6	0.408	0.008	C24	A5	0.352	0.024

The strongest correlation we discovered was between the competency of "speaking, reading, and writing in a foreign language" (C21) and average grade (AG). The correlation coefficient of r=0.601 indicates that students who think their competencies of communicating in a foreign language are good tend to have higher average grades. The correlation is significant (p=3.3E-5).

The second pair indicated quite a strong positive correlation (r=0.584) between the competency of "solving problems" (C17) and the aspect of "suitability of working with computers in the study process" (A1). This means that students who like using computers for studying think they are good at solving problems. The correlation is significant (p=6.1E-5).

The last pair we describe in more detail is the correlation of r=0.549 between the competency "using information and communications technologies" (C14) and aspect "contribution of e-learning to academic performance" (A6). This means that students who think that e-learning contributes to their better performance (i.e. high grades, lower number of admissions to exams) have a higher ability to work with computers and use information from the Internet. The correlation is significant (p=2.0E-4).

To summarize other significant findings we present two tables. In Table 4, we list all seven aspects of e-learning from our survey and the number of significant associations with competencies and average grades. For each aspect, we list competencies with a significant correlation and determine its correlation with the average grade.

Table 4
All Aspects of e-Learning from the Survey and Significant Correlations with Competencies and Association with Average Grade

Aspect of e-learning	Significant competencies	Association with AG
A1	C17, C21, C15, C16, C6, C4, C7, C24	Yes
A6	C14, C15, C18, C25, C13	No
A5	C5, C24	No
A2	C21	No
A3	C25	No
A4	0	No
A7	0	No

Table 4 indicates that the “suitability of working with computers in the study process” (A1) is strongly linked to eight competencies, including “solving problems” (C17) (r=0.584, p=6.1E-5), “speaking, reading, and writing in a foreign language” (C21) (r=0.53, p=3.3E-4) and “generating new ideas and solutions” (C15) (r=0.47, p=1.7E-4). All other correlations are positive and exceed 0.3. This aspect is also significantly correlated to the average grade (r=0.44, p=4.0E-4).

The second most influential aspect of e-learning was “contribution to academic performance” (A6), significantly linked to five competencies but not to the average grade. The significant competencies include “using information and communications technologies” (C14) (r=0.549, p=2.0E-4), “generating new ideas and solutions” (C15) (r=0.545, p=2.8E-4) and “ability to make autonomous business decisions” (C18) (r=0.433, p=4.6E-4).

The other aspects of e-learning resulted in less significant associations. Two of them, “satisfaction with technical support” (A4) and “replacement of face-to-face learning” (A7), produced no significant results. Table 5 presents 16 (out of 25) competencies with at least one significant correlation with either aspects of e-learning or the average grade.

Table 5
COMPETENCIES WITH SIGNIFICANT CORRELATIONS WITH EITHER ASPECTS OF E-LEARNING OR THE AVERAGE GRADE

Competency	Significant aspect of e-learning	Significant association with AG
C21	A1, A2	Yes
C15	A6	Yes
C24	A1, A5	No
C25	A3, A6	No
C16	A1	Yes
C4	A1	Yes
C5	A5	Yes
C6	A1	Yes
C14	A6	No
C17	A1	No
C18	A6	No
C13	A6	No
C7	A1	No
C12		Yes
C8		Yes
C19		Yes

Conclusion

The Bologna Process introduced a common European area of higher education, which called for many changes to be made at European universities. Due to the comparability of studies across Europe and the mobility of students and teachers, the focus in learning is shifting to competencies and skills based on knowledge. Knowledge alone is not enough – what is also important is which (professional) skills and competencies a student acquires and how they are able to use them. This, of course, has affected educational methods and student performance evaluations. We can certainly expect that education will increasingly take place in e-learning. Therefore, if we want e-learning to be successful, we need to understand the affecting factors.

In our study, we explored the correlations between the selected aspects of e-learning in the Moodle environment and the competencies students should acquire during their study. The research was based on two different questionnaires administered to Faculty of Administration students. We found that the competency of problem-solving is highly correlated to the adequacy of e-learning. One of the major problem we are facing in voluntary participation in survey research is the low responsiveness of our students, which was evident also in this case. This holds especially for students with lower grades – in the future we will pay more attention to motivate them to overcome potential bias in our sample. On the collected data, the survey results showed that the competency of problem-solving is highly correlated to the adequacy of e-learning. Our findings also suggest a strong correlation between the competency of computer skills and the usefulness of e-learning. Indeed, one of the main pre-conditions for benefitting from e-learning system use is that students have higher abilities in working with computers and using information from the Internet.

Our study's main limitation is measuring the level of competencies acquired. The recent measurement is based on self-evaluation which can produce biased results: some students overestimate their abilities while others underestimate them. Future work will focus on more objective measurements. One possible improvement will be to analyse competencies from course syllabuses and to link the listed competencies with grades in various courses. It will be also more relevant to ask the students about the level of competency acquired in the last year of study since our questionnaire was based on the survey, initially focussed on graduates. Nevertheless, the results we obtained could serve as a guide for faculty management when further investigating how to enhance students' competencies while employing modern solutions in the teaching process.

REFERENCES

Alsabawy, A. Y., Cater-Steel A., & Soar, J. (2016), Determinants of perceived usefulness of e-learning systems. *Computers in Human Behavior*, *64*, 843–858. doi:10.1016/j.chb.2016.07.065

Aparicio, M., Bacao, F., & Oliveira, T. (2017), Grit in the path to e-learning success. *Computers in Human Behavior*, *66*, 388–399. doi:10.1016/j.chb.2016.10.009

Aristovnik, A., Tomaževič, N., Keržič, D., & Umek, L. (2017). The impact of demographic factors on selected aspects of e-learning in higher education, *The International Journal of Information and Learning Technology*, 34(2), 114–121.

