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Towards Data-Informed Teaching Practice: A Model for Integrating Analytics with Teacher Inquiry

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Abstract

Data-informed decision-making in teachers' practice, now recommended by different teacher inquiry models and policy documents, implies deep practice change for many teachers. However, not much is known about how teachers perceive the different steps that analytics-informed teacher inquiry entails. This paper presents the results of a study into developing an Analytics Model for Teacher Inquiry (AMTI), which was then used to understand how teachers (N=10) construe the steps in the model and to explore the possible constraints as well as incentives for TLA-informed teacher practices (Teaching and Learning Analytics). In the final iteration experts (N=7) and teacher-researchers (N=2) tested and evaluated the developed model. Their feedback was used to improve the model and provide example cases with insights into possible scenarios for TLA-informed analyses of teaching.

Notes for Practice

- Teachers are encouraged to inquire about their practice using evidence, but little specific advice is given about what analytics solutions to use. To ease the process of teacher inquiry (TI), this study proposes an Analytics Model for Teacher Inquiry (AMTI) with supporting examples for teachers (including varied data types that could inform teachers).
- Present teacher inquiry models focus on learning analytics but teaching analytics should also be included for a holistic view. This indicates the need for better tools and technology to also collect and analyze teaching data (e.g., teaching methods and classroom activities and how these engage students and support learning).
- We tested the proposed AMTI with 19 practitioners through three iterations of Design Based Research (DBR) to improve the model and check how teachers perceive the process of analytics-informed teacher inquiry. Based on the outcomes, we provide design principles for TLA-related inquiry models.
- We also identified obstacles and incentives in the way to large-scale analytics adoption in teachers' practice. We realized that, for take-up, teachers need a clearer picture of the benefits of analytics for their work (gains vs. pains).
- To support a growth mindset, analytics-informed TI should provide opportunities for experiencing success and not become a tool for auditing teachers' practice.

Keywords

Data-informed teacher inquiry, teaching analytics, learning analytics, teacher inquiry model, thematic analysis

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1. Introduction

Changing times and student needs push teachers to review their practice and try new strategies (Priestley et al., 2012). In addition to assessment data and their own perceptions of classroom realities (Datnow et al., 2012), teachers could benefit from varied data (Mandinach, 2012; Schildkamp & Datnow, 2020) about their individual contexts (physical classrooms, teaching

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data) to make informed decisions about the feasibility of the teaching strategies used. However, the adoption of regular and systematic data-informed teacher inquiry in schools is still slow (Gleason et al., 2019).

Teachers' limited data use can be pinpointed to a lack of access to relevant data to satisfy their needs (Viberg & Gronlund, 2021) and its high workload compared to the expected gain (Hansen & Wasson, 2016). Still, not much research is available about this topic. Teaching and Learning Analytics (TLA) have emerged to address the issues of matching teacher needs with available data (Sergis & Sampson, 2017). However, in schools, where automatic data collection from learning management systems is scarce, teachers need help with data collection and analysis in technology-enhanced face-to-face classes. Making sense of these data and deciding on further action also seem to be aspects where teachers require assistance (Hansen & Wasson, 2016).

Researchers have suggested several teacher inquiry and data use models (Hansen & Wasson, 2016; Poortman & Schildkamp, 2016; Lai & Schildkamp, 2013). However, these focus on student learning rather than on teaching and can remain fairly theoretical for practising teachers if no examples or explanations for their use are provided. Also, little is known about how teachers understand the steps prescribed in these models or what assistance they would deem necessary to put them into practice in their own work (Hansen & Wasson, 2016). Additionally, teachers seem to need clearer examples on data types (e.g., student engagement and collaboration data or patterns of teaching activities) that could be collected and analyzed from their own physical classrooms.

So, it is also necessary to look at teacher inquiries from the perspective of teaching analytics and better explain the steps in teacher inquiry models for teachers' data use. Based on earlier teacher inquiry research, this study aims to develop an Analytics Model for Teacher Inquiry (AMTI) that guides teachers in every step of the process, provides explanations (e.g., options for data collection and sense-making) and, hopefully, reduces the efforts needed for setting up an inquiry process based on TLA. The paper reports on a design-based research effort to develop such a model (McKenney & Reeves, 2012) and find out how teachers construe the steps in the model, as well as identify possible inhibitors and incentives for regular TLA-informed teacher inquiry.

2. Conceptualizing Teachers' Data Needs and Sense Making

Although the effects of teachers' decisions on their teaching have been seen as affecting students directly, not much is known about what role teachers' perceptions of teacher inquiry steps might play in their analytics use for decision-making. As reported in a review of LAK and JLA papers between 2011 and 2018 (Dawson et al., 2019), most LA research dealt with student-related data only. However, some direction towards teaching analytics could be seen beginning in 2018. Feedback studies have also had a relatively minor role in LAK and JLA studies (Dawson et al., 2019). The lack of scale could be associated with low adoption of analytics use by practitioners, which is why it is of utmost importance to find out the reasons for this low uptake by teachers and provide the necessary tools and guidance to overcome any obstacles.

Sergis and Sampson (2017) define TLA "as a framework to guide the process of teachers' reflection on their educational design and delivery, based on evidence from educational data related to both their learners, as well as their own" (p. 6). Teacher inquiry "addresses the professional development of teacher practice by investigating student learning through action-oriented, evidence-based teacher-led research" (Hansen & Wasson, 2016, p. 2). Thus, teacher inquiry could entail collecting and analyzing both student (e.g., assessment, engagement, or collaboration) and teaching data (e.g., time allocation or methods used during a session) to address the specific needs of each practitioner. The present paper focuses on analytics-informed decision-making (within teacher inquiry), in which data do not drive but inform decisions (Schildkamp et al., 2019), and which could be promoted with the help of TLA tools and methods (Sergis & Sampson, 2017).

Schildkamp and Kuiper (2010) point out that teachers need data for instructional change, monitoring progress, identifying areas of need, evaluating their own performance, and supporting conversations with parents. To access such evidence, teachers can mostly rely on automatically collected data from Learning Management Systems (LMSs). However, as these data sources are limited at the primary and secondary school levels, where most instruction takes place outside an LMS, alternative ways are needed to collect more personalized and customized data from teachers' own (offline) contexts, i.e., data in, on and for action (Ferguson et al., 2014).

Also, at present, teachers seem to be mainly interested in data at the classroom level (not school self-evaluation data or inspection data; Schildkamp & Kuiper, 2010), so they usually use assessment data and make decisions based on what they see happening in the classroom relying on their own experience as teachers (Ingram et al., 2004; Schildkamp & Kuiper, 2010). Obviously, other types of educational data (e.g., information about teaching) should be considered as well (Sergis & Sampson, 2017) when making decisions about classroom practice. However, this is not an easy task since analytics use depends not only on teachers' readiness to collect and use data to transform instruction but also requires certain skills and competencies. Wayman and Jimerson (2014) outline six: 1) asking the right questions; 2) integrating data use with curriculum, instruction, and

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assessment; 3) analyzing and interpreting data; 4) linking data to classroom practice; 5) computer skills; and 6) collaborating around data. In addition, practitioners should be aware of data misuse, abuse, and misinterpretation issues, as well as ethical considerations connected with data collection and use.

Mandinach (2012) also points out the possibly low quality of educational data that teachers can manually collect. This emphasizes the need for suitable technology for collecting data from physical classrooms and assistance to teachers with the research aspect of their inquiries (Brown et al., 2017) and in working with data (Ebbeler et al., 2016). Wise and Jung (2019) stress the importance of helping teachers link pedagogically meaningful questions with data-informed answers and required interventions.

