International Journal of Mobile and Blended Learning
Volume 13 • Issue 1 • January-March 2021

A Multi-Stakeholder Perspective of Analytics for Learning Design in Location-Based Learning

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ABSTRACT

Promoted by the growing access to mobile devices and the emphasis on situated learning, location-based tools are being used increasingly in education. Multiple stakeholders could benefit from understanding the learning and teaching processes triggered by these tools, supported by data analytics. For instance, practitioners could use analytics to monitor and regulate the implementation of their learning designs (LD), as well as to assess their impact and effectiveness. Also, the community around specific tools—such as researchers, managers of educational institutions, and developers—could use analytics to further improve the tools and better understand their adoption. This paper reports the co-design process of a location-based authoring tool that incorporates multi-stakeholder analytics for LD features. It contributes to the research community through a case study that investigates how analytics can support specific LD needs of different stakeholders of location-based tools. Results emphasise opportunities and implications of aligning analytics and LD in location-based learning.

KEYWORDS

Authoring Tools, Learning Analytics, Learning Design, Location-Based Learning, Mobile Learning, Multi-Stakeholders, Situated Learning

1. INTRODUCTION

Advances in mobile and wireless technologies have made possible to extend the boundaries where learning happens. Location-based authoring tools are an example of these technologies that assist the creation of context-aware mobile learning (m-learning) activities outside the classroom (Muñoz-Cristóbal et al., 2018). Practitioners can adopt these tools to create innovative learning activities in line with their learning design (LD) goals (Burden et al., 2019). However, due to the distributed nature of learning in these environments, where learning happens across spaces (e.g., physical and virtual) and settings (e.g., formal and informal), designing, monitoring and evaluating LDs entail additional challenges, thus affecting practitioners (and other involved stakeholders) practices (Pishtari et al., 2020). In general, research in LD has considered as community stakeholders the community of practitioners around specific LD tools (Hernández-Leo et al., 2019). However, understanding the teaching and learning processes supported by LD tools is a matter of interest for other stakeholders

DOI: 10.4018/IJMBL.2021010101

as well. For instance, understanding the usage, impact, and adoption of the tools could also help researchers, developers, or managers of educational institutions.

The research communities of LD and Learning Analytics (LA) have provided different solutions for these issues. LD can help to guide and contextualise the analysis, by making them more meaningful for the involved stakeholders, while analytics can inform design decisions and help to evaluate LDs (Persico & Pozzi, 2015). In the context of m-learning, only a few works inquire about the benefits of aligning analytics and LD (Pishtari et al., 2020), while to the best of our knowledge none has considered all stakeholders around a given tool, with an interest in LD practices.

This paper reports the first steps of the development of a location-based authoring tool that integrates analytics for LD features (as dashboards), following a co-design process. The tool aims to support stakeholders with analytics to design innovative m-learning activities outside the classroom, as well as to understand the usage, impact, and adoption of the tool. The paper presents insights from practitioners, researchers, and managers of educational institutions, about how analytics can support their specific LD needs and is driven by the following research questions (RQ):

- (RQ1) What kind of information could help practitioners during the creation of LDs outside the classroom with location-based authoring tools?
- (RQ2) What aspects of the LDs would practitioners like to monitor, or assess from the students?
- (RQ3) How would practitioners assess the effectiveness of the LDs?
- (RQ4) What would the researchers and managers of educational institutions like to know about the creation and usage of LDs?

To answer these questions we carried out contextual inquiries with 5 practitioners (with a main focus on RQ1-RQ3), and semi-structured interviews with 2 researchers and 2 managers (RQ4) of two location-based tools (Avastusrada and Smartzoos). Findings were grouped using the AL4LD framework (Hernández-Leo et al., 2019) and the learning context that they pertain (see Table 1), which later served as guidelines for a design workshop that produced three dashboard prototypes that aim to support different stakeholders' LD practices through analytics (each based on a different metaphor), as well as their evaluation process.

The rest of the paper is structured as follows: section 2 presents the related work; section 3 gives an overview of the context of the research; section 4 describes the research methodology; section 5 presents the main findings of the interviews, the prototype dashboards, and their evaluation; section 6 discusses the implications from the results; section 7 concludes the paper and gives an outlook of future work.

2. RELATED WORK

LD, as an artifact, is the sequence of learning tasks, resources, and supports developed by practitioners that captures the pedagogical intent of a unit of study (Lockyer et al., 2013). Contributions from the LD field include representations, authoring tools, design frameworks and methodologies that support practitioners to create, share and implement lesson plans (Persico & Pozzi, 2015). In m-learning contributions include authoring tools, frameworks, and tools that integrate LDs across spaces (Pishtari et al., 2019a). Examples specific to location-based learning are usually in the form of authoring tools (e.g., Muñoz-Cristóbal et al., 2018).

Apart from satisfying research interests, data analytics support decision making of the different stakeholders involved at different stages of the learning process (Persico & Pozzi, 2015). In m-learning, we find solutions such as frameworks, guidelines and monitoring systems (Pishtari et al., 2019a). Even, some examples can be found that are specific for location-based learning, such as a monitoring system (e.g., Santos et al., 2011).

There is a growing research interest in aligning LD and analytical practices, where LD can make analytics more meaningful, while analytics can inform decisions related to LD (Persico & Pozzi, 2015). Nevertheless, the usage of analytics to support LD has not been explored enough and few works have addressed aspects such as supporting teachers to reflect on the delivery of the LD (Sergis & Sampson, 2017). Also, the main focus of this body of research has been on practitioners, without considering other stakeholders such as managers of educational institutions and researchers in a second plane (Mangaroska & Giannakos, 2018).

