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# Application of 1:1 Mobile Learning Scenarios in Computer Engineering Education*

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The paper aims at presenting case study on personalised mobile learning scenarios on Computer Engineering and other STEM subjects in Lithuania. Fleming (VARK) learning styles model was used to personalise Creative Classrooms Lab (CCL) project's mobile learning scenarios by establishing suitable learning components for particular students according to their personal needs. Personalised mobile learning scenarios were compared against traditional "one size fits all" learning scenarios. Comparison was performed on the base of the analysis of Lithuanian CCL teachers' answers on questionnaire during the 2nd cycle of CCL project implementation and previous research results on expert evaluation of these types of learning scenarios. During this cycle, inquiry-based learning (IBL) activities developed in mascil project and a number of mobile applications (apps) were used by Lithuanian teachers while implementing the mobile learning scenarios, and interconnections between personalised IBL sub-activities and mobile apps were established. The authors have also analysed CCL observation visits' final report in terms of learning personalisation, creativity and innovation in schools. Based on this three-fold research, the authors concluded that (a) pedagogical change is necessary to improve learning outcomes for students, and (b) the main success factors in implementing mobile learning scenarios in Lithuania were: (1) identification of students' learning styles; (2) identification and application of suitable learning activities, methods, learning objects, tools and mobile apps according to students' learning styles; and (3) use of proper sets and sequences of learning methods while implementing mobile learning scenarios.

**Keywords:** computer engineering education; STEM subjects; personalised learning; mobile learning scenarios; learning styles; inquiry-based learning; educational data mining; questionnaire for teachers; CCL project; mascil project

## 1. Introduction

According to [1], the interest in the area of tablet for schools has continued to grow among academic researchers. The aim of the literature review [1] performed by CCL [2] project experts was to identify and document results of published 1:1 studies related to a number of key themes, such as the innovative and creative pedagogical use of tablets for collaborative learning, active learning, personalisation, engagement and assessment.

According to [1], there is a lot of observational and anecdotal evidence on the impact of tablet technologies on engagement, concentration, motivation, self-directed learning and collaborative behaviour.

Touch screen interface adds a certain degree of curiosity and mystery to the content, and it is more efficient than interface operated with a computer mouse and helped learners use more advanced strategies. Other researchers believe that, in order for the technology to be appropriate for the development of learners it should be responsive to the ages and development levels of the children, to their individual needs and interests, and to their social and cultural contexts [1]. In any case, the technological impact of tablets has positive and not-so-positive aspects, and it is important to understand that their users, primarily young ones, may have different perspectives on the advantages and disadvantages of using them [1].

The terms 'innovation' and 'creativity' are mentioned relatively often in the curricula of the EU Member States [3]. Nonetheless, there is no widely used definition of creativity in the educational world [4] and many teachers and education experts still feel that the curricula in their countries do not sufficiently encourage creativity and innovation, mainly because it is not clear how the terms should be defined and how they should be treated in learning and assessment. According to [3], there is still little research on evidence of the status, barriers and enablers for creativity and innovation in compulsory schooling on the European level. Innovative teaching is the process leading to creative learning, the implementation of new methods, tools and

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contents which could benefit learners and their creative potential.

The term 'Information and Communication Technologies (ICT)-enabled innovation' for learning refers to profoundly new ways of using and creating information and knowledge made possible by the use of ICT (as opposed to using ICT for sustaining or replicating traditional practices. Such ICT potential to innovation is realised and accompanied by the necessary pedagogical and institutional change [5].

For the CCL project, the term 'creative classroom' is crucial. [6] describe Creative Classrooms as innovative learning environments that fully embed the potential of ICT to innovate and modernise learning and teaching practices. The focus is on what is possible in today's practices taking advantage of existing and emerging technologies. 'Creative' refers to innovative practices, such as personalisation, collaboration, active learning and entrepreneurship, fostering creative learning. 'Classrooms' is considered in its largest sense as including all types of learning environments, in formal and informal settings [1].

It is the aim of CCL project to foster the creative and innovative use of tablets in teaching and learning and to contribute to the evidence base in this area.

In CCL, Lithuanian schools used mobile learning scenarios based on personalised learning approach developed by the authors. What learning content, methods and technologies are the most suitable to achieve better learning quality and efficiency? The authors believe that there is no correct answer to this question if schools don't apply personalised learning approach and that "one size fits all" approach doesn't longer work in education.