Although several LA (Clow, 2012; Greller & Drachsler, 2012; Ferguson et al., 2014) and teacher inquiry models (Rolfe et al., 2001; Timperley et al., 2010; Lai & Schildkamp, 2013; Hansen & Wasson, 2016; Sergis & Sampson, 2017) have been proposed in the literature, their large-scale adoption is scarce. In our experience with teachers, we surmise that this might be because the provided models appear too theoretical. In general, to promote take-up, TLA should transition from generic to specific TLA models (Joksimović et al., 2019), providing teachers with hints and examples from formulating inquiry questions to considering possible data-collection options (relevant to their individual needs) and understanding the messages behind the collected data. Also, clear guidance about possible data types and technology that would make the process easier to manage (Michos et al., 2018) could help promote analytics-informed teacher inquiry.

With these suggestions in mind, we combine different models of educational data use and teacher inquiry into an Analytics Model for Teacher Inquiry, which could help overcome some barriers to data use among teachers. The model should assist teachers in developing skills necessary for teacher inquiry and analytics use, such as research skills, data-literacy (what data, why, and how to collect and analyze), and sense-making of the collected data (making decisions for application in practice; Wayman & Jimerson, 2014). We will pursue the following research questions:

RQ1: How can we design a process model for TLA that teachers find feasible to use in authentic teaching practice?

RQ2: What do teachers' perceptions of the steps in the AMTI reveal about their understanding of data use and predispositions for TLA?

RQ3: What do teachers see as obstacles to and possible incentives for TLA adoption?

3. Methods

In this study, we employ Design Based Research (DBR) and apply qualitative research methods as we seek to explore and understand the perspectives of teachers on their inquiry process when using TLA. DBR helps design solutions to real problems (McKenney & Reeves, 2012) and bridge the gap between theory and practice (Meyers et al., 2018). It enables the improvement of educational practice in collaboration with teachers through design, iterative analysis, and implementation.

Qualitative methods provide detailed descriptions of a problem and develop a detailed understanding of it through participants' thoughts (Creswell, 2012). So, we found thematic analysis most appropriate for our study, as it aims at a detailed account of the data in areas where not much is known (Braun & Clarke, 2006) and helps to extract and connect the ideas presented by teachers systematically. The overall design of the study is depicted in Figure 1.

3.1. Iteration 1

Procedure: To develop an initial Analytics Model for Teacher Inquiry (AMTI) and to answer our RQ1, we employed an iterative process based on the theoretical and empirical literature and followed the steps of DBR. First, we carried out a contextual inquiry to understand different approaches to analytics-related TI. Then we compared different TI models to identify common steps. As the identified steps lacked guidelines for data analysis and did not indicate possible data types that teachers could focus on, we explored different data use processes and looked for data types that research literature has found meaningful for teachers. In the end, we synthesized four themes that became the starting point for our initial AMTI model. An overview of the initial model development is presented in Appendix 1.

As teacher inquiries (including data collection and interpretation) should be perceived as doable even considering teachers' huge workload (Saar et al., 2022), we consulted several experts in the field of education and teacher training to see if the synthesized steps made sense for the practitioners, and extended the model with explanations and examples based on existing literature. Then the initial model was used as a template during the second iteration (to test the model and guide the think-aloud interviews with teachers).

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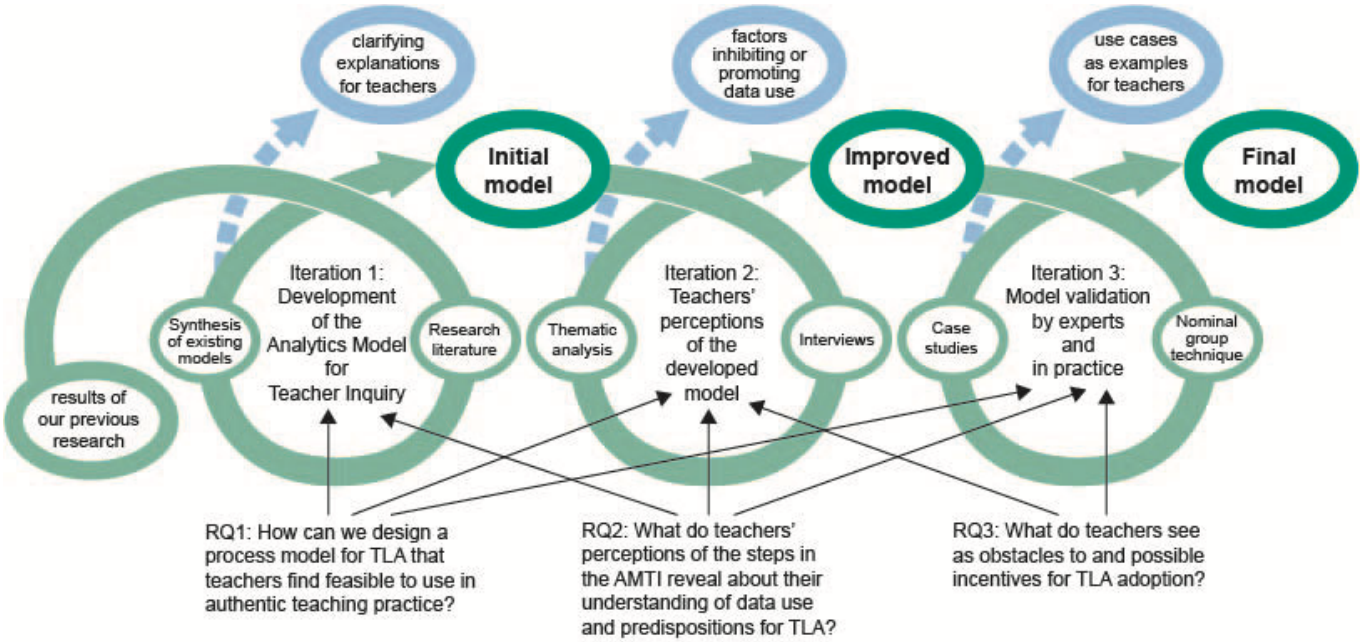

Figure 1. The DBR iterations of the study

3.2. Iteration 2

Context: To explore teachers' perceptions of analytics use and to answer our RQ2, the proposed AMTI was then used as a template in think-aloud sessions. The aim was, prior to use in action, to test the perceived applicability of the model for analytics-informed TI within possible school contexts, make improvements to the model, and probe the reasons for low TLA uptake by teachers.

Data collection and participants: Ten teachers from four secondary schools in Estonia participated in think-aloud interviews. Purposive sampling was used to find participants with different teaching experiences, subject areas, and genders, to form an overview from varied perspectives. The participants teach mathematics, languages, geography, civics, and chemistry, and have less than one year to over 20 years of teaching experience (Appendix 2).

Each think-aloud session lasted for 30–45 minutes and was recorded (using Zoom). Before the interviews, all participants were informed about the purpose of the study and written consent was obtained. All participants were guaranteed confidentiality, informed that their participation was voluntary, and that they could withdraw their data from the study at any time.

Eight interview questions, based on the AMTI, guided the think-aloud sessions. The teachers were asked to express their thoughts when working through the AMTI template (with examples), revealing their understanding of analytics use. As well as these questions about the AMTI, and to answer our third research question, additional open-ended questions (Q9–Q12 in section 4.2) were asked about teachers' predispositions for TLA/TI.

Data analysis: Thematic analysis (Braun & Clarke, 2006), informed by our AMTI, was picked to identify patterns within the interview data and get an initial understanding of teachers' perceptions about analytics-informed TI processes. First, interview data were transcribed verbatim using a transcription tool (Alumäe & Tilk, 2018, http://bark.phon.ioc.ee/webtrans), excluding the parts of the interviews that were not specific to the model use (e.g., demonstrations of the technological tools suggested in the model). After the data were cleaned and translated into English, open coding was used to analyze the data separately by two researchers who then discussed the initial codes to check for mutual understanding and ensure that no data items were excluded.

The initial codes were collated into potential themes and checked to see that all relevant coded data extracts had been considered. This check was carried out within all the coded extracts throughout our data set. While our aim was not a content analysis, the number of times a code appeared in the analysis was not important in developing the themes; however, we do provide this frequency data in the discussion to show the more prevalent ideas that emerged.

