User Centered Approach for Learning Analytics Dashboard Generation

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Abstract: The use of learning dashboards with analytics might help users to gain insight into their learning process and then to make decision. However, designing meaningful Learning Analytics dashboard (LAD) is still a complex process that requires an explicit understanding of the user needs. For this reason, we carried out a user-centered design (UCD) approach with the aim to provide users with adapted LADs to support their decision-making. Hence, we develop a UCD process composed of 4 steps: (i) we propose a participatory-based design tool for capturing contextualized needs (ii) these identified needs will be described using an independent formalism and LAD models in order to capitalize on them (iii) to automate these models, we propose a LAD generation process (iv) finally, we carried out an evaluation phase with the aim to review and refine our models. During our process development, an iterative user needs refinement confirmed that decision is considered as a centered element for LAD generations.

1 INTRODUCTION

In recent years, Learning Analytics (LA) has emerged as a research domain. LA is defined as the measurement, collection, analysis and reporting of data about learners and their contexts(Siemens and Long, 2011). It aims to propose the means to collect and model digital traces of e-learning, and implement learning indicators and visualizations. Nevertheless, LA is confronted with heterogeneity problems(Chatti et al., 2012). Therefore, analysis processes must be redefined when their implementation context changes: they cannot be reused, shared or easily improved (Lebis et al., 2016). Since data visualization is part of the analysis process, the definition of Learning Analytics Dashboard (LAD) models is necessary as a means toward the capitalization of LAD's structure. Actually, LAD is defined as a single display that aggregates different indicators about learner (s), learning process(es) and/or learning context(s) into one or multiple visualizations(Schwendimann et al., 2017).

In this paper, we aim to propose an independent formalism and models to describe LAD. We propose also an automatic process for generating LADs. Our aim is therefore to capture needs in the most exhaustive way possible, to capitalize on this capture through explicit models, and to propose a generation of learning dashboards based on these models. LAD has been studied by various researchers. Some existing works proposed LADs to help teachers during their learning activities(Xhakaj et al., 2017) or to study the effect of LA on student performance (Arnold and Pistilli, 2012). All these works occur in predefined contexts while presenting specific indicators with the aim to lead users to visualize what they want. Hence, we work on generating LAD in a dynamic way with respect to users contexts. The main idea is to support users identifying which and when the decision should be made. Therefore, we decided to follow a user-centered design (UCD) approach. We present therefore our works dedicated to answer these following research questions that focuses on:
How to capture user needs and contexts? We assume that users can make decision using LAD. Thus, LAD content should meet user requirements and answer their visualization objectives.

How to generate an adapted LAD? Our works aim to design LAD generation process in a dynamic and contextual way. The generation process should take into account a generic LAD model while highlighting the links between different key elements: learning indicators, visual displays and user contexts.

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2 USER-CENTERED DESIGN APPROACH

LAD design requires a well-understanding of user needs and their contexts so that we can help them make a decision. We conducted a User-Centered Design (UCD) approach. It is a well-known design approach that aims to develop, in an iterative way, an explicit comprehension of users(Jokela et al., 2003). UCD can help a designer to establish user needs, preferences and limitations, to discover design opportunities throughout the design process where user satisfaction becomes a key measure of design success (Lanter and Essinger, 2016), which helps to evaluate both the effectiveness and relevance of the tools (Miksch and Aigner, 2014), leading to a final validation by the user (Doroftei et al., 2017). UCD have four main phases:

Phase 1: Understand Users and their Context. The objective is to identify relevant method for capturing contextualized needs. As a result, we proposed a participatory-based tool.

Phase 2: Specify User Requirements. Capturing user needs is a means to create and refine our LAD's models mutually. This phase is considered as a direct interpretation of user needs.

Phase 3: Produce Design Solutions. We have carried out an automatic LAD generation from these models. In fact, we automate this phase with a LAD generation process (DGP).

Phase 4: Evaluate design proposal against requirements The evaluation aims, firstly, to review and refine our LAD's models and secondly, to capture new users' needs in order to provide adapted LADs.

3 PHASE 1: UNDERSTAND USERS AND THEIR CONTEXTS

We detail in this section, three iterations used to understand and to refine user needs: (i) We conducted a needs assessment study that demonstrated the difficulty to capture user needs (ii) We carried out participatory meetings with teachers and proposed sketch activities to enhance the user needs expression and finally (iii), we proposed a participatory-based tool.