It means that, first of all, before starting any learning activities, teachers should identify students' personal needs, e.g. their preferred learning styles. After that, teachers should help students to find their suitable (optimal) learning paths: learning methods, activities, content, tools, mobile apps etc. according to their needs. But, in real schools practice, we can't assign personal teacher for each student [7].

This should be done by intelligent technologies e.g. interconnections and ontologies, recommender systems, personal learning environments, learning analytics/educational data mining, and decision support systems to name some. Some of these intelligent technologies were applied in CCL learning scenarios. This is the essence of Lithuanian Intelligent Future School (IFS) concept aimed at implementing both learning personalisation and educational intelligence [7].

Personalised learning issues and application of intelligent technologies in education are of high interest for the researchers [8–10].

In the second CCL implementation cycle, Lithuanian teachers used Fleming's [11] VARK learning style model and inquiry-based learning (IBL) activities developed and piloted by the authors in Lithuanian schools in parallel mascil [12] project.

VARK inventory was designed by Fleming [11] and is an acronym made from Visual, Aural, Read/write and Kinaesthetic. These modalities are used for preferable ways of learning (taking and giving out) information:

- Visual learners prefer to receive information from depictions in figures: in charts, graphs, maps, diagrams, flow charts, circles, hierarchies, and others. It does not include pictures, movies and animated websites that belong to Kinaesthetic.
- The aural perceptual mode describes a preference for spoken or heart information. Aural learners learn best by discussing, oral feedback, email, chat, discussion boards, and oral presentations.
- Read/write learners prefer information displayed as words: quotes, lists, texts, books, and manuals.
- The kinaesthetic perceptual mode describes a preference for reality and concrete situations. They prefer videos, teaching others, pictures of real things, examples of principles, practical sessions, and others.
- Multimodals are those learners who have preferences in more than one mode. IBL has become popular in school education in recent years in Europe. Researchers have significant results by implementing IBL in STEM subject classes.

Mascil [12] is a design research project providing an intervention model for a widespread dissemination and implementation of inquiry-based learning. It is aimed at promoting a widespread use of inquiry-based science teaching in primary and secondary schools. In addition, mascil connects mathematics and science education to the world of work: both inquiry-based science teaching and the connection to the world of work will make mathematics and science more meaningful to students. When doing inquiry-based tasks, students work like scientists and by doing so, they acquire competencies they need for their future professional and personal lives as active citizens [12].

IBL is an instructional method was developed in response to a perceived failure of more traditional forms of instruction, where students were required simply to memorize fact laden instructional materials. Inquiry-based learning or inquiry-based science describes a range of philosophical, curricular and pedagogical approaches to teaching. Its core premises include the requirement that learning should be based around student questions. Pedagogy and curriculum requires students to work independently to solve problems rather than receiving direct instructions on what to do from the teacher. Teachers are viewed as facilitators of learning rather than vessels of knowledge. The teachers' job in an inquiry learning environment is therefore not to provide knowledge, but instead to help students along the process of discovering knowledge themselves.

Computer simulations enhance IBL in which students actively discover information by allowing scientific discovery within a realistic setting [12].

The inquiry-based method can be defined as one of a type of learning methods, i.e. 'bringing together a wide range of activities' [13].

[14] summarized the activities of inquiry based learning in the following way:

A1: Orienting and asking questions: students make observations or examine the scientific phenomena that catch their interest or arouse their curiosity. Ideally, they develop questions by themselves.
A2: Hypothesis generation is the formulation of relations between variables. Stating a hypothesis is a difficult task for many students.
A3: Planning in the narrower sense involves the design of an experiment to test a hypothesis and select appropriate measuring instruments for deciding upon the validity of the hypothesis.
A4: Investigation as the link to natural phenomena is the empirical aspect of inquiry based learning. It includes the use of tools to collect information and data, implementation of experiments, and organisation of data pool.
A5: Analysis and interpretation of data form the basis of empirical claims and arguments for the proposition of a model.
A6: Model exploration and creation is a fundamental aspect of science learning. Models are used in science for several purposes. Students should learn to explore, create, test, revise, and use externalised scientific models that may express their own internalised mental models.
A7: In conclusion and evaluation activities, students extract the results from their inquiry. Conclusions might be drawn from the data and used in comparison with models, theories or other experiments.
A8: Communication represents the collaborative element of inquiry based learning. Communication is a process that may span all other processes of scientific inquiry starting with the development of a research question and ending with the presentation or reporting of results.
A9: In a prediction, learners express their beliefs about the dynamics of a system, while in a hypothesis the relations of the variables are emphasised. This last category may also symbolise the unfinished inquiry process after reaching a conclusion where new questions and hypotheses arise from the research results.