Our next step was to align the generated themes with the eight steps in the proposed AMTI model (our theoretical framework) and the four additional questions asked about teachers' perceived readiness to analyze their own teaching

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systematically. So, we reviewed and clustered the themes accordingly (Appendix 3) to check whether they captured the essence of the coded data in relation to the interview questions. This helped us better interpret the data in the light of our research questions. This cyclical approach was also necessary because sometimes the answers provided by teachers did not match the interview question (e.g., instead of naming data that they would collect, teachers listed data-collection possibilities), so the answers were thematically grouped.

3.3. Iteration 3

Data collection: To validate the model, the Nominal Group Technique (NGT) was used with seven experts (researchers and teacher trainers), who expressed their ideas about the applicability of the model and ranked their suggestions based on their significance for teacher use. The nominal group technique (Varga-Atkins et al., 2017, introduced by Delbecq et al., 1975) is a highly structured approach where ideas are generated on an individual basis, although within group settings. The moderator keeps the discussion at a minimum; however, participants can see each other's responses and get inspiration for new ideas. Then the aggregated list of ideas is briefly discussed to ensure mutual understanding. Each participant then ranks the ideas based on their significance. This method was picked because it helps to assess the importance of the presented ideas efficiently. The experts' responses were collected on Post-it Notes (with the help of Mural, https://app.mural.co) and an audio recording of the session (via Zoom, https://zoom.us/).

Participants: Invitations were sent to five researchers and teacher trainers (from two universities in Estonia) actively involved in technology use in teacher education (including LA) and to ten teachers (school head teachers or master teachers — the highest professional rank in Estonia — all involved in teacher training). Overall, seven experts (three university researchers, two head teachers, and two master teachers, all with over 10 years of experience) participated in the NGT (Appendix 2).

To test the applicability of the model in practice and to provide use cases, two teacher-researchers used the AMTI and collected data during their actual teaching sessions. The teachers (with 25 and 8 years of experience, one at secondary school and the other at university, Appendix 2) chose to focus on student engagement, so research-validated questions were suggested (based on Fuller et al., 2018) to be used in the student feedback questionnaires. The teachers selected different technological options for data collection (Mentimeter: https://mentimeter.com and Prolearning: http://prolearning.realto.ch). The classes of the secondary school teacher took place face-to-face, while the classes of the university teacher were conducted over Zoom (due to pandemic restrictions).

One of the teachers used the model for two months in her British literature classes with 12th-form secondary school students; the other practitioner used the model for one semester in her university TEL research course. Ethical permission was obtained from all participants in the study and participation was voluntary. The European Code of Conduct for Research Integrity (ALLEA, 2017) and the Estonian National Code of Conduct (Hea Teadustava, 2017) were followed. Teachers' perceptions of the applicability of the model were obtained through an interview and teacher diaries.

Data analysis: The NGT allows a researcher to obtain data that have been already thematically grouped as well as ranked by the participants (Mullen et al., 2021). To identify patterns in the data and develop themes for further interpretation, the audio data from the NGT session was transcribed verbatim and thematically analyzed (Braun & Clarke, 2006) together with interview and teacher diary data from the case studies. This information was applied in the further development of the AMTI (RQ1) and to answer our RQ2 and RQ3.

4. Results

4.1. Iteration 1: Existing Teacher Inquiry Models Informing the AMTI

After comparing different evidence-based frameworks for TI, we chose to rely on models by Rolfe et al. (2001), Hansen and Wasson (2016), and Sergis and Sampson (2017). Rolfe et al. (2001) is well known and has been in use for two decades; the TISL Heart (Hansen & Wasson, 2016) was designed together with practitioners; and the model by Sergis and Sampson (2017) is based on recent literature in the field and provides steps for TI (the best match to our research goals). However, the outlined steps lacked guidelines for data analysis. To fill this gap, we split the data-interpretation step into sense-making (finding patterns) and interpretation (adding pedagogical knowledge to the data), as suggested in Wise and Jung (2019).

To address the limited data use by educators (Schildkamp & Kuiper, 2010), we looked for data types (other than assessment) that practitioners could find useful. We compared the common data types used by teachers (Marsh et al., 2006; Lai & Schildkamp, 2013) with those outlined by Saar et al. (2022) and combined these into a list of possible options (for teachers to pick from, based on their inquiry question). Although important in teachers' work, input and context data cannot be directly affected by a change in teaching practice and, therefore, need not be regularly collected. However, classroom activities directly influence learning and can be altered (by a teacher or context). Thus, process data (e.g., teaching methods,

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lesson activities, task types), outcome data (assessment), and student feedback (indicating the impact of the "changed teaching") were included in the AMTI so that they could be regularly collected and analyzed to inform practice.

To emphasize the fact that teacher inquiry does not always mean working around "problems" but could have an improvement goal in mind (Viberg & Gronlund, 2021), we did not start our model with "problem identification" but rather "purpose" (i.e., Lai & Schildkamp, 2013). We hope that this might draw more teachers towards analytics use. To promote TLA adoption, we provided explanations for all steps based on research literature so that practitioners would have a clearer idea of what each step in the model indicates and thus would find it easier to conduct their inquiry.

In their Reference Model for Learning Analytics, Chatti et al. (2012) describe four dimensions critical for data collection and analysis (what? — data and environments; how? — techniques; who? — stakeholders; and why? — possible reasons for data use). When compared to our proposed AMTI, the latter does not include stakeholders (who?); in a physical classroom, these are usually students and a teacher. However, the data and environments (what?) and the techniques (how?) dimensions are represented in both models, while AMTI also adds the action aspect (now what?). Inspired by Chatti et al. (2012), we also included the "why?" dimension (motivation or reason for inquiry) into the AMTI, which could help teachers see the benefits of TI on their work (e.g., to understand the suitability of a new activity). A comparative overview of the teacher inquiry models and data use literature that informed the steps in our initial AMTI is presented in Appendix 1. The next step was to test the developed model with teachers.

4.2. Iteration 2: Refining the Model with Teachers

4.2.1. Teachers' Understanding of the AMTI

Appendix 3 provides an overview of the themes developed based on the responses that ten teachers participating in the think-aloud interviews provided to the questions about the steps in the AMTI. Here the findings of the teacher interviews are presented based on the interview questions (the abbreviation [T2] denotes teacher number 2, etc.), and the implications of these findings will be discussed in section 5.

Q1: Why would teachers analyze their teaching practice? (motivation)

Although sometimes teachers (n=2) lack any motivation to analyze their work systematically, they still would do it if some conditions were met ("when I feel the need for a new approach" [T2]). In our study, teachers' motivation to analyze their own teaching falls under four broad categories: self-analysis (of work methods), understanding students, change, and problems.

From the **self-analysis** viewpoint, teachers (n=7) wanted to explore how doable new teaching methods or strategies were ("if I can manage"), as well as expected to see the (good) results of their work. They were also interested in finding out why some methods work and others do not, and to understand possible ways for professional development. As to students, teachers' responses could be divided into two sub-themes: exploring **students' needs or perspective** (n=5; "how my methods reach students") or **student development** (n=5; "what students have understood").

Change (n=5) includes both the change in the **context** (new students, switching to online teaching due to the pandemic) and **variety** in classroom activities, i.e., wish to try out something new. This willingness to change their teaching practice was further explained in responses to our additional question about **the triggers for change** (see Q9, below).

Q2: What would teachers want to learn about their teaching practice? (purpose)

Answers to this question fall under four themes: **supporting student engagement and development** (n=4; "to reach students better and activate their brain"); **selecting teaching methods** (n=4; "what would yield best results"). Three teachers would analyze their teaching when a **problem** was noticed or to overcome shortcomings. But here, the context of the response is also important (expressing **doubt**): "I have been teaching so long that I don't know what else there is to learn; this is necessary for novice teachers who cannot yet 'read' the students and should collect data; when some observer makes a comment or somebody would suggest something then I might even try" [T2].