3.1 First Iteration: Needs Assessment Study

The focus of this iteration was to develop an explicit comprehension of users contexts. This study includes survey and semi-structured interviews(Dabbebi et al., 2017). We organized the study around five questions based on the Five W's and How methods. Each question refers to a contextual dimension:*"Who, Why, What, How, When"*.

"Who" dimension is used to specify users and their roles.

"Why" dimension relates to the identification of users' objectives. In other words, it aims at understanding why it is important for the user to use LAD.

"What" dimension is dedicated to identifying LAD content especially indicators.

"How" dimension refers to the description of LAD structure.

"When" dimension is used to specify the way in which the dashboard is used.

Following this iteration, we noted that users found difficulties in expressing their needs clearly through a simple questioning. Actually, users couldn't easily project themselves into use of LAD or imagining the possibilities especially when asking teachers about the use of digital data and indicators. For this reason for the second iteration, we organized participatory workshops with the aim of stimulating their imagination and leading a brainstorming.

3.2 Second Iteration: Participatory Workshops

We organized participatory workshops with 8 elementary and high school teachers. This group of teachers use the same learning platforms called the Tactileo Map application (Sanchez et al., 2015). The workshop was organized around two main activities:

1) The sketch activity is making teachers, through a simple sketch, express their ideas, visualize what they imagine, share and discuss with others. This activity aims to gather additional information around the five contextual dimensions. During this activity, teachers start by identifying their main objective which was monitoring. The choice of this objective was logical. Indeed, (Schwendimann et al., 2017) did identify two main LAD objectives: self-monitoring or monitoring other. During this workshop, we noted that teachers did discuss this objective according to different levels of analysis. Actually, (Siemens and Long, 2011) did identify three levels of analysis: individual, class and departmental level. Teachers choose to work together on a single LAD description. The chosen LAD is dedicated to help teachers monitor their student activities according to class level.

2) Wireframe activity is a visual guide that represents an abstract LAD structure including content organization. During this activity, we extract two information: a) indicators related one to another are grouped

into the same section, b) indicators placed regarding their importance. During this iteration, we noticed that users project more easily in their decision to be made rather than their objective. Like (Xhakaj et al., 2017), we consider that the expression of decision-making related to LAD might influence its design. In fact, the dashboard, as a key concept in Business Intelligence (BI), is defined as a support that improves decision-making and user performance (Rasmussen et al., 2009). Our focus on BI is related mainly to the fact that LA at the beginning was emerged from BI (Siemens and Long, 2011).

We also noted the diversity of the user's needs that is difficult to capture. To go further, an adapted tool was therefore necessary and a participatory design method needs to be instrumented (Sanders et al., 2010).

3.3 Third Iteration: A Participatory-based Design Tool

Inspired by the conduct of our participatory workshops, we propose therefore this time a tool-based method. Despite its low use in LA (Abel and Evans, 2013), participatory tools allow a better expression of user needs and the exploration of design alternatives and it helps tools appropriation (Knibbe, 2016). We propose a design space (Shaw, 2012) through a tool to support the participatory LAD design. We have designed our design space around the same contextual dimensions (Gilliot et al., 2018). We represents this design space with cards and boards. As results of previous iterations, we decided to represent the decision to be taken as a centered element. The choice of decision must be explained and then characterized. Then, we represent the context of use. This is about characterizing elements around the specified decision to be taken. We propose to participants the opportunity to define the data needed to be visualized and to associate it with visual displays. Finally, to organize and define a LAD structure, we propose to participants a second board represent a paper prototyping steps. This participatory-based design tool was tested in two different contexts. A first test workshop was set up with teachers in computer science, and the other one was proposed to national education supervisory staff. The workshop process was observed and filmed, with the agreement of the participants. A satisfaction questionnaire was also used to gather the participants' opinions. We proposed seven questions requiring a level of agreement on a 5-level Lickert scale. Overall, the level of satisfaction we consider to be high (all answer was higher than 3). The first feedback from a test workshop is encouraging, and shows that this form of workshop effectively facilitates cooperation and further exploration of alternatives.