Donnelly, R. (2004), Different Thinking Hats: The Continuously-Evolving Role of the Instructor in E-Problem Based Learning (E-PBL), in L. Cantoni & C. McLoughlin (Eds.), Proceedings of *EdMedia: World Conference on Educational Media and Technology 2004* (pp. 2864–2870). Waynesville, NC: Association for the Advancement of Computing in Education (AACE). URL: https://www.learntechlib.org/d/12418 (accessed on 15th March 2017).

Dunning, P. T. (2014), Developing a competency-based assessment approach for student learning. *Teaching Public Administration, 32*(1), 55–67. doi:10.1177/0144739414522480

European Council (2009), Council conclusions of 12 May 2009 on a strategic framework for European cooperation in education and training ('ET 2020'). *Official Journal C, 119*(28/5/2009). doi:10.3000/17252423.C_2009.119.eng

Fito-Bertran, A., Hernandez-Lara, A. B., & Seradell-Lopez, E. (2014), Comparing student competences in a face-to-face and online business game. *Computers in Human Behavior, 30*, 452–459. doi:10.1016/j.chb.2013.06.023

Fryer, L. K. & Bovee, H. N. (2016), Supporting students' motivation for e-learning: Teachers matter on and offline. *Internet and Higher Education, 30,* 21–29. doi:10.1016/j.iheduc.2016.03.003

Galbis-Córdova A., Martí-Parreño J., & Currás-Pérez R. (2017), Higher Education Students' Attitude towards the Use of Gamification for Competencies Development. *Journal of e-Learning and Knowledge Society, 13*(1), 129–146. doi: 10.20368/1971-8829/1279

Gonzalez, J. & Wagenaar, R. (Eds.) (2003), *Tuning educational structures in Europe*. Final report. Phase one. Bilbao: Universidad de Deusto. URL: http://tuningacademy.org/wp-content/uploads/2014/02/TuningEUI_Final-Report_EN.pdf (accessed on 3rd April 2017).

Islam, A. K. M. N. (2016), E-learning system use and its outcomes: Moderating role of perceived compatibility. *Telematics and Informatics*, *33*(1), 48–55. doi:10.1016/j.tele.2015.06.010

Joo, Y. J., Joung, S., & Son, H. S. (2014), Structural relationships among effective factors on e-learners' motivation for skill transfer. *Computers in Human Behavior*, *32*, 335–342. doi: 10.1016/j.chb.2013.08.011

Novo-Corti I., Varela-Candamio, L., & Ramil-Diaz, M. (2013), E-learning and face to face mixed technology: Evaluating effectiveness of e-learning and perceived satisfaction for a microeconomic course using the Moodle platform. *Computers in Human Behavior, 29*, 410–415. doi: 10.1016/j.chb.2012.06.006

Reime, M. H., Harris, A., Aksnes, J., & Mikkelsen, J. (2008), The most successful method in teaching nursing students infection control – E-learning or lecture? *Nurse Education Today*, *28*, 798–806. doi: 10.1016/j.nedt.2008.03.005

Sun, P. C., Tsai, R. J., Finger, G., Chen, Y. Y., & Yeh, D. (2008), What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers and Education, 50*(4), 1183–1202. doi: 10.1016/j.compedu.2006.11.007

Upadhyaya, K. T. & Mallik, D. (2013), E-learning as a socio-technical system: an insight into factors influencing its effectiveness. *Business Perspectives and Research*, *2*(1), 1–12. doi:10.1177/2278533720130101

Zawacki-Richter, O., Hanft, A., & Bäcker, E. M., (2011), Validation of competencies in eportfolios: a qualitative analysis. *International Review of Research in Open and Distance Learning, 12*(1), 42–60. URL: http://www.irrodl.org/index.php/irrodl/article/view/893/1671 (accessed on 15th June 2017).

Yoav, B. & Hochberg, Y. (1995), Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B, 57*(1), 289–300. doi:10.2307/2346101

Je-LKS
PEER REVIEWED PAPERS
Vol. 14, n.3, 2018
ISSN: 1826-6223 | eISSN: 1971-8829
Journal of e-Learning and Knowledge Society
The Italian e-Learning Association Journal

A GENTLE INTRODUCTION TO COMPUTATIONAL COMPLEXITY THROUGH AN EXAMINATION OF NOODLE MAKING

Luisa Mich[1]
Daniel M. Berry[2]

[1] Department of Industrial Engineering, University of Trento, Trento, Italy
[2] Cheriton School of Computer Science, University of Waterloo Waterloo, Canada

Keywords: Algorithm, Computational complexity, Computational Thinking, Computer Science curriculum, Teaching.

Computational complexity is regarded by many Computer Science students as extremely difficult and as a topic to be avoided. However, the concepts of an algorithm and of computational complexity as a means of characterizing the resource consumption of algorithms are fundamental in Computer Science and are included in all curricula for it. To better motivate students and to increase their interest in computational complexity, this paper suggests introducing it by examining algorithms, a.k.a. recipes, for making noodles. This paper describes several traditional algorithms for making Chinese and Italian noodles and classifies each according to its computational complexity. It compares the power of the algorithms. It considers the nature of variations of the traditional algorithms. It examines machines that implement some of the algorithms. It cites a world speed record for making a large number of noodles using the algorithm with the maximal complexity. It shows how computational thinking and other topics can be introduced in the same

for citations:
Mich L., Berry D.M. (2018), *A Gentle Introduction to Computational Complexity Through an Examination of Noodle Making,* Journal of e-Learning and Knowledge Society, v.14, n.3, 77-92.
ISSN: 1826-6223, e-ISSN:1971-8829 - *DOI: 10.20368/1971-8829/1399*

manner. It concludes by mentioning avenues for further studies.