Q3: What questions would teachers pose to inquire about their teaching? (inquiry questions)

The inquiry questions that teachers formulated were mostly targeted at **student engagement**, e.g., "Which method would make students more actively involved?" "To what extent could a student work on their own?" Teachers were also interested in the **effectiveness of teaching**, i.e., methods that are easiest to manage but most effective/suitable. Two novice teachers also expressed concern about their own **competence** ("Am I competent to teach?" [T9]).

Q4: What data could help answer teachers' inquiry questions? (data needs)

When asked about data that teachers would collect to answer their inquiry questions, the responses could be divided into three broad themes: Process data (n=7), student-related data (n=9), and outcomes-related data (n=7). **Data about processes** (time spent on task, success rate) come mostly from online platforms that teachers use (KAE school, Kahoot!). Responses to **student-related data** are mainly linked to difficulties/successes that students experience, their emotions, participation, effort, contribution to group work, and assistance that students seek. **Outcomes-related data** are linked to formal and peer assessment, aims fulfilled, as well as mistakes made by students or topics that proved difficult to comprehend.

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Q5: How would teachers collect data? (data collection)

Both novice and experienced teachers were good at naming different data collection means and possibilities to answer their own inquiry question(s). For data collection, teachers in our study turn to data (n=2) from **electronic learning materials**, e.g., time spent on task, data inserted, mistakes, chats, success; student feedback (n=8) **questionnaires** (about difficulties, emotions, contribution, suitability of the method) or **conversations** with students or colleagues; personal observations (n=5; about students asking questions, working in teams, fulfilling the tasks) or observations with the help of apps or colleagues; and **exploring outcomes** (n=3) such as assessment data, student work, questions students ask, and mistakes they make. Some teachers would also collect **sensor data** (maybe brain sensors: n=1).

Q6: How would teachers make sense of the data? (sense-making)

Teachers use the collected data mostly to **understand students** (n=5; their effort and independence, actual need for assistance or clarifications) and their learning (typical mistakes, what needs revisiting), but also to understand the **tasks/methods used** (n=7; the difficulty level, time consumption, and effectiveness). In addition, teachers **assess their own practice** (n=1), or the possible reasons (n=1) for student problems (e.g., whether a student's "low results in writing might be caused by a medical condition," i.e., dyslexia;). This also demonstrates that teachers do use context data when they deem it necessary.

Q7: How would teachers interpret the data? (interpretation)

As to interpretations, the participating teachers wondered whether **modification of tasks** (n=5) would be necessary (to change work intensity, material presentation, work routines, or assessment). Two other interpretations were linked to **professional development** (n=4): **finding hints** ("What might help me improve as a teacher?") and **comparisons** (e.g., of student results from before the pandemic, their own teaching compared to "efficient" teaching).

Q8: What decisions can these data help you make? (decision-making)

In our study, all participating teachers (n=10) would decide **to act** based on their interpretations of the data. For example, teachers would find ways to provide help to weaker students. They would also use the gained knowledge in planning their work — selection of methods, tasks, activities, different time management, and deadlines for student work. One novice teacher responded, "if the method brings no harm nor gain but is more fun, then you could continue with it" [T9]. Another teacher explained that "testing different methods would help to select the more effective ones, to see how many students learned faster" [T7].

Q9: Why do teachers make changes in their teaching? (motivation and reflection)

Here teachers (n=8) explained that they mostly altered their routine for **variety** (n=8), to make the classes more fun, or for **efficiency** (n=6), e.g., to raise student motivation. Outcome indicators (n=6) or student failure, their puzzled faces, and **outside pressure** (from the school) were also mentioned as possible reasons for a change in teaching. One teacher also mentioned **shortcomings** ("When I notice a problem, I can react and make changes").

In addition, **reflection on their teaching** was pointed out separately by teachers (n=3); for example, to understand WHY something went wrong (i.e., was the topic difficult or had students not slept well the night before?). One teacher expressed an obvious reaction: "when they find a lesson boring, then I will not plan a similar lesson anymore" [T6].

4.2.2. Obstacles to Data Use and Necessary Assistance for TLA Adoption

Q10: What might be some reasons for the low adoption of data-informed analysis among teachers?

Responses to this question revealed that the main constraints were seen as **high workload** (n=4), **habits/routine** (n=3; "comfort, fear of anything new"), **low-quality data and skills** (n=2; "e-school analytics are not efficient," "I get stuck, need training"), and **predisposition** (n=3; "not necessary for experienced teachers but the novice ones"). In general, although the teachers admitted that regular self-analysis should be routine in teachers' work, and most of them analyze their teaching ("mentally"), none of the participants regularly collect data about their teaching.

Q11: What might motivate teachers to analyze their work?

What becomes evident from our question about any incentives that might help teacher inquiry to become a routine is that teachers would be more willing to be involved in this process if they could see **direct benefits** of these analyses on their students' outcomes and the process were a **regular** component of their work. Also, fewer classes to teach, some outward **influence** (personal feedback on reflections) and, most often, **inner motivation.**

Q12: What assistance do teachers deem necessary for such analysis?

Teachers in our sample voiced the need for **assistance** with their **motivation**, seeing the real gain in using data, opportunities for skills development (training, time for group discussions), suitable means for and help with **data use** (collection and analysis/examples), as well as an understanding of what to do with the data. No less important, teachers also need some support in getting used to discussions about their development ("Teachers have to learn the skill of analyzing their work and speak about it — the issues, success, and plans for the future" [T6]).

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Before the next iteration (NGT session), the model was improved based on the findings from these teacher interviews. Since teachers had difficulty with the data interpretation steps in the model, we also provided examples about teachers' use of analytics as possible options (providing hints for teachers; based on Marsh et al., 2006). Also, to help teachers with the decision-making steps, we added the findings by Wise and Jung (2019), which divide teachers' decisions into three broad categories: 1) taking action, 2) adopting a wait-and-see posture, and 3) reflecting on pedagogy. The improved model is presented in Appendix 4.

4.3. Iteration 3: Validating the Proposed Model

4.3.1. Nominal Group Technique

The themes that emerged from the NGT session with experts (Figure 2) fall broadly into three categories:

1. Two themes (improvements and examples) relate to the model
2. Two (pro-inquiry attitude and motivation) relate to teachers' individual gains and motivation to be involved in teacher inquiry
3. Two themes (social support and context/school culture) provide insight into aspects that could help in wider adoption of teacher inquiry.

The codes and themes developed during the NGT session are presented in Appendix 5.

The main suggestions for improvement to the model related to adding possible links to materials, providing explanations and suitable technological options, and changing the visualization (e.g., to emphasize process). The experts also suggested that the model be accompanied by some examples of use cases, as it "would make it easier to relate to the process."

In the two themes relating to teachers' pro-inquiry attitude and motivation, the experts pointed out that an inquiring teacher could set an example and inspire their students to define and add meaning to their activities, and that the model could promote the development of teacher inquiry systems at schools. The experts thought that the model helped set the teaching goals and systematically approach all teaching steps, as well as shift the focus to learning (including the teacher as a learner). It was also considered important that teachers adopted "boldness to err and experiment," became better aware of the components of learning and teaching, and transferred from subject-centred teaching to learning-skills-based teaching. In the experts' opinion, the model would help identify how to teach more efficiently (to gain the same results with less effort), clarify what benefits an analytics process might have, and could be used to improve teaching practices.