The rest of the paper is organised as follows: methodology of the research is described in Section 2, research results in terms of online questionnaire, analysis of CCL observation visits final report, and interconnections between IBL sub-activities and mobile apps are presented in Section 3, Discussion—in Section 4. The paper is concluded by Section 5.

## 2. Methodology of the research

### *2.1 Online questionnaire*

Online questionnaire was created by the authors and filled in by the lead teachers of Lithuanian schools participated in CCL from 30th of August to 10th of September 2015 after implementing the second cycle of CCL pilots. In Lithuania, five secondary schools participated in CCL and filled in the questionnaire, and 3 of them have implemented learning scenarios on computer engineering education.

The questionnaire for Lithuanian CCL schools consisted of 6 questions concerning different aspects of the proposed CCL mobile learning scenarios' impact on learning motivation and results. The formulation was as follows: "What characteristics of mobile CCL scenarios were helpful in terms of better students' motivation and learning results?" and the following characteristics were suggested:

(1) Identification of students' learning styles using proposed tool;
(2) Suitable learning activities, methods, learning objects, tools and tablet apps were identified and proposed for students according to their learning styles;
(3) A proper set and sequence of learning methods was used (e.g. problem solving, flipping, collaboration, content creation);
(4) The main mobile features of tablets were used (e.g. outdoor activities, shooting etc.); and
(5) IBL activities were used.
The last question was the open one: (6) 'Other success factors'.

After analysis of teachers' answers to this questionnaire and individual interviews while creating CCL videos, the results of the questionnaires were compared against the authors' previous research results on multiple criteria expert evaluation of different kinds of the learning scenarios.

*2.2 Analysis of CCL observation visits final report*

CCL observation visits final report [15] was analysed in terms of learning personalisation, creativity and innovation in schools, and the results of the analysis were compared with evidence obtained in Lithuania CCL case study.

*2.3 Interconnections between IBL sub-activities and mobile apps*

In order to successfully implement IBL-based learning scenarios, interconnections between personalised IBL sub-activities and mobile apps were established (see Table 1). These interconnections were helpful while preparing suitable (optimal) learning scenarios according to students' learning needs.

## 3. Research results

*3.1 Online questionnaire results*

Online questionnaire results were as follows:

(1) Positive (80%) and preferable (more positive than negative) (20%) impact. According to comments on the 1st question, 'Students were interested to know their learning styles. Learners felt comfortable and easily reached their learning aims'. There were students with different learning styles identified, e.g., in one class, 'the most of learners had strong preferences of visual and audial learning styles, and there were no one learner which had read/write learning style strong preferences'.
(2) Positive (60%) and preferable (40%) impact: 'Students used suitable learning content and tools, and this improved their learning results', 'Students could control their learning by themselves'.
(3) Positive (60%) and preferable (40%) impact: 'Variety of learning methods was used. These methods were successfully used in sequence'.
(4) Preferable (80%) and had no opinion (20%) impact: 'The lessons took place outside, and students used shooting and monitored computer simulations'. In some schools, there were legal problems to bring tablets out of school due to insurance problems. Students used their own devices outside. However, there were some problems with information processing.
(5) IBL activities were used in 60% of involved schools.
(6) Other success factors of mobile learning activities. Some schools consider that 'Tablets used in classes made students feel special and classical (traditional) classes to leave in the past'. Students felt free to use their imagination and creativity. Some schools successfully participated in different contests.

Thus, the main success factors in implementing mobile learning scenarios in Lithuania were: (1) identification of students' learning styles; (2) identification and application of suitable learning activities, methods, learning objects, tools and mobile apps according to students' learning styles; and (3) use of proper sets and sequences of learning methods while implementing mobile learning scenarios.