In m-learning, few works consider the usage of analytics to support LD (Pishtari et al., 2020). Santos et al. (2011) study the case of supporting teachers through data visualizations in location-based learning. Hernández-Leo & Pardo (2016) discuss the possibility of integrating LD and LA in a community platform where teachers can design learning activities using multiple authoring tools. The work is illustrated with activities across-spaces in a flipped-classroom scenario. Muñoz-Cristóbal et al. (2018) propose a set of guidelines and a monitoring system for awareness and reflection in ubiquitous learning environments. Although the focus is on learning orchestration rather than LD, monitoring reports produced by this system are organized according to the predefined LD structure and could be potentially used to reflect about their effectiveness. These works focus only on practitioners and do not consider other stakeholders, which may have related interests about the usage, adoption, and improvement of the support that the proposed tools offer to LD practices.

3. RESEARCH CONTEXT

This study has been carried out within the context of two projects: Avastusrada[1] and SmartZoos[2]. Both focused on developing web-based mobile applications that support the design and deployment of learning activities outside the classroom (SmartZoos relevant for a zoo context). These applications allow the design of gamified learning activities as tracks, which consist of a number of location points containing different tasks in each. Tasks can be selected from a list of templates (such as open and closed questions, or matching pair tasks). Practitioners can choose desired points on the map, attach tasks to them and form a meaningful track. Customisable features include among others the ability to select: whether the tasks could be answered randomly, or in a preferred order; if the tasks could be answered freely, or only when players (students) reach a specific distance from them.

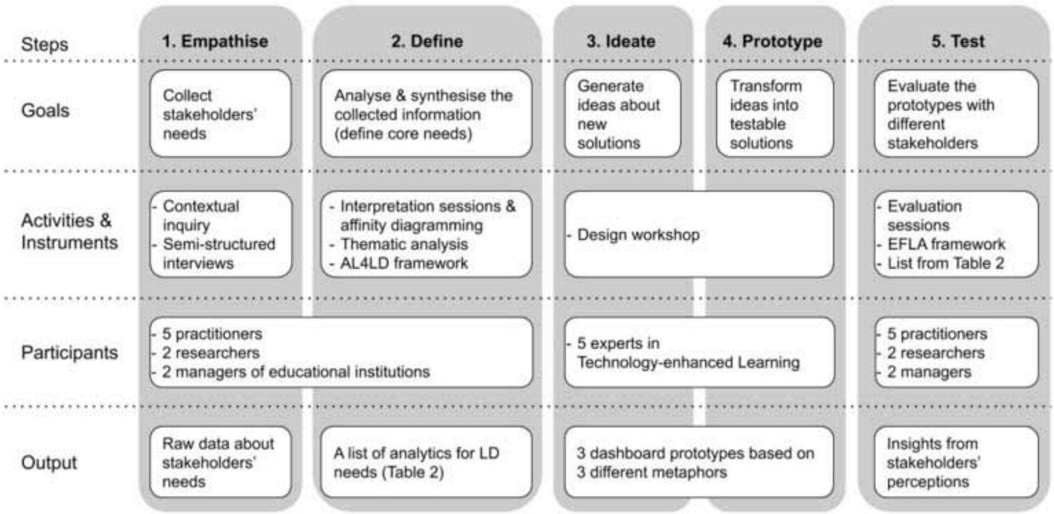
Contrary to Avastusrada, in Smartzoos single tasks are reusable open educational resources that can be used (as they are, or modified) in multiple tracks by other users, thus stimulating a co-creative environment (Pishtari et al., 2017). Both tools provide players with information about finished tracks, such correct answers, or points collected. Additionally, SmartZoos provides immediate feedback to the tasks completed in location points, and achievements are awarded by badges. Both tools collect and display basic information on dashboards for practitioners about finished tracks, such as the time spent on a track per user, the number of correct and wrong answers, etc.

Both projects encompass diverse communities of stakeholders around their respective tool (including teachers, learning designers, students, researchers, developers, and managers of educational institutions), thus constituting a strategic choice for a case study that inquires about how analytics can support LD needs of different stakeholders in location-based learning. We focused only on stakeholders with an interest in LD practices (see sections 4.1 & 4.2). Participants were selected considering Flyvbjerg critical case study criteria, stating that the retrieved information should allow deductions of the type: “if this is (not) valid for this case, then it applies to all (no) cases” (p. 230).

4. METHODOLOGY

The co-design process reported in this paper followed the Design Thinking Process Model (Plattner et al., 2009), which consists of five steps (Figure 1, Steps). This methodology was selected for its usefulness in tackling complex problems and providing solution-based approaches that consider human

Figure 1. Overview of the steps of the co-design process and their respective goals, activities, participants, and output



needs, through brainstorming, prototyping, and testing sessions (Plattner et al., 2009). The process was informed through various research and design activities (Figure 1, Activities & Instruments) that helped us to gain a multi-stakeholder perspective of how analytics can support LD in location-based learning. The current section describes these activities, their underpinning methodologies, as well as instruments used in each one. Pishtari et al. (2019b) includes a thorough description of the contextual inquiry and semi-structured interviews (4.1 & 4.2).

4.1. Contextual Inquiry

The focus of the contextual inquiry was to gather feedback from practitioners about: features that they (would like to) use to design a learning activity; information that they (would like to) collect; how they use the collected information to improve their LDs; and what complementary information could be useful in this direction (RQ1-RQ3).

- **Participants:** Five practitioners (3 females, 2 males) participated. Namely, 1 middle-school teacher, who had worked with Avastusrada and Smartzoos; 2 educational instructors from partner zoos of the Smartzoos project; 1 educational instructor from the Avastusrada project; 1 in-service teacher trainer that had used both tools in training sessions. All participants had extensive experience with at least one of the tools.
- **Procedure:** Contextual Inquiry is used to gather field data from users in order to understand who they are and how they work (Raven & Flanders, 1996). We used an *Artifact Walkthrough* implementation of a Contextual Inquiry, where participants have to recreate specific processes, using the artifacts that they would normally use in real settings. This method is preferred when an activity is not continuous in time and involves several people (Raven & Flanders, 1996), which corresponds to our case.