1 Introduction

A key question in Computer Science is “What can be (efficiently) automated?” (Dennis (Editor) *et. al.*, 1989). Answering this question requires understanding (1) how to devise algorithms to solve problems and (2) how to compare the efficiency of algorithms. Comparing the efficiency of algorithms entails comparing algorithms by their consumption of space and time as they run on the same inputs. A characterization of the run-time space and time consumption of an algorithm as a mathematical function of the size of an input to the algorithm is called the *computational complexity* of the algorithm. Computational complexity is fundamental for computational thinking and therefore for many disciplines, not just for computer science (Wing, 2006; Guzdial, 2008; Yadav, Stephenson & Hong, 2017).

Computational complexity as part of the theory of computability was included in ACM’s Curriculum 68 (Atchison *et al.*, 1968). Computational complexity was listed as one of the eight major components of the theory of algorithms and data structures in a framework for the discipline of computing (Denning (Editor) *et al.*, 1989) that served as a basis for a 1989 update to Curriculum 68. The 2001 Joint, ACM and IEEE-CS, Task Force on Computing Curricula included algorithms and complexity as one of the areas, namely Area 1, of the body of knowledge of Computer Science (The Joint Task Force on Computing Curricula, 2001). According to the glossary of the Task Force report, Algorithms and Complexity includes: “Computational solutions (algorithms) to problems; time and space complexity with respect to the relationship between the run time and input and the relationship between memory usage and input as the size of the input grows.”

Since the 2001 report, computational complexity has been introduced as a core or secondary topic in courses for undergraduate degree programs in Computer Engineering, Computer Science, Information Systems, Information Technology, and Software Engineering (ACM, undated). An item “Notion of algorithmic complexity” is included even in the ACM’s Computer Science Teacher Association K-12 CS Standards (CSTA, 2011).

Beyond the mathematical roots of computational complexity and computational complexity’s direct links with other computer science topics such as data structures and programming, computational complexity helps to understand the concept of automation in terms of “what computer technologies can and cannot do, and the impact of individuals, organizations and society of deploying technological solutions and interventions” (Shackelford *et al*., 2006, p. 36).

Computational complexity is notoriously a topic that computer science students find difficult (Gasarch, 2015; Trakhtenbrot, 2013; Gasarch, 2017) and, along with general theory of computation, do not like (Meek, 2012; Duan, 2017; Reddit, undated; Wang 2017). It is viewed by many as – shall we say – horribly and impossibly complex! Traditional approaches to teach computational complexity usually treat complexity determination as a mathematical problem, often illustrated by algorithms for searching and sorting of data. To better motivate students and possibly to increase student interest in computational complexity, this paper proposes a novel way to introduce it by describing algorithms, a.k.a. recipes, for making noodles. In particular, Section 2 of this paper compares the computational complexity of several traditional algorithms for making Italian and Chinese noodles. This section also cites a world speed record for making a large number of noodles using a traditional Chinese algorithm that is shown in this paper to require log n time to make n noodles, illustrates machines that implement some of the algorithms, and considers variations of the basic algorithms to make variations of the basic noodles. To demonstrate the applicability and the potential of the proposal, Section 3 reports data on how a previous version of the paper published online in a Computer Science satire conference proceedings[1] (Berry & Mich, 2016) went viral. Section 4 describes some other important Computer Science concepts that can be introduced through examination of noodle making algorithms. The conclusion in Section 5 mentions avenues for further studies. The References section includes an item (Berry & Mich, 2017) that points to an online site which contains (1) the previous version (Berry & Mich, 2016) of this paper and (2) slides for a lecture based on this previous version. Each of these in turn points to sites with videos of the operation of the various algorithms.

2 The Computational Complexity of Chinese and Italian Noodle Making

This section reproduces with a few modifications the essence of the previous version of this paper (Berry & Mich, 2016).

2.1 Introduction to Examination of Noodle Making

Each of the Chinese and the Italians make and eat a large variety of dough-based products of various sizes and shapes. This paper uses "noodle" as general term to name a single unit of any product of this type regardless of its national

[1] The present paper is a variation of this previous version. It includes almost verbatim the sections from the previous paper that describe the noodle making algorithms, their complexity, and a number of open questions. It adds material about the place of computational complexity in Computer Science curricula and the difficulties experienced in teaching it, as motivation for its proposal to consider the previous paper and a talk based on it as educational resources.

origin and regardless of its size and shape[2]. The Chinese call their noodles "miàn tiao" (面条) or just "miàn", and the Italians call their noodles "pasta". Therefore, this paper uses "miàn" and "pasta" when talking about Chinese noodles and Italian noodles, respectively. Note that "miàn" and "pasta" are collective nouns that denote collections of noodles. Thus, this paper needs to use "strand", perhaps prefixed by "miàn" or "pasta" as an adjective, when talking about one unit[3] of miàn or pasta.

This paper presents one key algorithm from each of China and Italy to make the country's most traditional kind of noodles from already made dough of the proper composition for what is being made. Later, it presents some other algorithms, again from China and Italy, for making other kinds of noodles. Each algorithm is characterized by its computational complexity, as a function of the number, *n*, of noodles produced. There are actually two complexity measures, the *local complexity* and the *global complexity*.

The local complexity is for time required for the algorithm to make one batch of noodles. Generally, the number of noodles that can be made in one batch is limited by a combination of the resources available and the physical properties of the noodle dough. The resource limits that come into play include the amount of flour that can be handled conveniently by the noodle maker, the amount of dough that can be worked on by the noodle-maker's rolling pin, the amount of dough that can be fed at once through a flattening device's rollers, the amount of flattened dough that fits on the noodle-making table, and the amount of flattened dough that can be fed at once through a cutting device. The main physical property of the noodle dough that comes into play is that a noodle with too small a cross section tends to break as it is stretched.

The global complexity is for the time required to make, with successive applications of the algorithm, enough batches to yield all the noodles needed for an occasion. Of course, in a home or in a restaurant that makes noodles to order, usually one batch suffices. In any case, the global complexity is always linear in the number of noodles produced, on the assumption that any algorithm requires about the same amount of time every time it is used to make the same-sized batch of one kind of noodles. Therefore, for each algorithm, only its local complexity is given.