According to [15, 16], similar results were obtained after the 1st CCL cycle in Lithuania.

According to [15, 16], mobile student centred learning activities using tablets based on problem solving, personalisation, collaboration, content creation, and flipped classroom are more flexible than traditional teacher centred ones, they have more possibilities for feedback, more actively engage students in learning, facilitate interaction and collaboration, employ multiple teaching methods, and incorporate learners' backgrounds, experiences and expectations.

Research results [15] also show that the proposed quality evaluation approach refined by Fuzzy method to establishing both quality criteria weights and values: (1) is applicable in real life situations when educational institutions have to decide on using particular learning activities for their education needs, and (2) could significantly improve the quality of expert evaluation of learning activities by noticeably reduce of the expert evaluation subjectivity level since they are quite simple and are based on sound scientific approaches. The experimental evaluation results [15] also show that proposed quality evaluation method of learning activities is quite objective, exact and simple to use for selecting qualitative learning activities alternatives for particular learning styles.

According to [16], the proposed quality evaluation approach refined by the original Fuzzy AHP method to establishing quality criteria weights is applicable in real life situations when educational institutions have to decide on use of particular learning activities for their education needs.

*3.2 Results of analysis of CCL observation visits final report*

According to [17], teachers have used the work in the CCL project to try new ideas in terms of changing the learning environments in school. It is evident from the observation visits that this has led to the change of practice in one classroom, but there is much work to be done for change to occur across the rest of the school.

Some CCL conclusions and recommendations provided in [17] are as follows:

**Table 1.** Interconnection between IBL sub-activities and mobile applications

| IBL sub-activity | iOS | Android | iOS + Android |
|---|---|---|---|
| A1: Orienting and asking questions: Students make observations or examine the scientific phenomena that catch their interest or arouse their curiosity. Ideally, they develop questions by themselves | Mindmapping, Question Bilder, Talkboard | | Popplet |
| A2: Hypothesis generation is the formulation of relations between variables. Stating a hypothesis is a difficult task for many students | Infographics, Grafio, Mindmapping, Talkboard | Hypothezis Based Testing, Hypothezis Testing Roadmap | Skitch, Evernote, Penultimate, Popplet |
| A3: Planning in the narrower sense involves the design of an experiment to test a hypothesis and select appropriate measuring instruments for deciding upon the validity of the hypothesis | Popplet, Kidspiration Maps, Inspiration Maps, Grafio | Color Note Notepad Notes | Evernote, SimpleMind+ |
| A4: Investigation as the link to natural phenomena is the empirical aspect of inquiry based learning. It includes the use of tools to collect information and data, implementation of experiments, and organisation of data pool. | Timeline 3D, Voice Thread, Nexticy, Free GPS | Formhub, GPS Coordinates | Device Magic, GoFormz, QuikTapSurvey, Fulcrum, iFormBuilder, TrackVia. Diigo |
| A5: Analysis and interpretation of data form the basis of empirical claims and arguments for the proposition of a model | Infographics, Grafio, Photo Stats, Data Analyzis, Graphical Analysis, Numbers | | MiLAB™ |
| A6: Model exploration and creation is a fundamental aspect of science learning. Models are used in science for several purposes. Students should learn to explore, create, test, revise, and use externalised scientific models that may express their own internalised mental models | Grafio, Photo Stats, "Body Scientific Charts & Books, Cell & Cell Structure, ColorUncovered, EMD PTE, GoSkyWatch, iLabTimer, LeafSnap, Microscope2, Mitosis, Molecules, NASA, Periodic Table, Planets, PLOs Reader, Science Glossary, Skeptical Science, SolarWalk, SPARKvue, Stellarium, "Body Scientific Charts & Books, Cell & Cell Structure, ColorUncovered, EMD PTE, GoSkyWatch, iLabTimer, LeafSnap, Microscope2, Mitosis, Molecules, NASA, Periodic Table, Planets, PLOs Reader, Science Glossary, Skeptical Science, SolarWalk, SPARKvue, Stellarium, The Elements, 3D Cell, 3D Brain, Urogenital System, Video Physics, Video Science, Visible Body, Weather Radar HD | | Evernote |
| A7: In conclusion and evaluation activities, students extract the results from their inquiry. Conclusions might be drawn from the data and used in comparison with models, theories or other experiments | Grafio, Video Scrib | | Evernote, Lino, Prezi |
| A8: Communication and justifying: Communication represents the collaborative element of inquiry based learning. Communication is a process that may span all other processes of scientific inquiry starting with the development of a research question and ending with the presentation or reporting of results | Weebly (Website and blog), Explain Everything, Skype, Twitter, Bump, Stoodle, Voice Tread, Talkboard, Doceri, Keynote, Face Time | | Evernot, Explain Everything |
| A9: In a prediction, learners express their beliefs about the dynamics of a system, while in a hypothesis the relations of the variables are emphasised. This last category may also symbolise the unfinished inquiry process after reaching a conclusion where new questions and hypotheses arise from the research results | | | Evernote, Socrative, Penzu, PoolEverywhere |