Practitioners were asked to start designing a scenario with their selected tool. Later, they were requested to take the role of a student and perform the designed activity. This part was added to help practitioners reflect about information needed to improve the LDs that can be gathered from their deployment. Afterwards, each practitioner checked the reports produced by the tools, and thought about the support that they provide to evaluate the LDs. During the entire process, practitioners were requested to speak loudly about what they were doing, by reflecting on issues that they faced, missing features, or additional information that could improve the processes. The observer did not interrupt the practitioner and the process was complemented with a follow-up interview with open questions regarding the observation and the research goals.

The entire process was video recorded and later transcribed to text. *Interpretation Sessions* and *Affinity Diagramming* were used to analyse the data, by three researchers. Interpretation Sessions are a team work, used to create a shared understanding of the data by writing them on post-it notes as key issues. Affinity Diagramming was used to discover patterns by clustering notes into groups, where an agreement between the three researchers had to be reached. The analysis resulted in approximately 400 notes, which were grouped into clusters that were later filtered based on the focus of our inquiry (see Table 1, RQ1-RQ3).

In addition, results were further mapped using the AL4LD framework (Hernández-Leo et al., 2019), defining three layers where analytics can support LD (see Table 1), namely:

- *Learning analytics*, concerned with engagement, progression, achievement and satisfaction metrics of learners during a LD and encourages awareness and reflection on the effects of LD.
- *Design analytics*, deals with characteristics of a LD and metrics of design decisions prior to their delivery and provides awareness and reflection about LD decisions, or for future implementations.
- *Community analytics*, concerned with patterns and metrics of design activity within a community of stakeholders and encourages collaboration by raising awareness and reflection over activity patterns, or by orientations on improving design practices.

4.2. Semi-Structured Interviews

The goal of the interviews was to gather input about the information that can help stakeholders to: have an overview of the designed activities; understand the usage of the activities; know more about the general usage of the tools and their adoption (RQ4).

- **Participants:** We considered as community stakeholders around Avastusrada and SmartZoos: the community of practitioners that uses one of the tools; managers of educational institutions that apply the tools as part of their m-learning strategies; and researchers involved in the projects. Practitioners were already considered in the contextual inquiry, therefore the focus here was on managers and researchers. From 4 participants (2 from Smartzoos, 1 from Avastusrada, and 1 involved in both), 2 had an academic profile and had been involved in the development and research activities around the tools, while 2 were zoo coordinators for the SmartZoos project and had an interest to understand the adoption of SmartZoos as part of educational activities organized in their institutions.
- **Procedure:** The participants were given minimal guidance in their responses. The questions were open ended and follow-up questions were asked to elicit in-depth responses/clarification. Interviews were all audio recorded and later transcribed to text. The data were first coded according to the type of information that participants were reporting. The segments related to a particular information were then coded according to how the gathered data would inform the stakeholders. Furthermore, results were mapped using the AL4LD framework (see Table 1, RQ4), as explained in section 4.1.

4.3. Design Workshop

The goal of the design workshop was to brainstorm around stakeholders' needs (identified in the previous steps) and produce design ideas that could address them in Avastusrada/Smartzoos (Figure 1, Step 3 & 4).

- **Participants.** Five researchers of Technology-enhanced Learning in Tallinn University were recruited. All of them had managed, or participated in previous research and development projects related to m-learning, LD, or LA. Only one of the participants (the organizer) had previous knowledge about Avastusrada/Smartzoos.
- **Procedure.** The procedure was an adaptation of the Design Sprint methodology (Knapp et al., 2016), into a four phases process.

  Phase 1: The workshop started with an introduction about its goals, Avastusrada/Smartzoos, and the results obtained in previous steps.

  Phase 2: Participants considered existing related solutions/tools (each explained for 10 minutes). Furthermore, each participant had to capture ideas considered as valuable from the existing solutions into post-it notes (as text, or drawing), which were later attached to a whiteboard. In continuation, participants had 30 minutes to take notes about relevant ideas appearing in the notes, followed by 30 minutes of private time to write down their own rough ideas/ solutions. In the consecutive step, each participant had to sketch eight variations of their own ideas (1 minute per sketch). This was followed by a 40 minutes to create a finished solution that transformed the previous sketches into a storyboard with three parts.

  Phase 3: All storyboards were hanged into a wall and kept anonymous. For 30 minutes, participants reviewed all solutions and voted (by attaching small stickers) the solutions (or parts of them) that they liked. This was followed by a discussion where it was decided which parts would go for prototyping (Figure 2).