2.2 Traditional Chinese Miàn Algorithm

It appears that the signature variety of miàn in China is the hand-pulled va-

[2] Admittedly, the term "noodle" connotes a string-like product, e.g., spaghetti. Nevertheless, even though many such products are string like, the term is generalized in this paper to include even short products, e.g., maccheroni or macaroni, and even shaped products, e.g., farfalle or bowties.

[3] Just as with "noodle", the term "strand" is used even when the unit is shaped differently from or is shorter than what is normally called a strand or noodle.

riety known as lā miàn, which originated in and around Lan Zhou, the largest city in the Gansu Province of Northwest China. Lā miàn is made by starting with a single strand of dough and repeatedly stretching and folding it to produce a large number of thin strands, the diameter of the final strands depending on the diameter of the single initial strand and the number of folds.

1. The lā miàn maker takes a previously prepared tube of very flexible dough of diameter D and of length L. (L needs to be no longer than the distance across the lā miàn maker's two outstretched arms, and D needs to be no bigger than what the lā miàn maker can grip with one closed hand.) Call this tube of dough "the *initial* bundle".
   - He[4] dusts the bundle with flour.
   - He folds the bundle in half and pinches each end,
     – in one case, to merge two ends into one, and
     – in the other case, to make an end out of a fold.
   - The bundle is now of length $L/2$.
   - By twirling the new bundle like a jump rope, he streches the new bundle back out to the original length, L.
   - The result is a new bundle with twice the number of strands as the previous bundle, and the diameter of each strand in the new bundle is $1/\sqrt{2}$ times the diameter of each strand in the previous bundle. These steps are repeated until the strands are of the desired diameter.

2. The lā miàn maker trims off the ends to leave strands of length $0.9 \times L$. Then, the lā miàn maker lays out the bundle of strands on the table and, in one swift cut perpendicular to the long axis of the strands, cuts all strands to leave two bundles of strands of length $0.45 \times L$.

For a video showing a Chinese chef making lā miàn, see https://www.youtube.com/watch?v=PHoQN9vQwHE, particularly the last minute and a half.

On the assumptions that D is 1 inch, that L is 1 meter[5], and that the final miàn are 1/16 inch (≈ 1.59 mm) in diameter, there are 8 folding and stretching steps, producing 256 trimmed strands each of length 90 centimeters. Then, the final cutting step produces 512 miàn, each of length 45 centimeters.

The local complexity of this traditional Chinese miàn making method is $\log_2 n$ to make $n = 2^m$ miàn in $m - 1$ folding-and-stretching steps making and 1

[4] We use "he" as a singular pronoun to reference a noodle maker of any gender.

[5] The reason that the diameter is in inches while the length and other dimensions are in meters is that it is easier to describe the effect of halving the diameter in terms of binary fractions of an inch.

trimming-and-cutting step[6].

2.3 Traditional Italian Pasta Algorithm

An Italian pasta maker rolls out a ball of the proper dough into a rectangular sheet of the desired thickness T and the desired length on one edge, hereinafter called edge L (for "length"). An edge that is perpendicular to L is called edge W (for "width"). (L and W need to be small enough for an $L \times W$ sheet of dough to be easily worked on by a hand-operated rolling pin). Both sides of the sheet are then thoroughly dusted so that they are not sticky. The sheet is then rolled up very loosely perpendicular to L so that the resulting tube is of length equal to that of W. The pasta maker decides the type of pasta that is being made to determine the width w of one strand. Ideally, the width W of the sheet is divisible integrally, n times, by w. For fettuccine, w is smaller than for lasagne.

1. The pasta maker uses a knife to cut away a section of the tube of width w.
2. The pasta maker unrolls the section into a strand of width w and of length equal to that of L.

This cutting and unrolling of sections is performed $n - 1$ times and then the remaining section is unrolled to produce the last strand of a total of n strands. All of this cutting and unrolling must be done quickly to prevent the rolled up tube from sticking to itself.

So, if one is making 30-centimeter long fettuccine whose cross section is 1/4 by 1/16 inch, then, w must be 1/4 inch, T must be 1/16 inch, L must be 30 centimeters, and W can be anything that be is less then the length of pasta maker's rolling pin and is a multiple of w. Let's assume that W is 8 inches. Then from one 8 inch by 30 centimeter sheet, the pasta maker will need $8 \times 4 - 1 = 31$ cuts to make 32 strands. For wider pasta, such as lasagne, fewer cuts are needed.

The local complexity of the algorithm is linear in the number of strands, n, made from $n - 1$ cuts and n unrollings in one sheet of dough.

There are at least two devices that allow cutting a prepared sheet of dough into a lot of strands in one step:

- a pasta cutter rolling pin whose cutting ribs are spaced w apart and
- a pasta making machine whose cutting blades are spaced w apart.

With either of these devices, there is no need to roll up the sheet and cut away one strand at a time. Instead,

- the cutting rolling pin is rolled once over the flat sheet of prepared dough, leaving the strands flat on the table with no need to unroll, or
- the sheet is fed through the machine, and the strands come out of the

[6] We are assuming that trimming and cutting take about the same amount of time asdoes folding and stretching.

machine already unrolled.

Several cutter rolling pins with ribs spaced different distances apart can be seen at the Eppicotispai Group's Website (Eppicotispai Group, undated).

The algorithm embodied by each of these devices can be described as a parallel, vector processing algorithm. Thus, the local complexity of the algorithm to make *n* strands from one prepared sheet with either of these devices is constant. That is, all *n* strands are made at the same time, in the time required to roll the cutting pin over the sheet or to feed the sheet though the machine.