- Create opportunities to pilot the use of new devices with students which may involve adapting the curriculum, exploring different timetables and making changes to the learning spaces.
- Learning tasks need to be differentiated and assess the progress of individual students using tablets. This should include evidence of student reflection to enable the teacher to be able to give feedback on digital work. All students should have a digital portfolio.

Fundamentally, the underlying issue is that pedagogical change is necessary to improve learning outcomes for students. The CCL project has shown that there is still much work to be done, but there is more than a curiosity with the technologies, there is now evidence to show that teachers from a methodological process to change learning and teaching alongside pedagogical support in their classrooms and the opportunity to reflect on innovation in practice [17].

In the 'Liberating Learners' scenario, Lithuania and Portugal used the questionnaires according to VARK model (Visual, Aural, Read/write and Kinaesthetic) which is free to use for educational purposes. The teachers used the findings from the questionnaire to organise the groups for collaborative work, trying to identify students with different learning styles to work together [17].

Throughout the CCL project, teachers have been keen to increase their knowledge and awareness of apps. However, discussions during the observation visits and the webinars highlighted that teachers need to refine the numbers of apps for their own use and student use in the development of learning activities. During the planning of the second CCL scenario cycle, teachers were asked to identify some apps that could be used, but were also encouraged to allow the students to make independent decisions. The second phase of visits has reiterated teachers' comments that students should be able to identify other apps/tools that will support their learning [17].

Interconnections between these apps and IBL sub-activities are presented in Sub-section 3.3.

It is obvious that the results of [17] correspond to Lithuanian CCL teachers' questionnaire results in terms of pedagogical change that is necessary to improve learning outcomes for students (e.g. personalised learning scenarios (liberating learners), students felt free to use their imagination and creativity etc.).

### *3.3 Establishing interconnections between IBL sub-activities and mobile apps in CCL*

Classification of inquiry-based learning is presented in Fig. 1.

In the 2nd CCL cycle, Lithuanian schools used open inquiry-based learning activity thus analysing and piloting 9 sub-activities that were previously interconnected with VARK learning style classification. For example, Visuals extremely prefer the following IBL sub-activities:

A2: Hypothesis generation ('State hypothesis' stage),

A3: Planning ('Equipment and actions' stage),

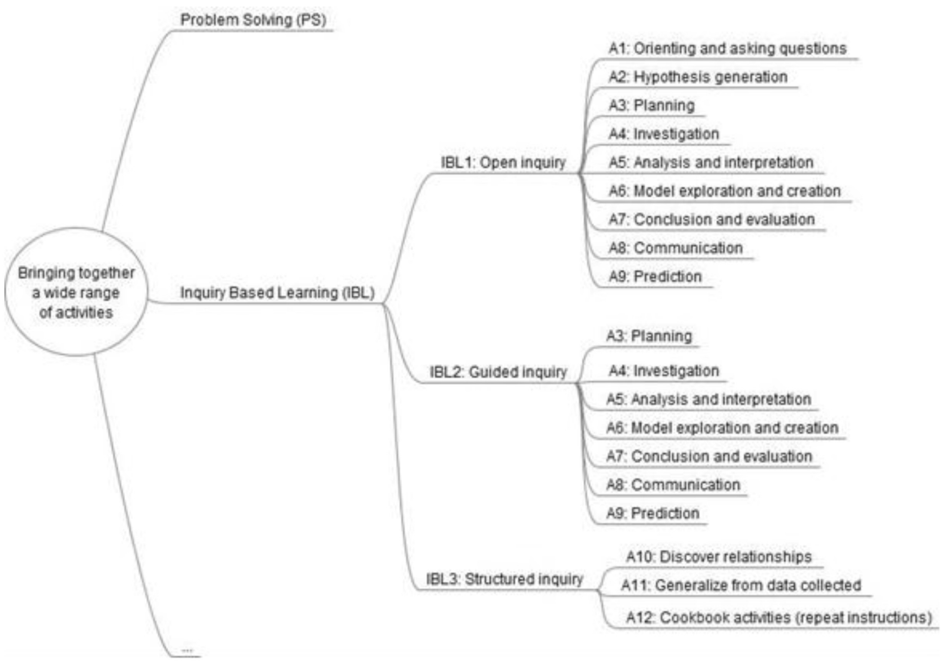


**Fig. 1.** Classification of IBL (according to [13]).

A4: Investigation ('Explore' stage),
A5: Analysis and interpretation ('Interpret data' stage), and
A6: Model exploration and creation ('Expose' stage).

After identifying IBL sub-activities suitable to students' learning styles, Lithuanian CCL teachers tried to interconnect the other learning components in order to create suitable mobile learning scenarios according to their students' needs.

One of the most important interconnections was the one between IBL sub-activities and mobile apps both for iOS and Android operating systems (see Table 1). Both teachers and students participated in this work. These personalised IBL sub-activities and mobile applications were used to create and implement personalised learning scenarios during the 2nd CCL cycle. In these 'Liberating Learners' scenarios, Lithuanian teachers organised the groups for collaborative work by identifying students with different learning styles to work together.

## 4. Discussion

Based on this three-fold research, we believe that (a) pedagogical change is necessary to improve learning outcomes for students, and (b) the main success factors in implementing mobile learning scenarios in Lithuania were: (1) identification of students' learning styles; (2) identification and application of suitable learning activities, methods, learning objects, tools and mobile apps according to students' learning styles; and (3) use of proper sets and sequences of learning methods while implementing mobile learning scenarios.

In the future, we would like to put more attention to creating integrated learners' models (profiles). These profiles should consist of (1) Selecting suitable taxonomies (models) of learning styles, e.g., Felder & Silverman [18], Honey & Mumford [19], and Fleming's VARK style; (2) Creating integrated learning style model which integrates characteristics from several models. Dedicated psychological questionnaires should be applied here; (3) Creating open learning style model; (4) Using implicit (dynamic) leaning style modelling method; and (5) Integrating the rest features in the student profile (knowledge, cognitive traits, interests, goals etc.) [7].

After that, ontologies-based personalised recommender system should be created to suggest learning components (learning objects, activities, methods, tools, apps etc.) suitable to particular learners according to their profiles. Thus, personalised learning scenarios could be created for particular learners for each topic according to curriculum/study programme. A number of intelligent technologies should be applied to implement this IFS approach, e.g. ontologies, recommender system, intelligent agents, decision support systems to evaluate quality and suitability of the learning components etc. Existing experience of IFS implementation by applying mobile learning scenarios in Lithuania has shown that this approach is effective in computer engineering education [7].

Creating decision support systems based on multiple criteria decision making theory, alternatives' quality criteria and expert evaluation methods should be further applied in order to analyse quality and efficiency of any learning components, e.g. learning scenarios and activities [15, 16].

Learning analytics/educational data mining is also very important part of our future work. The research interest of using data mining in e-learning (or learning analytics) is constantly increasing. The database of learning management system includes much useful information, which can be used effectively for the improvement of e-learning process, for personalisation and making the appropriate course content in the appropriate way [20] or course adaptation for learners. Using data mining methods, many kinds of knowledge can be discovered e.g. to help to monitor learners' progress and to achieve the desired learning goals. The discovered knowledge can be used to better understand students' behaviour, to access student's learning style [21], to adapt a course content according to student's knowledge and abilities, to assist instructors, to improve learning and teaching process. Literature describes a number of scientific research works, which prove the implementation of data mining methods on e-learning data, present case studies that use the same approach e.g. to identify behaviour of failing students to warn students at risk before final exam [22]. Other authors propose to use a specific data mining method—neural networks for predicting student's marks. M. Laugerman et al. [23] proposed to use educational data mining also in higher education sector to determine graduation rates in engineering.