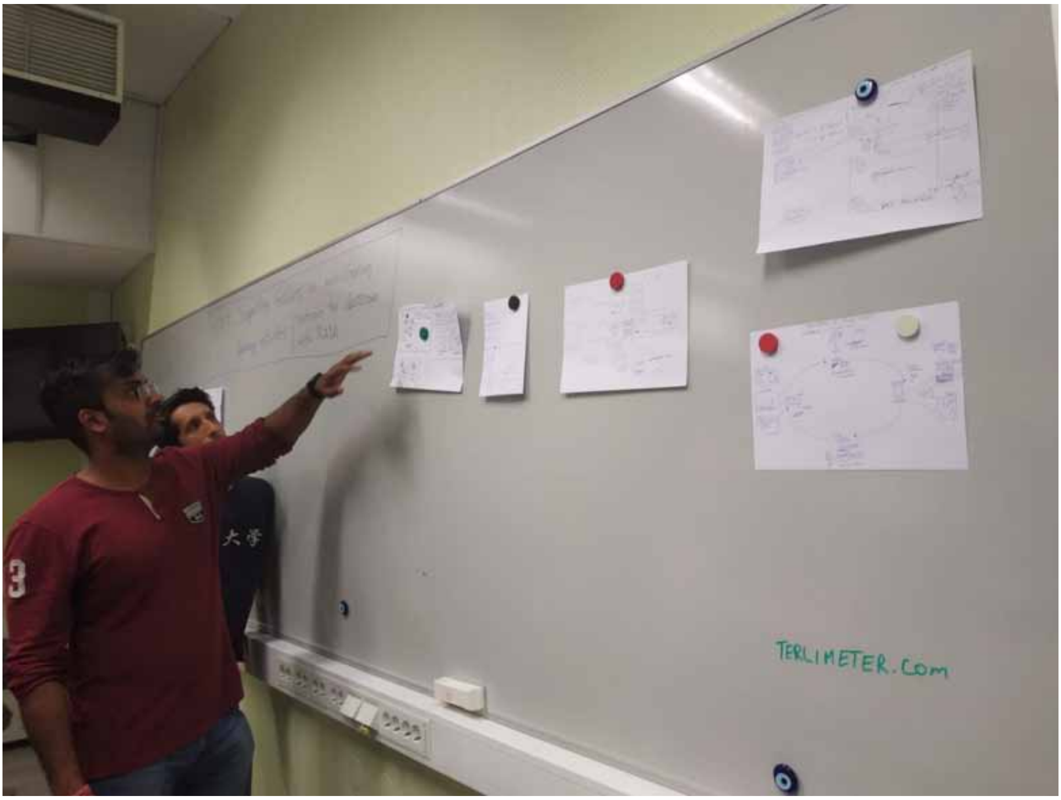
  Phase 4: Paper prototypes were created based on the selected ideas. Namely, two dashboards for practitioners and one for the other stakeholders (see section 5.2).

4.4. Prototypes Evaluation

The evaluation session had a double goal, to collect insights from stakeholders' perceptions about the prototypes (Figure 1, step 5), as well as to extend the lessons learned from the contextual inquiry and interviews (based on our RQs).

- **Participants:** The same participants of contextual inquiry and interviews were recruited for the evaluation of the prototypes. Respectively 5 practitioners that evaluated two corresponding prototypes, as well as 2 researchers and 2 managers that evaluated one dashboard.
- **Procedure:** First, participants were presented with the results from Table 1 and asked to identify elements that they consider as important, as well as to think about missing ones. In continuation, the observer revealed the prototype, which participants had to use as a real tool, while speaking loudly about every action, thought, or questions that they had. Each dashboard was informed with real data from Smartzoos (when possible). One observer facilitated the process by clarifying specific functionalities, when needed. Furthermore, participants were asked if they thought that the dashboard supported the elements that they identified as important from Table 1. In the end, practitioners (only) had to fill the EFLA framework to evaluate each prototype, for which the score was calculated as explained in Scheffel et al. (2017). EFLA was chosen as a validated instrument that can provide insights about practitioners' perception and experience with the tools, facilitate the comparison between the two dashboards, as well as supply evidence if the prototypes fulfill their purposes. The entire process was repeated twice for practitioners (once per prototype). The evaluations were video-recorded and transcribed to text. Results were analysed contextually, based on how intuitive the prototype felt to the participants, as well as to what extent the prototype (or parts of it) supported participants' priorities (as they defined when considering results from Table 1).

Figure 2. Participants discussing the storyboards



5. RESULTS

This section presents the results obtained along the co-design process. First, we present insights obtained during the contextual inquiry and interviews (Figure 1, steps *Empathise* & *Define*) together with related insights obtained during the prototypes evaluation, that further extend lessons learned about each RQ. In continuation, we present three prototype dashboards that resulted from the design workshop (steps *Ideate* & *Prototype*). Finally, we present the results from the prototypes evaluation (step *Test*).

5.1. Insights from Stakeholders

This subsection presents results from the contextual inquiry and interviews, organized alongside the RQs. Furthermore, findings are grouped using the AL4LD framework and the learning context that they cover (Table 1). Finally, we present the insights obtained from stakeholders, during the prototypes evaluation, when they considered results from Table 1 (explained in 4.4).

RQ1: Results from the contextual inquiry show that practitioners use location-based tools to design activities in line with their pedagogical goals. These goals can be learning objectives, skills, or competences, influenced rather by competence frameworks (the case of the in-service teacher trainer), or the local curriculum. One practitioner expressed that it would be helpful if the tool would offer templates of LDs with predefined structures based on specific pedagogical goals, or curriculum subjects. A common issue was the importance of being familiar with the situated environment where learning activities would happen. One practitioner mentioned that, "this requires extra time in order to go in person and check the place", adding more workload. Practitioners preferred a detailed level of customization when designing learning activities, which directly affects the kind of information that they might need. These included options related to the social planes, like individual, or collaborative; general metrics, such as duration, or difficulty level; and type of tasks, e.g., quizzes, assignments, or other assessment tasks (performed by students, or evaluated by practitioners). All practitioners expressed that students' data from previous activities, such as performance and process metrics (e.g., engagement), or students' satisfaction and preferences, could help to understand parts of the design that are effective, or that should be modified. Practitioners working with Smartzoos liked the option that allows them to reuse and adapt existing LDs, done previously by them or others. One practitioner mentioned that, "this has a direct impact on my workload, as I do not have to create the activity once again from the beginning, when I want to change just a part of it".

RQ2: For each student, practitioners try to track their performance and improvement. They tend to create students' profiles, rather formally, by adding information into a Moodle database (2 practitioners), or informally (3 practitioners expressed that they create an idea about students' performance based on the results shown in the tool and their engagement in complementary activities). Performance metrics are the main source of information that practitioners would like to monitor. Some of this data is found in Avastusrada/Smartzoos like, responses to quizzes. Other metrics that were emphasized and which are not currently available include, real-time location of users (5), location and time spent by students performing a specific task (4), visualizing the path that was followed by students during the activity (2). Regarding performance metrics related to gamification elements, one practitioner mentioned that connecting badges (from Smartzoos) to some curriculum outcome could be useful. Another theme that emerged was the need for process metrics, including among others, students' behaviour, engagement, collaboration, as well as where and when a specific process occurred. One practitioner also suggested the usage of hints for specific tasks that would be triggered by students, which usage could be later monitored.