2.4 World Record Setting Chinese Lā Miàn Maker

In 1993, Kin Jing Mark, who holds the Guinness World Record as the fastest human noodle maker, established a world record stretching out 4,096 lā miàn hand-pulled dragon beard noodles in 41.34 seconds (Youtube, 2007). The number, 4096, of strands that Kin Jing Mark made, is telling: $4096 = 2^{12}$. It is clear that no one spent time counting the individual strands to arrive at 4096. It is equally clear that the number of folds was counted and that number was used as the exponent of 2 to calculate the number of strands. Thus on average, Kin Jing Mark did one fold and stretch every 3.445 seconds. Clearly, the cook and the people who made the video understand the exponential growth of the number of strands in the algorithm.

2.5 Automation of Algorithms

Searching for "Italian pasta making machines" on the Web finds pasta sheeters and cutters that automate the Italian pasta-making process. These machines simulate the human pasta maker's behavior, to make so-called perfectly formed pasta every time.

There does not appear to be any machines that automate the making of Chinese lā miàn. There are machines that automate the mixing and kneading of the dough, but there do not appear to be any machines that automate the folding and stretching. Perhaps the main reason that lā miàn are called in English "hand-pulled" is that they *must* be made by a human's hand.

Indeed, one day, an engineer from Barilla (one of Italy's largest past manufacturers) and a Japanese visitor came to observe Paola Abraini making Italian pasta a method that is very similar to the traditional Chinese miàn method (Locci, 2016), with the aim of building a machine implementing the method. They left after concluding that such a machine was impossible[7] (Pinna, 2016).

---

[7] Un giorno è venuto un ingegnere della Barilla con un giapponese; hanno osservato, volevano costruire una macchina e produrlo. Sono andati via sconsolati: impossibile.

2.6 Other Methods of Making Noodles

China does have other methods of making miàn (LinLiu, 2013; Wikipedia, undated*a*):

- Cut (qie): A sheet of dough is cut into strands of the desired width, as in the traditional Italian pasta algorithm of Section 3. The local complexity of this process is linear in the number of strands produced.
- Squared (piàn): As one is making cut miàn, directly above an open pot of boiling water, each (long) strand is torn by hand into square-sized pieces (short strands). The local complexity of this process is linear in the number, n, of pieces produced: If s long strands are produced with $s - 1$ cuts, and from each long strand are produced p short strands with $p - 1$ tears, then $s \times p = n$. The total number of steps is $(s - 1) + (s - 1) \times (p - 1) = (s - 1) \times p$, which is approximately $s \times p = n$.
- Extruded (jíya): Dough is pushed through a die with holes of the desired shape to form strands, one per hole in the die. The local complexity of this process is constant, since all the strands are produced at the same time.
- Kneaded (róu): A small ball of dough is worked on a flat surface to form it into a strand of the desired shape. The local complexity of this process is linear in the number of strands produced.

Also Italy has other methods of making pasta (Hildebrand & Kenedy, 2010, Wikipedia undated*b*):

- Short cut: As one is following the traditional Italian pasta algorithm of Section 3, the s unrolled (long) strands are laid out in parallel, side-by-side into a striped sheet. Then, $p - 1$ equally spaced cuts perpendicular to the axis of the length of the strands are applied across the whole sheet, to produce $s \times p = n$ rectangular pieces (short strands). The local complexity of this process is in the order of the square root of the number of pieces produced: The complexity analysis for this process starts as for the production of $n = s \times p$ squared piàn. The difference is that all s long strands are cut together in only $p - 1$ cuts. Thus, the total number of cuts is $s - 1 + p - 1$, which is approximately $s + p$. If the sheet is close to being a square, then $s \approx p$, and $s + p \approx 2\sqrt{n}$, since $s \times p = n$. In a complexity estimate, a costant multiplier of $\sqrt{n}$ can be ignored, because the main contributor to the growth of $2\sqrt{n}$ is $\sqrt{n}$, and not the constant multiplier. There is a variation of the pasta cutter rolling pin, mentioned in Section 3, that has cutting ribs running along the long axis of the pin, perpendicular to the strand-cutting ribs. This variation is for producing a whole sheet's worth of short-cut pasta in one roll of the pin over a prepared sheet of dough. The local complexity of this method of making short-cut pasta is constant.

- Extrusion: Dough is pushed through a die with holes of the desired shape to form strands, one per hole in the die. The local complexity of this process is constant, since all the strands are produced at the same time.
- Short-cut extrusion: Each extruded pasta long strand is cut perpendicular to the length of the strand into short pieces. The local complexity of this process is in the order of the square root of the number of pieces produced, by the same analysis as for the above short-cut pasta.

Additional shaping may be applied to the pasta produced by any of the described methods.

There are machines that automate all the various ways of making Italian pasta, for example, as shown under the "Products" menu at the Arcobaleno Website Arcobaleno, LLC (undated).

2.7 Comparison of Algorithms

The Chinese repeated-folding-and-stretching algorithm, with its logarithmic complexity is significantly more powerful than any Italian cutting-based algorithm, with linear complexity, in two different ways:

1. The logarithmic-complexity algorithm can generate so many more noodles in a time duration than can any linear-complexity algorithm, particularly when the noodle maker is folding and stretching quickly, and he goes beyond six folds. Twelve folds and stretches in 41.34 seconds suffices to make 4096 noodles. Making 4096 noodles by any linear-complexity algorithm would require a *lot* more than 41.34 seconds.
2. When the two algorithms are operated totally manually, it is a lot easier to achieve uniformity in the cross section of the noodles with the repeated-folding-and-stretching algorithm than with any cutting-based algorithm.