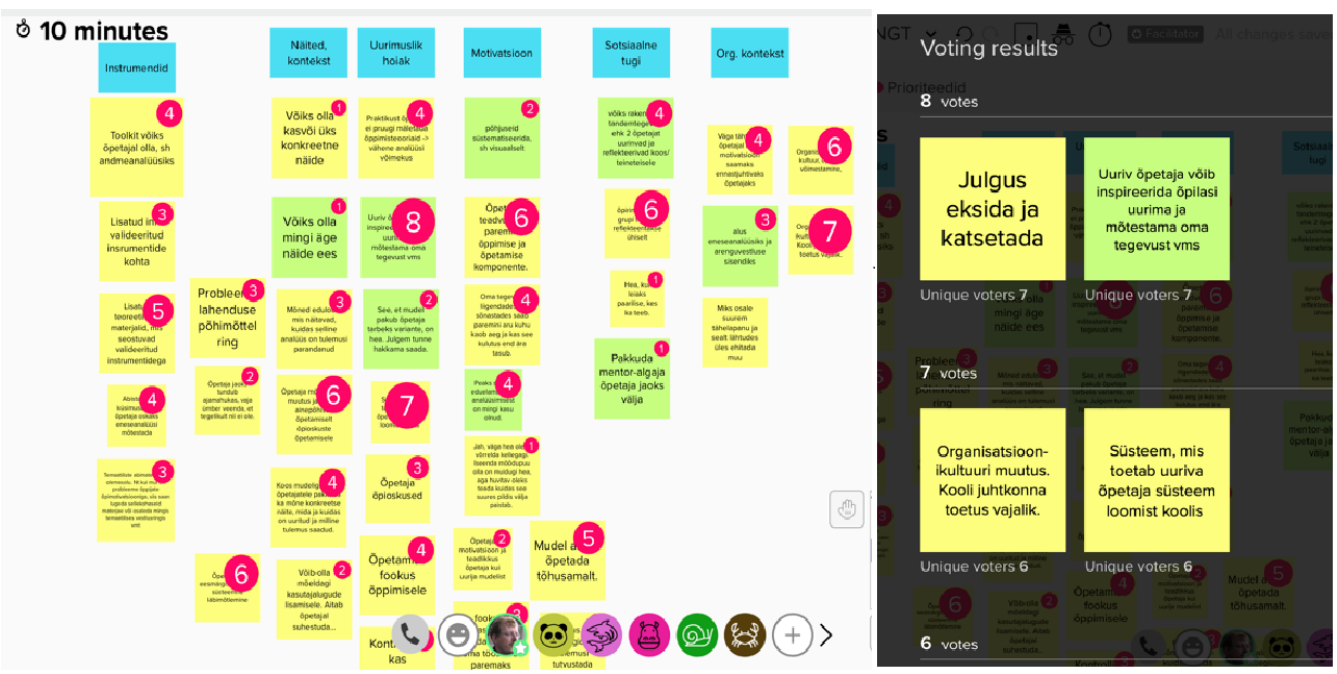

Figure 2. Data collection in the NGT session: the blue squares above the columns denote the themes that emerged, with corresponding ideas below; the red dots show the number of votes each idea got during the 10-minute voting session; the yellow/greenish slips show the ideas expressed, with corresponding votes. The English translations are in Appendix 5.

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The experts pointed out aspects that cannot be addressed with the help of the model, such as social support and school context. It was found important that teachers had a growth mindset and readiness to analyze their teaching, and that school culture supported an inquiry mindset and empowerment of teachers. After the NGT with experts only the AMTI visual was changed from a table into a diagram (to emphasize the iterative nature of inquiries; Figure 3).

4.3.2. Case Studies of the AMTI Use in Practice

Both teacher researchers, who used the AMTI in practice, were motivated to analyze their teaching because they hoped to develop professionally and provide more engaging learning possibilities for their students (so their inquiry questions were formulated around engagement). One teacher collected data (using an app and a questionnaire) about the pattern and length of classroom activities, student perception of their cognitive, emotional, and behavioural engagement, and assessment data. The other teacher collected student opinion, her own notes, and video data of her classroom (in Zoom). As she initially noticed some inconsistencies in the collected data, she also had a feedback session with her students to deeper understand her teaching situation.

Both teachers found the collected data informative and useful (although their sense-making and interpreting strategies were different). The first teacher got some interesting results, which were not surprising to her, but raised new questions about whether the good level of engagement resulted from the type of activity used or from the novelty of the activity. So, she decided to use similar activities with the same and different students to compare the results. Since the other teacher faced some data collection problems, she decided to change her lesson plan to give herself enough time for data collection during her classes.

Both teachers also made suggestions for technology improvement that would assist teachers in data collection and analysis. A comparative, more detailed overview of the two cases is provided in Appendix 6.

5. Discussion

From ten teacher interviews, an NGT session with seven experts, and two case studies of actual use of AMTI in practice, we synthesized outcomes that informed our model development and answered our research questions. Although our sample was small and we cannot generalize the data, some preliminary insights into factors promoting TLA adoption can be drawn.

RQ1: How can we design a process model for TLA that teachers find feasible to use in authentic teaching practice?

Participants in all our iterations found the AMTI logical and suitable for teaching analysis, as well as easy to apply. However, the experts suggested modifying the AMTI visual (to reinforce its iterative nature). In general, we found that:

- A TLA model should not focus on problems but should inform teaching practice in general (e.g., when trying out innovative methods). The teachers in iteration 2, especially experienced ones, did not see teacher inquiry as a way to tackle problems but, rather, driven by inner motivation, wanted to try out novel teaching activities and explore the impact of the changed teaching on student development and needs. By starting with a purpose, as done by Lai and Schildkamp (2013) or Hansen and Wasson (2016) who use "kick-off," the model would be attractive to teachers focusing on continuous development.
- A TLA model should draw attention to an inquiry question. Although findings of Wise and Jung (2019) demonstrate that teachers do not always start their analysis with inquiry questions but rather with exploring some data and trying to make sense of it (through identifying noteworthy patterns and adding contextual knowledge to them), keeping the inquiry question in this step of the model is still important, as it might encourage teachers to seek additional data for their inquiry questions. This is consistent with Schildkamp et al. (2016) and Corrin et al. (2016); however, more assistance should be provided to teachers in this respect (e.g., prompting more data variety).
- A TLA model should indicate how student data could be complemented by teaching data. Currently, even when their goal is to change/improve teaching, teachers do not aim at collecting teaching data. Obviously, teaching data is still a novel concept for teachers, not widespread in practice, and has had limited focus in research (Ndukwe & Daniel, 2020). However, as T6 in iteration 2 put it, "when I ask my students about how they have managed, it also tells me about my teaching." So, systematically collecting student feedback (as demonstrated by Gaertner, 2014) would empower students to take an active role in designing their own learning, while also enhancing teaching.
- For better structure, a TLA model should help teachers divide their teaching analysis into different but logically linked steps (as in Sergis & Sampson, 2017). The sense-making and interpretation steps (Molenaar & Knoop-van Campen, 2018), however, proved rather confusing for teachers (looking for patterns in the data and interpretation of the outcomes — i.e., adding pedagogical knowledge — seem to happen simultaneously but not consciously). Thus, in case of lack of suitable interpretation skills, teachers should be directed to seek assistance (from e.g., colleagues, literature, training), as suggested by the expert panel.

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Interestingly, contrary to earlier research (Goertz et al., 2009), the "Now what?" question did not prove as complicated to answer for our sample as the interpretation question. When Wise and Jung (2019) suggest that teachers' pedagogical response to data can vary from "wait-and-see" and "reflection on pedagogy" to "taking action," in our study all teachers would take some action based on the data (maybe because the AMTI prescribes decision-making as one of its steps).

Overall, the developed AMTI model (Figure 3) shares features with other teacher inquiry models, but it extends previous models as it starts with the question about teachers' reason for inquiry, emphasizes learning from shared practices (rather than problems), explains the structured steps, and provides clarifying examples (taken from data-use and decision-making models by Hansen & Wasson, 2016; Schildkamp & Kuiper, 2010; Wise & Jung, 2019). The design emphasizes that a teacher could start the inquiry cycle from any of the proposed steps (as deemed necessary). Also, the two case studies presented in this paper could be used as example use cases (see Appendix 6).