RQ3: Practitioners reported using a variety of data to assess their LDs done with location-based tools. Most of which does not come directly from the tools but from discussions, complementary tasks, or assessments that happen before/after the activity. All practitioners pointed out that they would like to assess activities based on specific pedagogical goals (e.g., learning objectives, or learning outcomes), which could be evaluated based on the individual or group performance of the students. Various students' satisfaction criteria emerged from the analysis. Four practitioners considered that some kind of students' satisfaction and feedback would be useful to assess the effectiveness and improve LDs. Two practitioners suggested the usage of a feedback system to evaluate students' experience, one of each suggested its usage not only for entire activities, but also for specific tasks. Two considered that voluntary comments by students could be helpful to assess the LDs. Practitioners' design effort was another theme that emerged. Two practitioners expressed that they would like to know how much time they spent on a LD, or specific parts of it.

RQ4: From the semi-structured interviews, resulted that researchers and managers were mainly interested in understanding the adoption that the tools are finding in practitioners' LD practices, as well as in an institutional level. All 4 stakeholders expressed that they would like to understand the kind of LDs that practitioners are creating through some visualizations of general metrics about the characteristics of LDs (e.g., of type of tasks, or numbers of designers per subject). Two researchers mentioned that they would want to label LDs based on different characteristics like pedagogical approach, curriculum target, objectives, or target users. One researcher mentioned that it would be useful if the system would help to find patterns related to the learning environments that were chosen by practitioners, which might help to identify the ones that might be adequate for particular curriculum subjects, or learning objectives. Managers related to Smartzoos, which allow to copy and modify existing LDs done by others, expressed that they would like to understand how the LD artifact evolves, in terms of the reusability of LDs by others (versioning),

Table 1. Classification of needs according to the AL4LD framework, RQs, and the learning context (general vs. location-based). Marked with (*) items considered as important by practitioners, while with (+) the ones by managers and researchers, when presented with the results during the prototypes evaluation.

AL4LD Layer	RQ	Needs	
		General AL4LD Context	*Location-based Context*
Learning analytics for LD	*(RQ1, RQ2)*	- Creating and updating students' profiles. - Time of the completion of tasks. - Performance metrics of a learning activity.* - Process metrics of a learning activity (e.g., behaviour, engagement).* - Students' satisfaction and preferences.	- Real-time monitoring (e.g., live location).* - Location of the completion of tasks. - Knowing the time spent per location. - Visualising the path followed by students.
Design analytics for LD	*(RQ1, RQ3)*	- Measuring the achievement of pedagogical goals (e.g., learning objectives).* - Properties of a learning design (e.g., type of tasks, social spaces). - Identifying parts of a LD that need to be revised (learning re-design).* - Practitioners' design effort (in terms of time or actions).	- Bridging between analytics from physical and digital Spaces. - Identifying parts of the situated learning environment that need to be changed.
Community analytics for LD	*(RQ4)*	- Labeling LDs (e.g., by pedagogical approach, curriculum subject, objectives, target users).+ - Metrics about the characteristics of LDs (e.g., number of designers per subject, or most used type of tasks).+ - Reusability of LDs by others (versioning). - Identifying successful LDs that can be suggested (as templates).* - Usability metrics.+	- Identify situated environments that might be adequate for particular curriculum subjects, or learning objectives. - Usability and technical issues related to Location-based Learning (e.g., GPS problems).

as well as which LDs (with which characteristics) were being re-used the most. Since the user experience can affect not only the adoption but also condition the teaching and learning process, another aspect that emerged was related to usability metrics. These could be technical issues, or feedback that helps to understand if the application is intuitive enough and if it is perceived as useful in supporting the creation of LDs.

Overall, when presented with the results (Table 1) during the evaluation sessions, practitioners considered all items to be relevant. The ones that were mostly emphasized include: performance metrics (5 practitioners), process metrics (4), as well as real-time monitoring (4), from the LA layer; parts of the LD that need to be revised (4) and achievement of pedagogical goals (3), from the design analytics layer; as well as identifying successful LDs that can be suggested as templates (3) from the community analytics layer. Managers and researchers considered important items such as Labeling LDs (3), metrics about the characteristics of LDs (2), and Usability metrics (2). One manager mentioned that a missing element from the Community analytics could be having a heatmap, of locations in the map where LD have been designed (which is similar to "Identify situated environments that might be adequate for particular curriculum subjects, or learning objectives").

5.2. Dashboard Prototypes

Three main ideas (as metaphors) resulted from the design workshop, two focused on supporting practitioners' LD practices through analytics, and one that informs managers and researchers. A distinguished paper-prototype was designed for each metaphor. To simplify the process and avoid confusion during the evaluations, similar features were not repeated across dashboards.

The first metaphor was named Zoom-in (Figure 3), because the corresponding dashboard allowed practitioners to zoom into/out of data of a specific track (e.g., answers, or time spent in a specific task, by a specific student; average correct answers, or average time of all students for the same task).

The second dashboard was named Timeline (Figure 4), because it allowed practitioners to monitor an ongoing activity in real-time, through a news-feed, where events (e.g., response from a specific student to a specific task) popped-up chronologically, on top. Practitioners could switch between this view and a map view that showed the real-time location of the students. When clicking on the location of a specific student, related performance metrics would pop-up.

The third metaphor was Reporting and its corresponding dashboard intended to support managers of educational institutions and researchers to inquire about the usage of the tool, based on their specific interests (see Figure 5). It aimed to guide them to create a report through three steps. First, stakeholders had to define their interest (information that they wanted to know, or visualise) as questions. In continuation, they could choose from a set of predefined visualizations (as graphs, or plots) from the available data that could inform their questions. In the end, the dashboard allowed stakeholders to write down their conclusions, based on the obtained evidence, and download the report.