2.8 Variations of the Basic Noodles

The different algorithms for making noodles lead to variations of the basic noodles that we see in the two countries. The fact that a flat sheet of dough is cut into strands that become the noodles suggests cutting the sheet into other shapes. Hence, we see noodles in the shapes of triangles, squares, rectangles, circles, stars, etc. Once we have these different shapes, we begin to see yet other variations, such as pinching a rectangle into a bowtie, molding a circle into a shell. Once we have shaping and pinching, with the addition of a bit more water, pinching can be used to paste edges together. Then rolling and pasting a wet rectangle yields a tube that can be filled. Covering part of a shape with some filling and folding and pinching wet edges around the filling yields filled tortellini. Once all this is automated, shapes that can be made by machinery become possible.

The Chinese lā miàn algorithm does not lend itself to these cutting-based variations. There are variations in the length and diameter of the noodles, the raw material used to make the noodles, and the twistiness of the noodle achieved by variations in the process of drying the noodles, e.g., by spiraling the wet noodles around a dowel of an appropriate diameter.

2.9 Conclusion to Examination of Algorithms for Noodle

Making There are a number of questions, each of which can trigger a discussion about other computational concepts and which is useful to better understand the roles of algorithms and their automation.

- Perhaps, the space required for an algorithm should be considered. Is there a meaningful space–time tradeoff? Does the size of the available kitchen make a difference, e.g., as for a home versus a restaurant kitchen?
- What is the interaction between the algorithms and the ingredients used to make the dough?
- What is the interaction between the algorithms and the issue of fresh versus dried noodles?
- What is the interaction between the algorithms and the local culture?
- Can a Chinese algorithm be applied in Italy and can an Italian algorithm be applied in China? As a matter of fact, One Italian pasta maker, Paola Abraini, uses a method that is very similar to the traditional Chinese miàn method to make Italian pasta (Pinna,2016).
- How easily learned is each algorithm?
- How automatable is each algorithm?
- Which algorithm is most appropriate to use in a restaurant in which food is made to order?
- What are the empirically determined threshold values for n (the number of noodles made in a batch), below which the traditional basic and parallel Italian algorithms are more efficient locally than the traditional Chinese algorithm?

3 Evidence of the Effectiveness of the Gentle Introduction

This section offers indirect evidence that the gentle introduction appeals people.

Author Mich uploaded to ResearchGate (2016) the previous version of the paper, which had been published in the proceedings of SIGBOVIK, a Computer Science satire conference (Berry & Mich, 2016). ResearchGate reports that the paper went viral on September 2016, and that as of 10 October 2018, the paper had 1888 reads. There are an unknown number of reads of the copy at Author Berry's Web site (Berry & Mich, 2017).

One version or another has been mentioned in a variety of other sites. For example, one continues the tongue-in-cheek application (Imgur, undated) of complexity to a serious recipe (Rebrn, undated). This tongue-in-cheek application is shared by some other sites, including that of Reddit Programmer Humor (Reddit Programmer Humor, undated; Sizzle, undated; Imgur, 2016). In another, Dan Eastwood cites the ResearchGate copy in a brief blog titled "Noodling around, FOR SCIENCE!" (Eastwood, 2016).

A Google search in Safari on a Mac for the exact title of the previous version achieves about 104 hits as of 10 October 2018. Most of the hits are pointers to pages that mention that previous version.

The lecture Berry gave at the publishing venue, the slides of which can be found at the Author Berry's Web site (Berry & Mich, 2017), was well received. He has given the lecture four more times as part of his department's outreach to high school students to convince them to apply to study Computer Science in his department. The lecture was well enough received that he was asked to plan on giving it again the next year.

More recently, DocPlayer, an educational resource, began offering at its Website a paged copy of the paper and the possibility of downloading the full PDF for free (DocPlayer, undated*a*). The home page of the organization says (DocPlayer undated*b*),

> What tasks does our website help to tackle? Our website makes it easy for you to find books that will help prepare for an examination, complete reports and research papers, as well as self-study books in various areas. Educational Library of the web resource contains thousands of training manuals, articles and books in a wide variety of academic subjects.

The authors did not ask DocPlayer to put it there. Someone else, perhaps at DocPlayer, decided that it was a good resource for DocPlayer's site. If that someone was from outside DocPlayer, the both that someone and DocPlayer agreed!

4 Other Topics and Concepts Introduceable Through Examination of Noodle Making

This section shows how a number of core topics and concepts of Computer Science could be gently introduced through examination of noodle making. Only a few are given here, but there are possibly others.

The most important concept in Computer Science is that of an algorithm. According to the everyday definition, “algorithm” is synonymous to “procedure”. However, a precise definition requires that to be an algorithm, a procedure has to satisfy five proprieties, namely, it has to (1) be finite, (2) be defined (unambiguous), (2) have input, (2) have output, and (5) be effective (Knuth, 1997, pp. 4–5). Each of these features could be introduced through examination of noodle making.

Knuth also compares the concept of algorithm with that of a cookbook recipe, emphasizing that a “recipe presumably has the qualities of finiteness (although it is said that a watched pot never boils), input (eggs, flour, etc.), and output (TV dinner, etc.), but it notoriously lacks definiteness”. To be definite, the actions to be carried out in each step must be rigorously and unambiguously specified. That is why formal languages have to be used when an algorithm cannot be described using mathematical formula. As for effectiveness, following a noodle making procedure – even with a video available illustrating the procedure – is still quite difficult, in both the Italian and the Chinese ways. Showing this point could be useful to introduce the concept of executor, i.e. the processor, that must have some specific characteristics to be able to accomplish the procedure’s steps. In the case of noodle making, the executor, i.e. the cook, must have enough expertise in following imprecise recipes.

Any algorithm has to be described in terms of input and output. The actual output and its quality depends on the input, a.k.a. “garbage in, garbage out”. If you do not use the right kind of flour, i.e., grano duro for Italian pasta, your noodles will not be able to be be cooked al dente, but even worse, in both the Italian and the Chinese procedures, if the dough is not correct, e.g., if it is sticky, you are not able to produce noodles; you will make mush.