3.4 Findings

During these iterations, we identify four points:

First, the context in which LAD is used influences its organization. It is therefore necessary to be able to formalize this context, both to help users reflect and to capitalize on these uses for reuse. Even if each LAD depends on a particular user's objective, we noted it can be related to the user's contexts. In our example, we noticed that teachers are more interested in monitoring their students activities while administrative staff aims to monitor courses popularity(Dabbebi et al., 2017).

Second, we consider that LAD reflects users during their learning situation. So, we noted that the expression of decision-making related to LAD visualization can affect its design.

Third, we found out that representing indicators in LAD is connected to different levels of analysis. Teachers have organized their proposed indicators based on the three level of analysis: departmental, class and individual level.

Finally, LAD displays different indicators (Schwendimann et al., 2017). These indicators can be visualized through simple textual representation, or through the use of sophisticated visual display. The choice of visual displays depends on the user's preferences, the context of use and the choice of indicators itself. In the end, we noted that our participatory-based design tools take into account the identification of these findings. Actually, this tool is being used from need capture to LAD modeling, which it will be discussed in the next phase.

4 PHASE 2: SPECIFY USER REQUIREMENTS

The two phases "understand users and their contexts" and "specify user requirements were tightly coupled as our models were refined at each iteration. The main objective of these iterations is to specify all the elements that make it possible to characterize the relevant LAD's structure(s) and gradually refine all our conceptual models. The modeling phase can be used to formalize and to evaluate the identified needs with the aim to make it operational. LAD can be considered as an aggregation of a set of components, including indicators and visual displays that serve to answer user context (Schwendimann et al., 2017). Indeed, identifying these components separately can be used to promote their reuse in similar contexts. In our work, LAD reuse is maintained by three main points:

1. A meta-model used to describe LAD components in a generic way to ensure its reuse.
2. A LAD pattern used to specify how to organize LAD components regarding user contexts.
3. A generic description of LAD key elements to ensure its identification and its reuse in similar contexts.

4.1 LAD Meta-model

We proposed meta-model in order to describe mainly the organization of LAD components. In other words, it represents explicitly LAD structure.

We propose an hierarchical structure to better organize displays and to facilitate generations according to user needs. In our work, we focus on screen visualizations. So, we adopt a classic document structure. We propose LAD meta-model based on three hierarchical components: widget, section and view.

A widget is an atomic component which represents visual elements such as a graph, grid, table or image. It is usually represented by a pair of information indicator,visual display.

A section represents an intermediate component. It aims to regroup a set of related widgets in order to highlight their relationships.

Finally, the view is considered as the root component. It may be represented as a graphical container. It was created mainly to provide a context in which the various components can be arranged and displayed. The definition of a view is about to regroup and organize a set of sections to meet a specific objective.

4.2 LAD Pattern Modeling

A pattern is used to group a set of generic specifications around the selection and organization of LAD in a specific context of use. The pattern is about describing both LAD structure and content in a generic way. Actually, it is a main element to assist LAD to data storytelling (Knaflic, 2015) in order to facilitate decision-making. This generic specification is designed mainly to ensure LAD reuse in similar contexts. We propose then to associate a pattern to LAD view to guide its structuring.

Decision Guidance. The choice of pattern is mainly related to user decision. In fact,in BI, decisions are made at different levels in the organization's hierarchy: Operational, tactical and strategic(Golfarelli et al., 2004).

The operational decision relates to the day-to-day running of an activity. They are mainly dedicated to the different business lines, which aims at measuring the performance of a specific action or process.

The tactical decision level, which is narrow in scope and short-term in nature, helps to implement the strategy. These kinds of dashboards are usually built for middle management.

The strategic decisions are long-term in their impact. They affect and shape the direction of the whole organization. They are generally made for senior managers. Decision levels in general depends on (1) the frequency of dashboard visualization and (2) on the level of detail. (1)The frequency indicates the period of time in which indicators should be presented. (2)In LA, we identify mainly three level of analysis that may be represented by three levels of detail which they are individual, class or departmental level. The choice of decision level influence the choice of indicators. Only key performance indicators (KPI) should be providing it to users(Pauwels et al., 2009). To assist LAD to data storytelling, we need to identify decision levels and to help users to focus their attention on a particular target. Indicator can be focused on learning activity, data producers, time and learning context (Schwendimann et al., 2017). Thus, to guide decision, we need to identify decision level and LAD targets.