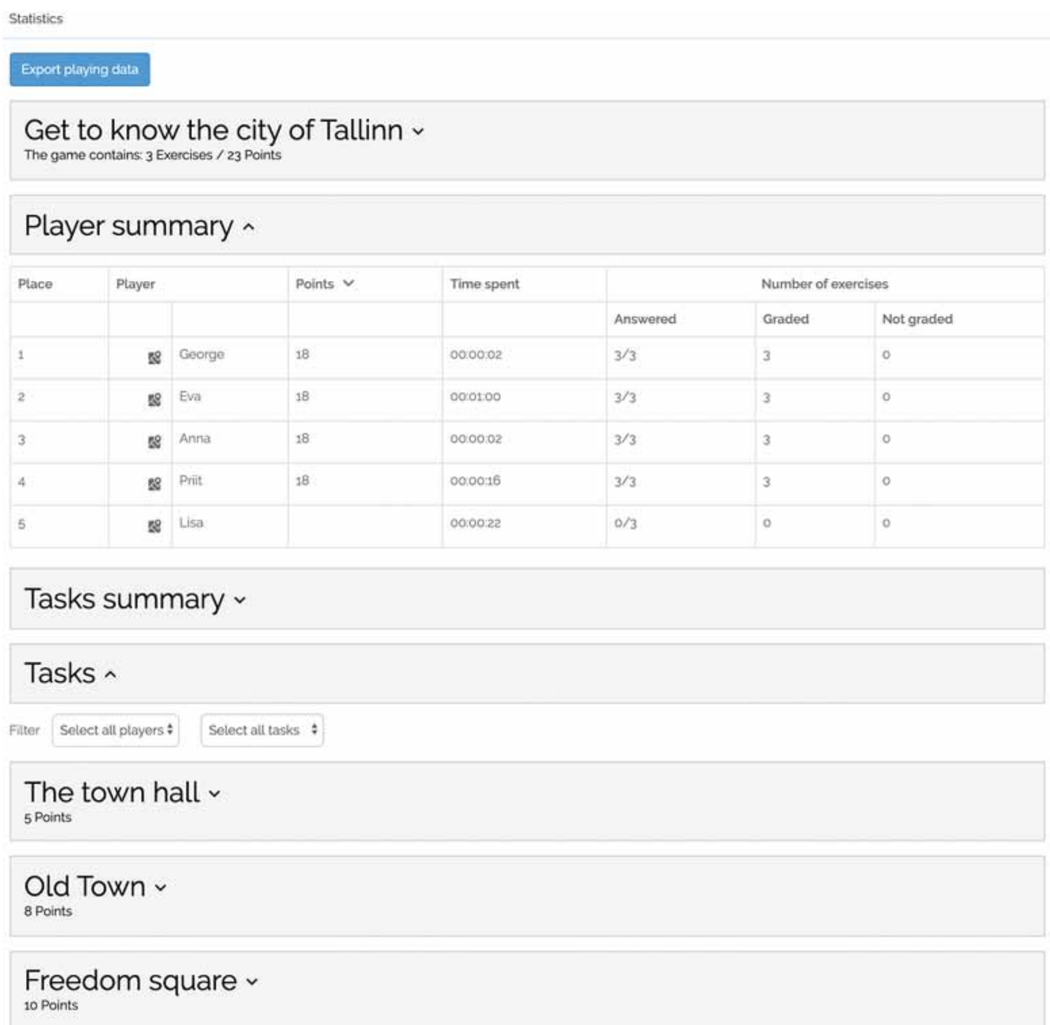
5.3. Prototypes Evaluation

The Zoom-in dashboard resulted to be more intuitive for practitioners, while most of them did not understand at first the scope and functionalities of the Timeline dashboard. Four practitioners explicitly stated that they preferred the organization and simplicity of the Zoom-in, while one preferred the interface of the Timeline (especially the ability to filter events). Two practitioners also liked that the goals of the activity are visible (to them and to students) in Zoom-in. Despite the fact that Zoom-in was preferred most, its graphical representations were considered as confusing. Two practitioners mentioned that they preferred to have just the tables with the data (shown in Figure 3). Furthermore, despite that the Timeline dashboard was not understood at first, practitioners appreciated the possibility to monitor in real-time students' location and performance (also among items identified as important in Table 1). One practitioner preferred a combination of the basic interface of Zoom-in (to support a reflection about the LD), with the map view from Timeline (for real-time monitoring).

Overall, Zoom-in received an EFLA score of 69, while Timeline scored 55 (out of 100). Zoom-in performed better than Timeline in the Data section of EFLA (78 vs. 53, out of 100), from which we could deduct that practitioners considered its representation of data to be more understandable (Figure 6). Practitioners also considered that Zoom-in can stimulate them to teach more efficiently and effectively, as seen from the results of the Impact section (72 vs. 51). Meanwhile, Timeline was perceived to better support processes such as awareness and reflection (61 vs. 58).

The Reporting dashboard resulted to be intuitive, as all stakeholders understood its purpose straightforwardly. However, all of them expressed that they did not consider the procedure as useful. Two researchers expressed that they did not need a guided process, while one manager mentioned that the guidance could be in the form of pop-up windows that suggest actions instead. One researcher suggested that the dashboard could show a catalog of visualizations (grouped thematically), from which users would select the relevant ones. Nevertheless, all stakeholders considered the ability to filter the information as useful and in line with the needs that they had identified as important from Table 1. Visualizations that were mentioned as relevant included the usage of the tool over time, the ability to filter LDs based on pedagogical labels (such as the topic), as well as the ranking of the most popular tracks.