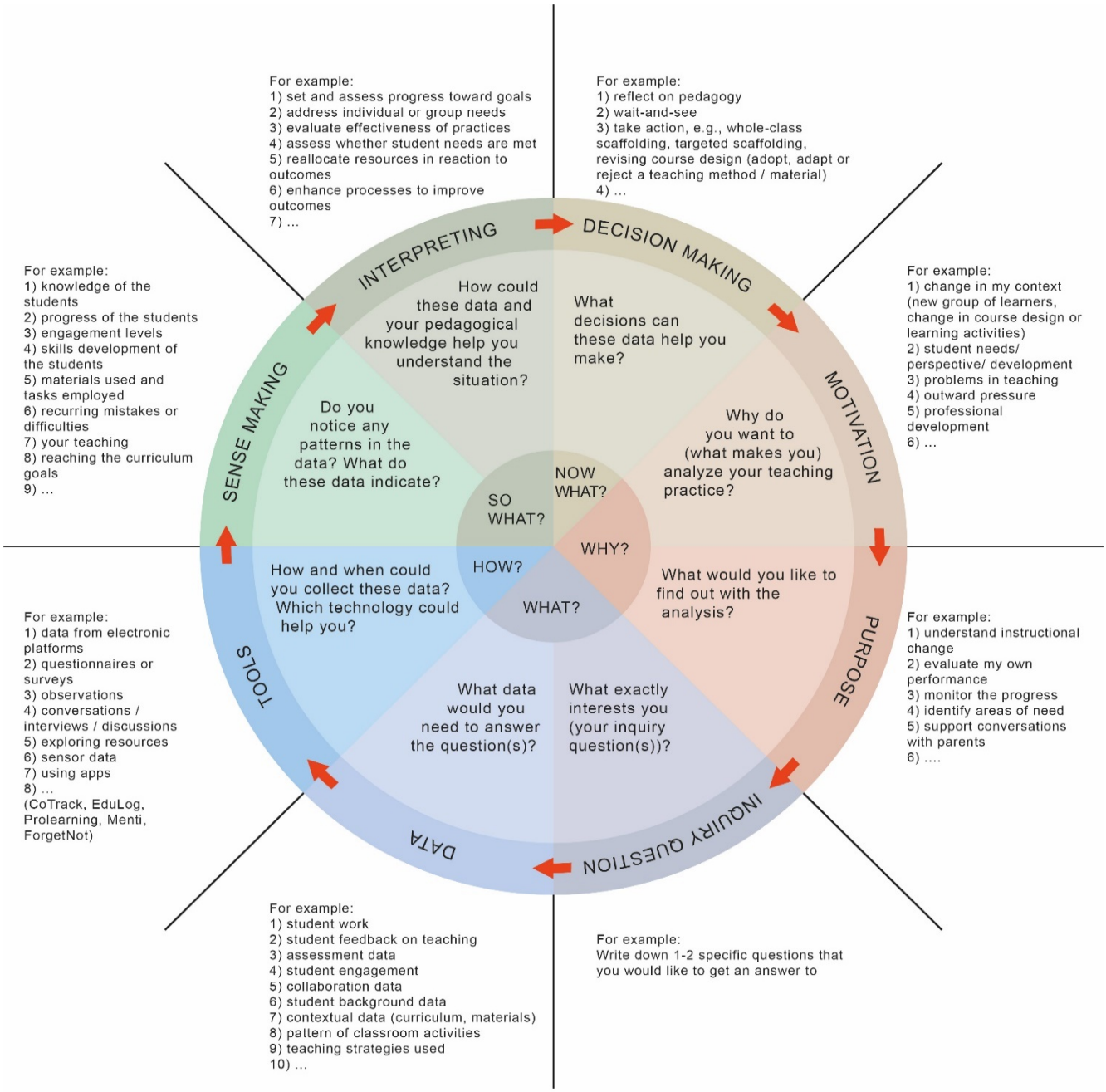

Figure 3. The AMTI model with examples for teachers

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RQ2: What do teachers' perceptions of the steps in the AMTI reveal about their understanding of data use and predispositions for TLA?

Self-analysis of teaching is mostly connected with teachers' internal drive to be a good professional and cater to the needs of their students rather than to outside obligations (participating teachers seemed to be motivated by possibility to improve, not obligation). Also, our teachers' purposes for inquiry match well with those outlined by Schildkamp and Kuiper (2010).

However, some teachers are not yet ready to analyze their teaching. Sometimes teachers, independent of their experience, do not want to learn about their weaknesses (or articulate critical incidents as pointed out by Seidal et al., 2010). Less experienced teachers also express concern that there are no reference points for effective teaching (Maulana et al. 2017). This makes analytics use rather unattractive to them since they do not expect really good results (yet). Therefore, to promote adoption, analytics tools should provide teachers with comparisons and reference points (Wise & Jung, 2019), and should account for the different needs of novice and experienced teachers (Hansen & Wasson, 2016), their predispositions, and skills.

Options for data collection and analysis are inadequate. While participating teachers could name some electronic data collection tools, these were mostly limited to questionnaires. This indicates that teachers would really need more guidance about and access to tools for data collection from physical classrooms. It also indicates the need for such technologies (as expressed in Ndukwe & Daniel, 2020). The expert suggestion was also to provide teachers with a toolkit of technology and validated instruments for data collection and analysis.

RQ3: What do teachers see as obstacles to and possible incentives for TLA adoption?

The obstacles to TLA implementation can be divided into two large groups: those that can be removed by changing the teaching context (teachers' workload and routine, perceptions of being judged and not allowed to make mistakes); and those that an inquiry model could assist with. These include making the process as effortless and understandable as possible, providing guidelines and examples, and pointing to possible solutions (e.g., technological means for data collection and analysis). Also, as teachers have already developed some lesson analysis routines, the steps in the models should follow these routines, so that teachers can smoothly blend their existing skills (Hansen & Wasson, 2016; Wise & Jung, 2019) with those needed for analytics-informed teacher inquiry.

Primarily, teachers need to be convinced of the benefits that TLA brings into their work. Before adopting a new routine, practitioners need to understand the ratio between "the pain and the gain" and see the direct benefits of teacher inquiries on student outcomes. It could be argued that the pro-inquiry attitude and decision to analyze one's teaching might already be an important step towards improved teaching since it drives the teacher to put in even more effort (to get good feedback). The panellists in our NGT session agreed that an inquiring teacher could set an example and inspire their students and colleagues. This would be an important step in promoting TLA adoption.

In addition to inner motivation, teachers seek outside support and influence (e.g., school policy). Our study reveals that teachers in Estonia are not used to discussing their own teaching methods with colleagues. Therefore, a supportive atmosphere and joint efforts to improve teaching practice (routine teaching analysis and discussions in groups) should be promoted at schools. This is consistent with findings in earlier research that stress the importance of school cultures to support data use (Schildkamp & Datnow, 2020). First, the long-standing issue that teachers feel overburdened by different responsibilities and are rarely allocated special time for sharing their practice or inquiring about their teaching (expressed by Elmore, 2004) must be tackled.

Opposition to TI can also be traced to the desire to avoid negative perceptions. Instead of dealing with problems, teachers could spend their energy on trying out new, more efficient strategies. Such an approach would allow the teacher to experience success (yes, I could do it!) and gradually replace the practices that failed or did not yield the expected gain. Therefore, to support the growth mindset, TLA models should consider these fears and provide possibilities for teachers' self-analysis even when they are not yet ready (or do not have possibilities) to share their practice and discuss their teaching with others (mentors, colleagues, data teams). To promote teacher development (and diminish fear), teacher inquiry and TLA should not become tools for auditing teachers' practices (Edström, 2008).

6. Conclusion

The present study set out to propose and validate an Analytics Model for Teacher Inquiry in (physical) classrooms. The aim was to provide teachers with scaffolding in action research about teacher inquiry into their own practice.