4.3 LAD Key Elements

LAD generation requires three mandatory key elements to be modeled (Dabbebi et al., 2017): indicators, visual displays and user context.

Indicator Modeling. In our case, indicators are already calculated by several analysis platforms. These indicators are focused on a particular learning objective. This model answer mainly to the "What" dimension. Indicators modeling aim to index and to categorize indicators. This model includes the type of indicator, the context of use (Learning objective, learning situation, etc.) and its technical characteristics (data quantity, dimensions, etc.). In our model, indicators description should be sufficiently detailed in order to facilitate their representation regarding the adequate level of analysis, the level of detail and to facilitate visual displays selection.

Visual Display Modeling. Data visualization helps users to get into indicators and understand what is happening in a simple way. The choice of an adequate visual display may be critical. Indeed, presenting a wrong visual display or providing a sophisticated one can cause a wrong data interpretation. We, therefore, propose a visual display model with the aim to describe and to index the existing visualization methods. The choice of visual display depends mainly on user preference and on the characteristics of indicators. Visual display can be used to empower indicators objectives. This model represents mainly the "How" dimension.

User Context Modeling. LAD generation requires to understand who is the user. Each user has their role, objectives, preferences, learning environment, and which decision needs to take. This model will help our generation process to provide the user with an adapted LAD to make decision easily.

Using these different models in general aim to assist and guide LAD generations. Thus, identifying, organizing and presenting these key elements will form the main steps of the generation process.

5 PHASE 3: LAD GENERATION PROCESS

In this section, we present our LAD generation process (DGP). The purpose is to produce LAD in different contexts in a dynamic way. We define in this section the steps followed for LAD generations.

5.1 Process Description

DGP is organized around the same contextual dimensions. Each dimension is represented within the different LAD models that will be operated by DGP. In fact, DGP should respect LAD meta-model and the chosen pattern to ensure the links between LAD key elements. Hence, LAD should present a group of learning indicators in line with the user context. These indicators should be well-organized in a way to respect to LAD meta-model and the pattern description. Then, to make these indicators easy to understand, the identification of an appropriate visual display is required.

We can resume DGP workflow in three steps:1) Content identification, 2) Content organization and 3)Dashboard Presentation;

5.1.1 First Step: Content Identification

This step of content identification is detailed in Fig1.

1) Identifying User Context: Based on user context model, DGP start by identifying the user role, learning platforms and learning activities and learning objectives (etc.) in order to be able to prepare the dedicated learning indicators and to understand his preferences. 2) Identifying user decision: Depending on expressed users objectives and on what and when the decision needs to be made, DGP select

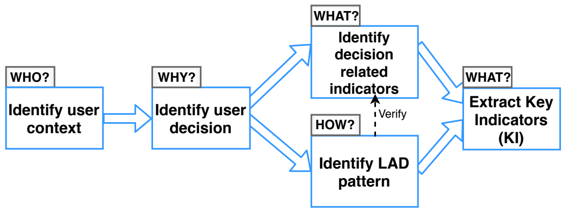

Figure 1: Content identification step.

LAD patterns which describe the level of decision including the level of detail and the decision target. 3) Extract Key indicators (KI): The selected pattern verify whether the selected indicators are considered as key indicators (KI) or not. In BI, KI is defined as a set of measures that are considered most important for an organization. Following the same logic, DGP should identify only important measures. To evaluate its importance, DGP should follow the pattern indication including mainly the decision target, the level of detail. For example, when user decides to plan their learning activities dedicated to a specific class, DGP selects only the indicators related to the learning activity as a decision target and it should extracts and regroup all measures to represent a synthetic view of a specific class activities. At this stage, LAD content is ready to be used.

5.1.2 Second Step: Content Organization

This step is about establishing relationships between indicators according to LAD meta-model. This step is based mainly on a set of organizational rules with the aim to:

- Propose an elaboration rule for representing a pair of KI when one gives additional information related to another KI. This rule can be applied when the two KI share the same context, the same source of data (same learning activity).
- Group indicators together when one provides a short summary, it can be a textual indicator or even a global indicator that summary the result visualized in another indicator.
- Propose a group of indicators together when they represent all the same information with a different level of detail.