Figure 3. Mock-up of the main page of the Zoom-in dashboard showing results from a track. It includes the sections: General information (displaying LD' goals as defined by practitioners; in the figure, it appears when clicking the title of the track "Get to know the city of Tallinn"); Player summary; Tasks summary; and Tasks (that allows selecting among different players and tasks, currently showing three tasks).[3]



6. DISCUSSION

Findings from the co-design process help to start a discussion about the support that analytics could offer to LD practices of different stakeholders, in location-based learning. Based on the AL4LD framework, it results that needs in the *LA layer* can be grouped into analytics that support awareness and reflection about specific LDs, and analytics supporting monitoring the deployment of LDs (real-time). Needs dealing with awareness and reflection (such as performance and process metrics in Table 1) can be supported with actions, learning resources, social, and context (LA) indicators. Rodríguez-Triana et al. (2017) state that while actions and learning resources indicators have been largely studied in blended-learning, context indicators (that can support needs under the Location-based Context in Table 1) and social indicators (related to Process metrics) could be more relevant

Figure 4. Mock-up of the main page of the Timeline dashboard where events of the activity appear in real-time. The dashboard includes a search option, a start button (that initiates the activity), a map view button (that shows students' location in real-time), a chat-box to communicate with students and other instructors (upper part), and a provisory ranking of students (right).

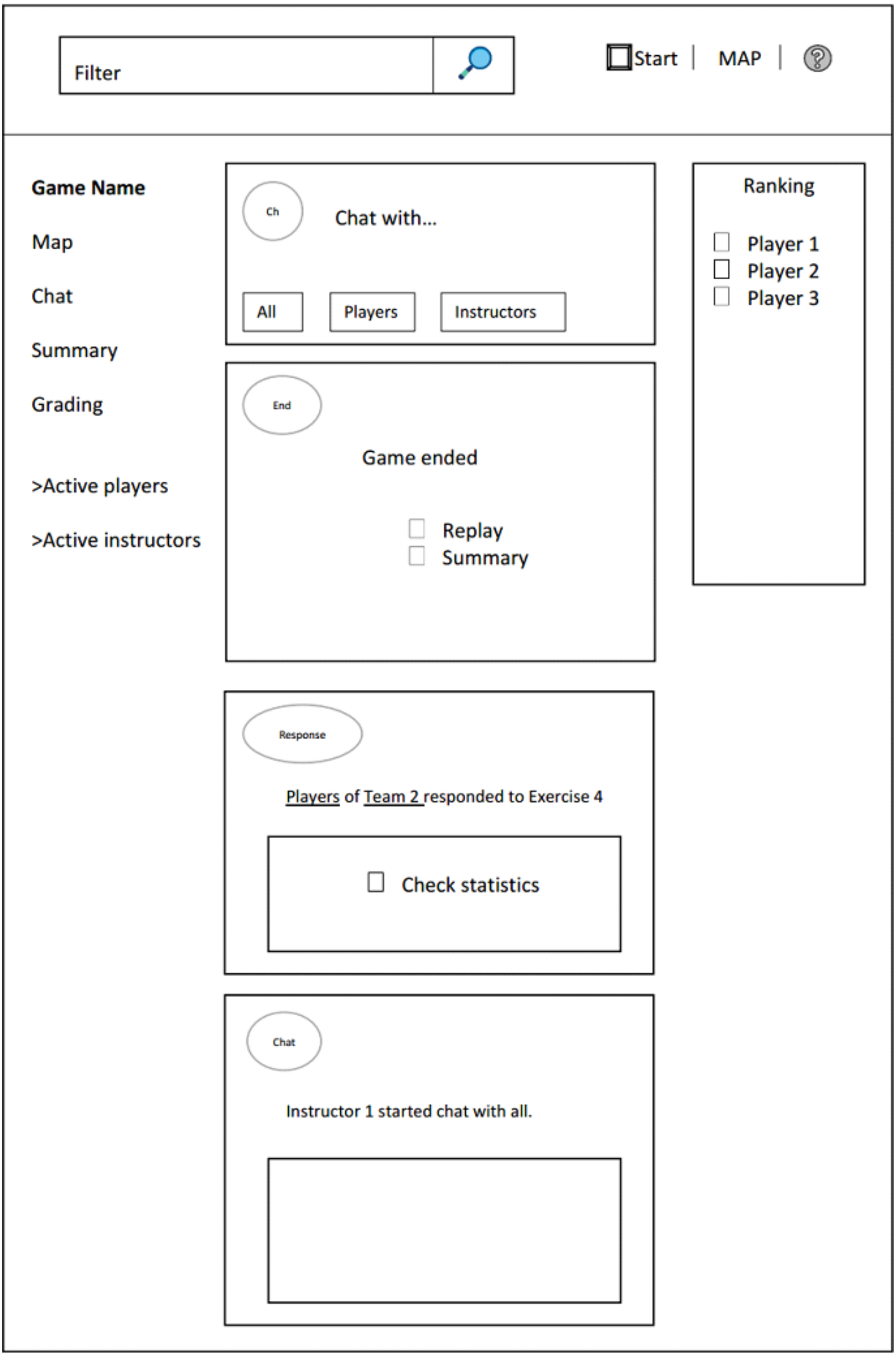


Figure 5. Mock-up of the Reporting dashboard with the guided process (right). The dashboard includes a set of variables (upper part) that, when selected, pop-up a set of related graphs (center). The current graph illustrates the number of visitors per day during a month, appearing after selecting Time.

Figure 6. EFLA scores for the Zoom-in (left) and Timeline (right) dashboards[4]

for reflection purposes. These indicators could also support practitioners to reflect on the delivery of the LDs, identified as a research gap by Sergis & Sampson (2017).