The first iteration of our DBR revealed that researcher-driven TI models often follow quite similar steps that can, however, remain abstract if they lack practical explanations for teachers. This might be one reason for the gap between research and practice, as suggested by Joksimović and colleagues (2019). Based on existing TI, TLA, and data use literature, this paper proposes eight steps (with examples) essential for analytics-informed inquiries: the steps about **motivation** and **purpose** drive teachers' curiosity; the **inquiry question** should lead to the suitable **data types** and **means for data collection**; the analysis

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step, when further split into **sense-making** and **interpretation**, guides to linking data with pedagogical knowledge to inform **decision-making**.

From iteration 2 with practitioners, we saw teachers' difficulties in working with data. The steps in the proposed model were complemented with examples (vs. explanations in the initial model), which teachers can use or modify based on their needs. It also became evident that to improve adoption, teachers must clearly see the benefits of TI in their teaching and student learning, otherwise TI cannot compete (for time and effort) with teachers' other responsibilities.

Finally, iteration 3 demonstrated the feasibility of the approach; participating teachers were able to analyze their different teaching strategies while not feeling overwhelmed by the additional workload that research inevitably brings. However, the model requires further testing with a larger, more versatile sample. The main improvement to the model based on iteration 3 was its circular shape to emphasize that TI could start at any step of the inquiry cycle and should be an iterative process.

Regarding TI models, it is also important to focus on analytics-informed teaching practices instead of addressing problems. To overcome teachers' fears of finding out about their poor performance, practitioners could initially focus on the aspects of their work that they consider worth testing and sharing.

In terms of data types, in addition to student data, teachers need more possibilities to collect data about their own teaching. This idea, voiced by Sergis and Sampson (2017), remains quite novel for the teachers in our sample; they posed inquiry questions mostly about their students, not their own teaching. The collected data might also lead to some new inquiry questions and iterative processes, as indicated by Wise and Jung (2019), and to teacher inquiry becoming an integral part of daily teaching.

Another implication of our work, supported by earlier research (Michos et al., 2018; Wise & Jung, 2019; Herodotou et al., 2019), is that teachers would need better TLA tools and technology for data collection and analysis, based on their context. Though small, our study indicates that teachers would benefit from data about **lesson processes** and **teaching methods**, student **engagement** and **motivation**, as well as **outcomes**. Technological tools to enable such data collection from physical classrooms, however, are scarce. More emphasis should therefore be laid on the development and dissemination of TLA tools for teachers to help measure the impact of teaching on student success.

Just as teacher workloads, predispositions, and intrinsic motivations for professional development are important factors in promoting analytics-informed TI, school culture also plays a huge role. Collaboration — along with a supportive environment, pro-inquiry attitude, and support in integrating TI into the regular work processes of teachers — should become routine practice at schools (see also Schildkamp et al., 2019). Research, however, should help with the necessary toolkits, good practices, and reference points or chances for comparison ("of my work with standards"). To provide teachers with useful insights into their own teaching and their students' learning, more research is required to help teachers effectively interact with TLA (see Gleason et al., 2019).

The main limitation of our study is its small sample size. Although the questions used in the think-aloud interviews were based on the AMTI, they were not validated, which might have caused some confusion (e.g., the difference between the motivation and purpose). To compensate for that, future interviewers could always clarify the meaning of their questions first. For our part, we analyzed the interview data thematically in several cycles. Although teachers' answers did not always correspond exactly to the interview question, the answers could be realigned with the more appropriate question. This also helped clarify the emerging codes (e.g., data needs vs. data collection). The developed model was also validated by an expert panel whose opinions helped to triangulate the data collected in teacher interviews and diaries.

One of the future goals of TLA research is to explicitly demonstrate its benefits to teachers. Before adopting a new routine, practitioners must be certain of its advantages. Also, TLA should better correspond to the different needs of novice and experienced teachers. Namely, novice teachers would need more skills development in all the aspects of TLA, but mostly support in developing their pedagogical skills and self-belief. Experienced teachers, however, would rather explore new approaches in teaching and how these affect student outcomes, engagement, and satisfaction. Therefore, TLA should not emphasize "the mistakes" but indicate possibilities for alternative, more effective ways of teaching. Also, as team discussions might not always work (as none of the participating teachers had any data teams in their schools), and teachers' individual interest points might be neglected in team efforts, options for individual TLA should also be provided (e.g., models, examples, use cases, best practices, and suitable technological tools).

Additionally, testing the AMTI model with a larger sample would help to ascertain its suitability for teacher inquiries. Also, it is important to reduce the imbalance between teaching and learning analytics used in teacher inquiries, so teaching analytics should be emphasized more in later models. Finally, our study demonstrates the different needs of novice and experienced teachers for teacher inquiry; however, further studies could shed light on the needs of teachers with yet other characteristics.

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Declaration of Conflicting Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendices

Appendix 1

The Model Development Process and the Initial AMTI (Used as a Template in Iteration 2)

Models from research literature:

Critical Reflection Model Rolfe et al, (2001)	**Process of Data Use** Lai & Schildkamp (2013)	**The TISL Heart Model** Hansen & Wasson (2016)	**Inquiry Cycles** Sergis & Sampson (2017)	**Possible steps:**
	Purpose	**Kick-off** **Assumptions** **Research question**	**Problem Identification;** **Inquiry questions**	Motivation /reason: Purpose: Inquiry question(s):
		Method	**Educational Design**	Planning Data Collection within the Educational Design (including picking suitable technology)
What? + (**Data types** by *Marsh et al*: Input, Process, Outcome, Student Feedback)	**Data Collection** (Input data, Context data, Process data, Outcome data)	**Changing teaching and assessment**	**Delivery of Educational Design; Data Collection**	Delivery of Educational Design, Data Collection (Input data, Context data, Process data, Outcome data and Student Feedback)
So what?	**Analysis and Interpretation**	**Learning outcome**	**Analysis of Educational Data**	Sense making, Interpretation
Now what?	**Action**	**Feedback and sharing**	**Reflection on Data**	Decision Making about Practice (Innovation)

The developed themes:

1) Why? **Trigger interest**	2) What? **Data types and sources**	3) How? **Technological means**	4) Now what? **Pedagogical action**
Motivation/reason	Inquiry question(s)	Collect	Interpret
Purpose	Data needs	Analyse	Make decisions

The initial model (with explanations):

	WHY?		**WHAT?**		**HOW?**		**NOW WHAT?**	
MODEL	Motivation	Purpose	Inquiry questions	Educational design and Data needs	Educational delivery and Data collection	Sense making (finding patterns)	Interpretation (adding pedagogical knowledge)	Decision making (response)
EXPLANATION	Trigger for the change, e.g. teacher performance, student progress or needs (better motivate students, reduce homework assignments)	Assess the feasibility /suitability of a (new) teaching strategy	To what extent would the applied approach help to achieve the aims? e.g. deeper learning?	What data would help to answer these questions? e.g. Process data, Feedback data, Outcome data? When should these data be collected?	What technology could be used to collect such data? e.g. Student feedback, Student results, Activity logs, Collaboration data, etc. Tools: Prolearning, EduLog, CoTrack, etc.	Comparisons: e.g. How much learning? How successful? How much time? How engaged? What activities?	What does this tell me? Does this answer my inquiry questions? e.g. engagement vs success vs time	Steps for further action, e.g. Adopt strategy? Adapt strategy? Reject strategy?