The purpose is to transform LAD from a simple information visualization (which is a minimum LAD requirement) to a decision-making tool by relying on cause-and-effect relationships. By identifying these relationships, DGP will be able to constitute and organize LAD components: widget, section and view. This step ends by adjusting the chosen pattern to be more adapted to user preferences.

5.1.3 Third Step: LAD Presentation

This step is about preparing a list of possible visual displays and populating LAD with data. 1) Selecting

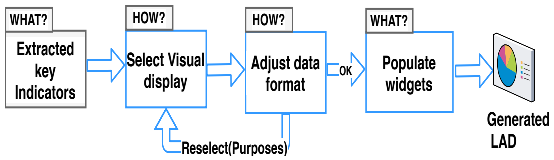

Figure 2: LAD Presentation's Step.

visual displays are based on different criteria. Firstly, DGP should connect both indicator and visual display models. Thus, it compares KI descriptions with those of visual displays like their dimensions and data quantity. Secondly, DGP will check users model to identify user preference. In the case of having more than one visual displays for each KI, DGP propose visual display by default. In case of failure, for example, when kI measures represent the time evolution, but DGP select a bar chart rather than a timeline chart because of the technical choices (regarding dimensions or amount of data). Thus, DGP will reselect another visual display sharing the same purpose as a bar chart and represent the time evolution. Actually, this step is based mainly on the kI visualization where each extracted key indicators will be presented into adequate visual displays.

2) Adjust data format: The adjustment step is performed automatically by the system. Considering that each visual display has different data format requirements, it is necessary to adapt the kI measures. Then the KI measures can be reprocessed individually according to the required format. In case of failure, DGP choose another visual display sharing the same purpose.

3) Populate widget : After the KI measures are adjusted based on the format, they are sent to the corresponding visualization algorithms. Actually, DGP will work on populating every widget with their respective data (measures and dimensions). Data will be represented according to the chosen period of time and LAD level of detail.

6 PHASE 4: EVALUATE DESIGN PROPOSAL AGAINST REQUIREMENTS

This phase is about evaluating the design proposal throughout the iterative cycle. This is used mainly to acquire feedback on DGP and to refine our models. Moreover, we tried to highlight decision impacts on LAD generations. Actually, the need to establish an iterative evaluation phase is justified by our need to ensure the effectiveness of our DGP. Indeed, (Dick et al., 2005) recommends the use of rapid prototyping throughout iterative cycle as a strategic and effective approach to ensure product effectiveness. We conducted this evaluation phase by implementing LADs to TactileoMap teachers. We carried out two LAD generation iterations. The first iteration was about ensuring an automatic LAD generation. The second iteration was about taking into account user decisions. LADs was evaluated during focus groups. These focus groups were semi-structured. The idea is to guide participants to evaluate and analyze LAD's components, although the discussion was open.

6.1 First Iteration: LAD Dynamic Generation

The first LAD was designed and developed for the same group of teachers. We proposed LAD to help teachers in monitoring student performance (Fig3). The choice of LAD content and structure depends mainly on teacher needs. Thereafter, we carried out

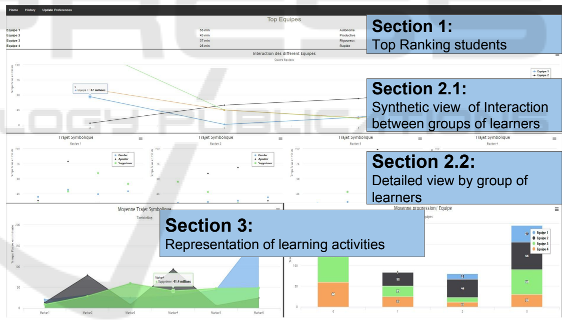

Figure 3: First LAD Generation.

an evaluation session based on focus group method. We organized this session with two groups of teachers(G1 and G2). Each group should evaluate LAD content and structure. In other words, they should evaluate, first, the usefulness of learning indicator in regard to their learning objective. Then, they evaluate whether LAD presentation was easy to interpret.

Findings: Therefore, we detail teacher feedback:
Structure: Both G1 and G2 shared the same idea about LAD structure. Actually, they found LAD organization conforms to what they expected.
Content: The evaluation includes the indicators and visual displays.