Results also emphasise needs specific for location-based learning (Table 1). Visualizations of these analytics could enhance practitioners' awareness about students' performance and engagement, which is difficult in the context of location-based learning, due to their distributed nature, where students constantly move (Muñoz-Cristóbal et al., 2018). While multiple aspects may be of interest for practitioners (such as visualising the path followed by students), which ones are appropriate to be monitored depends on the context, the content, and the learners. From the evaluation of the dashboards, it resulted as appropriate to support awareness and reflection processes and real-time monitoring, through two different interfaces, encompassing different sets of functionalities/visualizations.

When considering the *Design analytics layer*, it results that apart from identifying parts of the LD that might be re-designed, in location-based learning practitioners could be supported to identify parts of the situated learning environment that might need to be changed. Data sources in this context usually come from both physical and digital spaces, which should be combined to better inform the LD. Furthermore, aligning analytics across-spaces with LDs (such as an integration driven by the workflow of a LD), could address challenges related to the heterogeneous data and different contextual aspects in m-learning (as suggested for a flipped-classroom in Hernández-Leo & Pardo, 2016). Insights from the interviews also showed that in location-based learning it is important to support practitioners with functionalities that allow the re-design of existing LDs (during and after the activities).

The adoption of location-based learning solutions (and m-learning in general) depends not only on individual needs, but also on community level aspects (e.g., institutional decisions). Regarding the *Community analytics layer*, we could argue that stakeholders with a managerial role are interested in analytics that help understanding the adoption and the efficiency that these tools offer to LD. From the dashboard evaluation, stakeholders further emphasized needs such as "mapping LDs with the curriculum for later analysis", could be potentially useful to understand parts of the curriculum that are suitable for m-learning pedagogical approaches and parts that could require some reinforcements.

Furthermore, we noticed three clusters of technical implications, which can be addressed by analytics for LD in location-based, and more broadly in m-learning:

- **Support compatibility at the technical level:** Practitioners talk about integration, or compatibility at the user level (i.e., with tools and devices already adopted). To make it happen, it is necessary to enable compatibility at the technical level, e.g., using data formats that are widespread (both for LD and analytics) and support importing the designs, traces, or carry out context-aware analysis (as also stated by Muñoz-Cristóbal et al., 2018).
- **Adapt data sources to stakeholders data needs:** While often tools focus on digital traces and content analytics, integrating the mechanisms to collect data about the user perception (e.g., practitioners' and students' experience with the LDs), would contribute to a richer understanding of the LD at the different layers, as also reported in the case of teacher-driven data collection (Saar et al., 2018).
- **Support the process of LD:** It is important that the process of LD should not add a significant workload, but if possible lower it. Based on analytics (e.g., from previous LDs), authoring tools can support practitioners with suggestions about LD structures that are related with practitioners' objectives, learning outcomes, or local curriculums (Persico & Pozzi, 2015).

To support the reported processes and technical implications, we argue that it is important to involve multiple stakeholders during the design and implementation phases. Indeed, our iterations with the stakeholders helped us to identify different requirements, which when mapped with results from the literature in LD, LA, and m-learning, might ensure that the implemented solutions will be tailored to stakeholders' needs (Pishtari et al., 2020). The Design Thinking Process proved useful for structuring the research/design activities that involved multiple stakeholders. Proposing three very different dashboards, also helped us to collect a substantial array of insights from stakeholders. Neither prototype proved to be a perfect solution, but each offered clues of functionalities/visualizations that might be appropriate for specific LD processes. For instance, practitioners considered the map view in the Timeline dashboard (real-time monitoring) to better support their awareness and reflection about specific LDs, while the data representation resulted more understandable in the Zoom-in (confirmed also by EFLA results).

The case-study nature of this research could be considered as a limitation. However, common doubts about case studies have been addressed by Flyvbjerg (2006), that also considers that successful case studies involve a strategic choice of the case and the participants. We argue that participants in our study follow Flyvbjerg's critical case criteria (see section 3).

7. CONCLUSION

This paper presents the design process of analytics for LD features (as dashboards) in the context of location-based learning. We first gathered feedback from the stakeholders of two existing location-based tools (Avastusrada and Smartzoos) and later co-designed and evaluated three dashboard prototypes.

Our findings provide insights regarding the needs of different stakeholders about analytics for LD in location-based settings. While practitioners would like a system that helps to monitor and evaluate the effectiveness of LDs, managers of educational institutions and researchers are more interested in the adoption and integration of these m-learning solutions and the way that they support LD. To the best of our knowledge, this is the first study that investigates how multi-stakeholder analytics can support LD in a mobile and situated learning context. The findings may be of interest for multiple stakeholders (such as researchers interested in the field; developers/designers of m-learning systems; or practitioners that would like to select a location-based tool for their practices).

Apart from the potential refinement of the tools considered in this study, the results will guide the design of location-based tools with analytics features to support LD needs from different stakeholders. Future research will also consider practitioners' pedagogical practices in m-learning. For example, we could use the IPAC framework (Kearney et al., 2012) to outline LDs corresponding to pedagogies that support effective/innovative m-learning, as well as the role that stakeholders play on them. Later on, we could inquire on how analytics could support the LD practices of each stakeholders-group. Furthermore, we will conduct pilot studies in real settings to evaluate the effectiveness of the proposed features. Learners will also be involved in future co-design steps, not only to include LA solutions intended for them (e.g., for self-monitoring), but also about them (i.e., what data are students willing to expose without invading their privacy).

ACKNOWLEDGMENT

This research has been partially funded by the European Union in the context of CEITER (Horizon 2020 Research and Innovation Programme, grant agreement no. 669074). The authors would like to thank the participants for their contribution to this study.

CONFLICTS OF INTEREST

The authors of this publication declare there is no conflict of interest.

Process Dates:

Received: March 20, 2020, Accepted: July 7, 2020

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ENDNOTES

[1] https://avastusrada.ee/
[2] https://smartzoos.eu/
[3] Document containing mockups used in the evaluation of the prototypes: http://tiny.cc/dashboardmockups
[4] Document with the full results from the EFLA framework: http://tiny.cc/eflaresults

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