Finally, for a given problem there could be different algorithms, and their analysis in terms of complexity is useful to adopt the most adequate according to the input, output, and available processors. For example, if you lack expertise, you can buy a machine to make noodles.

In addition, some noodle-making tasks can be accomplished in parallel, and others cannot. Thus, the concept of parallel processing can be introduced.

Another important point in Computer Science is computational thinking (Wing, 2006). Computational thinking is the ability to think of real-life problems, not involving computing, in an algorithmic way, i.e., to understand everyday phenomena as instances of computations, driven by algorithms performed by some agent, not necessarily a computer, e.g., human beings. Understanding the whole process of noodle making as a computation and seeing the various methods of making noodles as algorithms are manifestations of computational thinking. Indeed, Author Berry came to this realization when in a fancy Hong Kong restaurant in 1987, the cook prepared his noodles to order, in front of him at the table, using the traditional Chinese miàn algorithm. He remarked to his meal companions, most of whom were computer scientists, that this cook was using a log-base-2 algorithm!

Even deeper computational thinking is demonstrated when cooks begin to understand the computational power of a recipe in which each step doubles the number of items produced. For example, Paola Abraini states that she produces two, four, eight, sixteen, thirty-two strands, always thinner, up to 256 strands (Pinna, 2016). She understood that 256 is probably the limit because more than that, the strands might be so thin that they will break. Abraini trusts that the number of strands doubles with each fold and stretch and apparently feels no need to count the strands to check. The same trusting occurs in reporting that the World's record setting production of Chinese miàn produced 4096 noodles. That the number reported is exactly a power of two indicates that the reporter counted the number of folds, 12, to determine that the final number of noodles is $2^{12} = 4096$ and not the number of noodles. If he or she had attempted to count the noodles, it is unlikely that the count would have come out at exactly 4096 (from miscounting, not from there being a different number of noodles).

Conclusion

This paper illustrates a new and original approach to introduce the teaching of computational complexity, a topic of great relevance to the concept of algorithms. The idea is to observe, understand, analyze, and compare several Italian and Chinese ways of making noodles. The differences between constant, linear, and logarithmic algorithms are brought to life by examining the algorithms embodied in the real-life activity of working with dough to make noodles.

The approach can be considered both a gentle and an unplugged (CS Unplugged, undated) introduction, as it mitigates the students' traditional aversion to the subject combined with the traditional (boring) catalog of sorting and search algorithms by appeal to the ever popular activity of food preparation. Students' curiosity can be stimulated also by the cultural context and the discovery of how the world's record was achieved by use of the power of a logarithmic algorithm. The paper also describes other computational concepts that could be introduced through the discussion of different ways of making noodles.

At a more general level, the approach offers the possibility to involve teachers of subjects other than computer science, for example, home economics, geography, or history, in a multidisciplinary teaching approach, which is often recommended for teaching in secondary schools.

The paper offers testimonials from colleagues and online data about the appeal of this approach to introducing computational complexity.

Future work needs to investigate the efficacy of the approach at different school levels, in different curricula, and extensions of the approach for teaching other computer-science concepts, as suggested in Section 4.

Through the URL in an item (Berry & Mich, 2017) in the References section, additional materials are provided at a site containing the previous version of this paper (Berry & Mich, 2016) and slides for a lecture based on this previous version. Each of these documents contains URLs pointing to videos showing the algorithms being executed by cooks.

Acknowledgments

Thanks to Nachum Dershowitz, Dick Kemmerer, Mickey Krieger, Chryss Mylopoulos, Frank Tompa, and Dave Tompkins for comments on an earlier draft. Frank, in particular, offered some insights that led to a number of improvements to the paper.

REFERENCES

ACM (undated), *Curricula recommendations*. http://www.acm.org/ education/curricula-recommendations, (accessed on 10 October 2018).

Arcobaleno, LLC (undated), *Homepage*. https://arcobalenollc.com, (accessed on 10 October 2018).

Atchison, W. F., Conte, S. D., Hamblen, J. W., Hull, T. E., Keenan, T. A., Kehl, W. B., McCluskey, E. J., Navarro, S. O., Rheinboldt, W. C., Schweppe, E. J., Viavant, W. & Young, Jr., D. M. (1968), Curriculum 68: Recommendations for academic programs in Computer Science: A report of the ACM Curriculum Committee on Computer Science, *Communications of the ACM* 11(3), 151–197.

Berry, D. M. & Mich, L. (2016), The computational complexity of Chinese and Italian noodle making, in *Proceedings of SIGBOVIK 2016*, pp. Paper 6, pp. 0x248fd1aa778f4c65964afe5512748fe503a3d796ec35721e3fb68c0a7063dff5, ff. http://sigbovik.org/2016/proceedings.pdf.

Berry, D. M. & Mich, L. (2017), *Pasta paper materials*. https://cs.uwaterloo.ca/~dberry/FTP_SITE/tech.reports/PastaPaper/, (accessed on 10 October 2018).

CS Unplugged (undated), *Computer science without a computer*. http://csunplugged.org, (accessed on 10 October 2018).

CSTA (2011), *CS Standards Crosswalk with CSTA K-12 Computer Science Standards for State/District/Course Standards*. http://c.ymcdn.com/sites/www.csteachers.org/resource/resmgr/Docs/Curriculum/Crosswalk_Templates/SampleCrosswalkGrades6-12CST.pdf?hhSearchTerms=%22complexity%22, (accessed on 10 October 2018).

Denning (Editor), P. J., Comer, D. E., Gries, D., Mulder, M. C., Tucker, A., Turner, A. J. & Young, P. R. (1989), Computing as a discipline, *Communications of the ACM* 32(1), 9–23.

DocPlayer (undated*a*), *The computational complexity of Chinese and Italian noodle making*. https://docplayer.net/ 63565057-The-computational-complexity-of-chinese-and-italian-noodle-making. html, (accessed on 10 October 2018).