We noted that each group had its own vision about LAD content. The first group (G1) need more detailed indicators. While the second group (G2) asked to have fewer indicators with synthetic data.

We have deduced that visual display choice was affected by LAD level of detail and indicators. In fact, G1 preferred to move from using simple histograms to drill-down histograms with the aim to visualize more detailed indicators.

We concluded that LAD generation was fully adequate for both groups. We noticed that LAD was evaluated based on if it helps teachers take decisions and not based on only their objective. In fact, we noted even if teachers share the same learning objective, they did not share the same need to make the same decision. Whereas, the use of dashboard is clearly illustrated in BI process. Thus, we noted that this iteration confirms the need to adopt the BI approach.

6.2 Second Iteration: LAD Generation of Decision-making

We carried out another LAD generation with a refined LAD model. This iteration guided by decision and pattern specifications. We propose two versions of LAD where each version represents a specific decision level. As we mentioned, decision level is defined by the level of detail and the frequency of use (decision horizon). These LADs are dedicated to answer the same objective about monitoring learner performance. However, each one of them will be guided by different decisions (decision target and level).

We proposed for G1 an operational LAD (Fig4). This choice was justified by the need to visualize detailed indicators daily. Thus, we offered G1 the same indicators with detailed view. In addition to decision level, DGP presented kI according to G1 decision target which is learners. Actually, kI should be, on the one hand, about learners. On the other hand, measures that represent learners should be presented mainly on x-axis. This will guide teachers to focus more on learner performance rather than another target.

For the second group of teachers (G2), we proposed a tactical LAD (Fig5). This decision level was justified by the need to visualize relatively frequently of fewer indicators. This is a medium-term decision. Therefore, DGP selected only two indicators. The purpose is to help teachers to evaluate and to organize learners into teams for their future activities. Thus, LAD decision target is the same as G1. Since the frequency of use is different and G2 will not be able to visualize daily indicators, DGP propose presenting measures over a period of time to provide more synthetic view. To conclude, the evaluation phase was used to validate the effectiveness of our DGP. While the first iteration was a way to refine our models, the

Figure 4: Operational LAD: Monitoring learners performance over time.

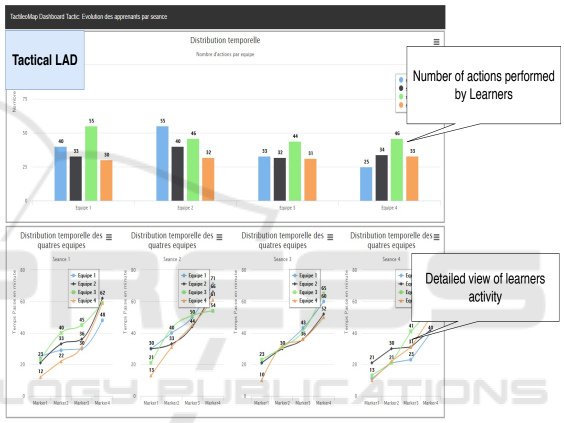

Figure 5: Tactical LAD: Monitoring learners performance over a period of time.

second iteration demonstrated the impact of the decision on LAD's generation. Thus, we can conclude that decision is considered as a centered element for LAD generations. Actually, by changing only the decision, DGP proposes a different dashboard automatically.

7 CONCLUSION

A key assumption of our work is that users can make decision using LAD. The idea is LAD can be more effective if it is designed with a thorough understanding of user needs and contexts. In this paper, we carried out a complete user-centered design approach with the aim to capitalize, in an iterative way, an explicit comprehension of users. We propose an equipped approach from capturing the user needs to LAD generation thanks a dedicated DGP which allows rapid prototyping to have user evaluations. During our first iteration, we identified the users' difficulties in expressing their needs. We have made the choice to introduce the decision as a dimension of the process. The introduction of the decision provided a number of information: During the first phase, we found a richer expression of needs. During the third phase of LAD generation, we found that introducing decision contribute to the generation of different LADs. During the last phase, we validate that these different LADs were relevant to the decision identified. We therefore confirm that considering the decision as a centered dimension in our work has a positive impact on the design of LAD. The next stage of our work is to evaluate our DGP with other users while refining decision making modeling. We also aim to capitalize LADs to enhance the ability of our process to propose alternatives.

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