In future works we will implement data mining algorithms to establish the relative effectiveness of using of mobile devices for teaching some subjects.

Different data mining methods are using for e-learning data analysis. The most common ones are association, classification, and clustering and outlier detections. The choice of data mining methods, tools, and its realisable algorithm depends on available data, set research goals and intended results.

One of the main projects in the area of learning analytics is LACE [24]. The LACE project has created eight visions of the future (2025) of learning analytics. They are:

(1) Learning analytics support self-directed autonomous learning.
(2) Individuals control their own data.
(3) Open systems for learning analytics are widely adopted.
(4) Learning analytics systems are essential tools of educational management.
(5) Learning analytics are rarely used in education.
(6) Classrooms monitor the physical environment to support learning and teaching.
(7) Most teaching is delegated to computers.
(8) Personal data tracking supports learning.

We believe that the following visions of the future of learning analytics/educational data mining are mostly desirable and feasible in Lithuania:

- Learning analytics support self-directed autonomous learning: In 2015, learners in educational institutions and in businesses had to follow a curriculum developed by others. In 2025, they create groups that work together to decide their learning goals and how to achieve these. A 'Learning Trajectory System' uses analytics to support information exchange and group collaborations, and learners receive support from mentors, rather than teachers. Activity towards a learning goal is monitored, and analytics provide individuals with feedback on their learning process. This includes suggestions, including peer learners to contact, experts to approach, relevant content, and ways of developing and demonstrating new skills. Formative assessment is used to guide future progress, taking into account individuals' characteristics, experience and context, replacing exams that show only what students have achieved. Texts and other learning materials are adapted to suit the cultural characteristics of learners, revealed by analysis of their interactions. As a result, learners are personally engaged with their topics, and are motivated by their highly autonomous learning. There is also convergence between the learning activities of the education system and the methods used by employees to develop their knowledge and skills [24].
- Learning analytics systems are essential tools of educational management. In 2015, companies were beginning to develop systems to recommend resources and to predict outcomes. By 2025, these systems are highly developed. A wide range of data about learner behaviour is used to generate good quality, real-time predictions about likely success. Learners, teachers, managers and policymakers all have access to live and accurate information about how well a learner is likely to do. Learners and teachers plan their work on the basis of reliable tools that can produce detailed and personalised recommendations about what should be done to achieve the best learning outcomes [24].
- In 2025, most teaching is delegated to computers. In 2015, people were beginning to assemble datasets that could represent learner's activities. By 2025, these are used on a large scale in teaching, and this has led to the development of enormous datasets containing information about hundreds of thousands of learners. Analysing in detail the progress of such a wide variety of learners has made it possible to provide reliable evidence-based recommendations about the most successful routes to learning, as well as identifying the learning materials and approaches that are most suitable for each individual at each point in their progress. These recommendations are better informed and more reliable than those that can be produced by even the best-trained humans. Learners now spend most of their time working with analytics-driven systems, and the role of teachers has been reduced. Education policy is driven by the evidence generated by the use of these systems [24].

## 5. Conclusions

Pedagogical change is necessary to improve learning outcomes for students. The CCL project has shown that there is still much work to be done, but there is more than a curiosity with the technologies, there is now evidence to show that teachers from a methodological process to change learning and teaching alongside pedagogical support in their classrooms and the opportunity to reflect on innovation in practice.

The results of CCL observation visits final report correspond to Lithuanian CCL teachers' questionnaire results in terms of pedagogical change that is necessary to improve learning outcomes for students (schools personalised their learning scenarios (liberating learners), students felt free to use their imagination and creativity etc.).

Inquiry-based learning activities and a number of mobile apps were used by Lithuanian teachers while implementing CCL mobile learning scenarios and interconnections between personalised IBL subactivities and mobile apps were established.

The main success factors in implementing mobile learning scenarios in Lithuania were: (1) identification of students' learning styles; (2) identification and application of suitable learning activities, methods, learning objects, tools and mobile apps according to students' learning styles; and (3) use of proper sets and sequences of learning methods while implementing mobile learning scenarios.

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