DocPlayer (undated*b*), *We offer you effective and free publishing and information sharing tools*. https://docplayer.net, (accessed on 10 October 2018).

Duan, J. (2015), *Sorting is boring: Computer Science education needs to join the real world*. http://www.huffingtonpost.com/jessie-duan/sorting-is-boring-compute_b_6675650.html, (accessed on 10 October 2018).

Eastwood, D. (2016), *Noodling around, FOR SCIENCE!*. https://plus.google.com/+DanEastwood/posts/Mkg3fQbamzZ, (accessed on 10 October 2018).

Eppicotispai Group (undated), *LET'S MAKE PASTA TOGETHER: Spaghetti, tagliatelle, fettuccine, pappardelle*. http://www.eppicotispai.it/?we-love-pasta/spaghetti-tagliatelle-fettuccine-pappardelle, (accessed on 10 October 2018).

Gasarch, B. (2015), *Why do students do this?*. http//blog.computationalcomplexity.org/2015/01/why-do-students-do-this.html, (accessed on 10 October 2018).

Gasarch, B. (2017), *Students try to memorize rather than understand! Who knew! (Everyone)*. http://blog.computationalcomplexity.org/2017/05/ students-try-to-memorize-rather-than.html, (accessed on 10 Oc- tober 2018).

Guzdial, M. (2008), Education: Paving the way for computational thinking, *Communications of the ACM* 51(8), 25–27.

Hildebrand, C. & Kenedy, J. (2010), *The Geometry of Pasta*, Box Tree, London, UK.

Imgur (2016), *A sharing of Imgur (undated)*. http://imgur.com/nrfWekQ, (accessed on 10 October 2018).

Imgur (undated), *A commenting on Rebrn (undated)*. http://i.imgur.com/nrfWekQ.png, (accessed on 10 October 2018).

Knuth, D. E. (1997), *The Art of Computer Programming*, Volume 1 (3rd Ed.): Fundamental Algorithms, Addison Wesley Longman, Redwood City, CA, USA.

Lin-Liu, J. (2013), *On the Noodle Road: From Beijing to Rome, with Love and Pasta*, Riverhead Books, The Penguin Group, New York, NY, USA.

Locci, M. (2016), *I segreti dei "fili di dio", l'arte di Paola Abraini a Nuoro*, Corriere della Sera TV. http://video.corriere.it/i-segreti-fili-dio/ 129ebe82-9b99-11e6-92af-45665cb81731.

Meek, T. (2012), *Math nerds vs. code monkeys: Should Computer Science classes be more practical?*. https://blog.smartbear.com/careers/ math-nerds-vs-code-monkeys-should-computer-science-classes-be-more-practical, (accessed on 10 October 2018).

Pinna, A. (2016), *Chi `e la custode dei "fili di dio" la pasta che nessuno sa imitare*, Corriere della Sera. http: //www.corriere.it/cronache/16_ottobre_26/chi-custode-fili-dio-d0fb0a94-9bc5-11e6-92af-45665cb81731.shtml?refresh_ce-cp.

Rebrn (undated), *[oc] Made ramen the other day. hardest thing I've ever attempted but was absolutely worth it*. http://rebrn.com/re/ oc-made-ramen-the-other-day-hardest-thing-ive-ever-attempted-but-2815792/, (accessed on 10 October 2018).

Reddit (undated), *Why do many comp sci majors hate math?*. https://www.reddit.com/r/compsci/comments/42fo42/why_do_many_comp_sci_majors_hate_math, (accessed on 10 October 2018).

Reddit Programmer Humor (undated), *A sharing of and a commenting on Imgur (undated)*. https://www.reddit.com/r/ProgrammerHumor/comments/5270w2/programmer_redditor_explains_why_ramen_is, (accessed on 10 October 2018).

ResearchGate (2016), *The computational complexity of Chinese and Italian noodle making*. https://www.researchgate.net/publication/299605105_The_Computational_Complexity_of_Chinese_and_ Italian_Noodle_Making, (accessed on 10 October 2018).

Shackelford, R., McGettrick, A., Sloan, R., Topi, H., Davies, G., Kamali, R., Cross, J., Impagliazzo, J., LeBlanc, R. & Lunt, B. (2006), Computing curricula 2005: The overview report, *SIGCSE Bulletin* 38(1), 456–457.

Sizzle (undated), *A sharing of Imgur (undated) and Reddit (undated)*. https://onsizzle.com/i/oc-made-ramen-the-other-day-hardest-thing-ive-ever-2336720, (accessed on 10 October 2018).

The Joint Task Force on Computing Curricula (2001), Computing curricula 2001, *Journal on Educational Resources in Computing* 1(3es), Article 1.

Trakhtenbrot, M. (2013), Students misconceptions in analysis of algorithmic and computational complexity of problems, in *Proceedings of the 18th ACM Conference on Innovation and Technology in Computer Science Education (ITiCSE)*, pp. 353–354.

Wang, D. (2017), *Why do so few people major in computer science?*. http://danwang.co/why-so-few-computer-science-majors, (accessed on 10 October 2018).

Wikipedia (undated*a*), *Chinese noodles— Wikipedia, the free encyclopedia*. http://en.wikipedia.org/wiki/Chinese_noodles, (accessed on 10 October 2018).

Wikipedia (undated*b*), *List of pasta— Wikipedia, the free encyclopedia*. http://en.wikipedia.org/wiki/List_of_pasta, (accessed on 10 October 2018).

Wing, J. M. (2006), Computational thinking, *Communications of the ACM* 49(3), 33–35.

Yadav, A., Stephenson, C. & Hong, H. (2017), Computational thinking for teacher education, *Communications of the ACM* 60(4), 55–62.

YouTube (2007), *'The ring of truth: Atoms' featuring Chef Kin Jing Mark*. https://www.youtube.com/watch?feature=player_embedded&v= auhHl5-6VdY, (accessed on 10 October 2018).