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Appendix 2

Participating Teachers and Experts

Iteration 2			
Teacher	Subjects	Working at (with)	Teaching experience
T1 female	Mathematics	School (years 5–12)	> 20 years
T2 female	Mathematics	School (years 6–12)	> 20 years
T3 female	Chemistry	School (years 8–11)	4 years
T4 female	Mathematics	School (years 6–12)	2 years
T5 female	Chemistry	School (years 5–12)	7 years
T6 female	Foreign languages	School (years 5–12)	16 years
T7 female	Foreign languages	School (years 5–12)	16 years
T8 male	Geography	School (years 5–12)	3 weeks
T9 male	Social studies	School (years 5–12)	2 years
T10 male	English	School (years 5–12)	3 years
Iteration 3			
Expert/teacher	Subject	Working at	Teaching experience
E 1 female	Educational Technology	University (MA)	17 years (15 at university)
E 2 female	Educational sciences	University (PhD)	34 years (6 at university)
E 3 female	Teacher development	University (MA)	15 years (4 at university)
E 4 female	Mathematics	School (head T)	42 years
E 5 female	Elementary teacher	School (head T)	28 years
E 6 female	Social Sciences	School (master T)	22 years
E 7 female	Geography	School (master T)	24 years
T1 female	Foreign language	School (master T)	32 years
T2 female	TEL education	University (PhD)	8 years

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Appendix 3

Codes and Themes that Emerged from the Think-Aloud Interviews Based on the Proposed AMTI Model

Interview topic/theoretical framework element	Themes	**Codes** (in bold) and quotes from interviews	Teacher
Motivation	**Inner motivation:** Self-analysis (of my work methods)	To see the results of **my (good) work**, how doable a new teaching **method** or strategy is (can I manage), why some methods work and others don't; to understand possible ways for my own **development**; no idea (as self-reflection is part of my studies, it helps to see how my methods reach students)	1–5, 7, 10
	Understanding student needs and development	How my methods reach students, how I provide instructions to them, what is **suitable for the students**, whether students like it and are interested, feeling well, not afraid of me	1, 3, 4, 7, 8
	Outer motivation: Change (in context; variety)	What students have **understood**, are they learning, help students to set their goals; when I ask my students about how they have **managed**, it tells also about my teaching	2, 3, 6, 8, 9
	Problem	A **new situation** (curriculum, new students, Zoom classes); to try something new, variety in activities	2, 3, 5, 7, 9
		When I notice a **problem**, I can react and make changes	6
Purpose	**Support student** engagement and development	to reach students better and activate their brain, to raise the rate of "**active participation**," what works better/what would yield best results, students feel well	1, 3, 4, 8
	Select teaching methods	How **doable a method** is (can I manage), how suitable, to raise the rate of "active participation," variations in methods	3, 5, 7, 9
	Problem solving	if an observer makes a comment, when a problem has been noticed, to overcome **shortcomings**;	2, 6, 10
	Doubt	I have been teaching so long that **I don't know** what else there is to learn; this is necessary for novice teachers who cannot yet "read" the students and should collect data; when some observer makes a comment or somebody would suggest something then I might even try	2
Inquiry question	**Effectiveness** of teaching (methods and competence)	Methods **easiest to manage but most effective**/suitable, leads to reaching the goals, can be used with different age groups and over the years; am I competent to teach, how should I change my teaching	5–10
	Student **engagement**	Which method would make students more **actively involved**, to what extent could a student work on their own, which students would need more assistance	1–4, 9
Data needs	**Process data**	*KAE* school (time spent on **task**, wrong directions taken), assistance sought, questions asked, managing to cover my lesson plan/aims	1–6, 10
	Student-related data	About students' **emotions**, students asking questions, working in teams, fulfilling the tasks, **effort**, **assistance** needed, participation, contribution, method — what helps them learn, students' mental engagement, their **personality** (slower/faster), disabilities (dyslexia)	1–7, 9–10
	Outcomes/related data	**Assessment** data (also peer assessment), success, aims fulfilled, student **work**, task difficulty, mistakes, and difficult topics, *Kahoot!* results	1–5, 8, 10

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Data collection	**Digital sources**	*KAE school*: task **logs**, chats, data inserted, mistakes, wrong directions in tasks, *Opiq* analytics	1, 3
	Observation (personal, apps, observers)	Listen to group work; observe classroom activities; I am bad at multitasking, would not use any apps but I would like to be notified if a student has a problem	1, 4, 6–8
	Outcomes	Tests (comprehension), student **work**, what they have understood, mistakes made	3, 9, 10
	Questionnaires and conversations	To obtain **student feedback**, ask about their contribution/task difficulty; conversations with students and colleagues, discussions with students (this would also provide feedback about my work)	1–3, 5–9
	Sensors	Maybe brain **sensors**	8
Sense making	**Understanding students and their learning**	**Need for assistance**, clarifications, effort, medical condition (dyslexia), how much can they cope on their own, how much students are ready to work at home, to understand what helps the learner	1, 3, 5, 7–8
	Understanding tasks/methods	**Difficulty levels**, mistakes, time management, engagement, lesson **effectiveness**, use new strategies to make the lesson more exciting, the method works if time spent on task and student effort are moderate	2–7, 9
	Assessing practice/problems	I would need something that helps me assess that the class went well and the students were learning — how to check this? find out the possible reason for the **problem** (e.g., dyslexia)	9, 10
Interpretation	**Task modification** (materials or work routines)	**Mistakes** (what needs revisiting), **assessment** (what needs to be changed), **group** work (grouping students), independence, **presenting** the material, work **intensity**	1, 3, 5–6, 10
		make the material more "edible" for the students	
		Finding hints: what might help me improve as a teacher, am I on the right track	6, 9
	Professional development	**Comparisons**: of results (student development, with similar results from before the COVID-19 pandemic), my own teaching (compared to good teaching standards)	2, 9
Decision making	**Taking action**	How to **provide help** to weaker students, how to ensure that they think	1, 3–5, 7–10
	Reflection on pedagogy	**Planning work**: selection of methods, tasks, activities, improvement, different time management, deadlines,	
		If the students find that I am explaining things in very complicated ways that do not let them work along even when they want to, I'd change my teaching; if the method brings no harm nor gain but is more fun, then you could continue with it	
		to understand **why** something went wrong; when they say that the lesson was boring then I will not plan a similar lesson any more	3, 6
Change in teaching	**Variety**	More **fun** (for all), when I get **bored**, raise student motivation, all (new) students are different, heterogeneous groups need different approaches	1–2, 9, 4–7, 10
	Efficiency	Different results, failure, joy; when I sense that something **works better**	2, 3, 6–10
	Outside pressure	when you are told that you cannot continue the same way in this job; outside **pressure**; puzzled faces	6, 9

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Obstacles	**Habits**	Old **routines and thinking**, comfort, fear of anything new; no need when I see from students' faces that things are okay	3, 6, 8
	High workload	Time **constraints** (if I had more time, I would maybe collect data twice a week, but now we do it in our heads), high work-load	4, 6–7, 10
	Low quality data	e-school analytics are **not efficient**	1
	Skills	Get stuck, poor **skills**, need training, when you cannot understand what is expected from you, it creates defiance	7
	Predisposition	Do not **see the point** in it, first need to see value in data-informed analysis; not necessary for experienced teachers but the novice ones; teachers fear the outcome	4, 7, 9
Incentives	**Outside influence**	To get personal feedback for my reflection, working in a **team**, seeing **others** with a similar issue, that making mistakes is okay	1, 3, 9
	Innate motivation	**Understanding value** in data-informed analysis, self-development	3–4, 8–9
	Routine	If it were part of my duties, done **naturally**	3, 10
Assistance	**Data collection and use**	Suitable means for **data collection and understanding** what to do with the data, data collection	1, 3, 9
	Skills development	**Training, examples**, analyses and discussions in a team, maybe specific examples — the ones in the table were really useful	6, 8–10

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Appendix 4

The Improved Model

Needs analysis: WHY?		Educational design: WHAT? and HOW? + Educational delivery			Data analysis: SO WHAT? + Decision making: NOW WHAT?		
Motivation	**Purpose**	**Inquiry Questions**	**Data needs**	**Data collection**	**Sense making**	**Interpretation**	**Decision making**
Why do you want to (what makes you) analyze your teaching practice?	**What** would you like to find out with the analysis?	**What** exactly interests you?	**What** data would you need to answer the question(s)?	**How** and when could you collect these data? Which technology could help you?	Do you notice any patterns in the data? What do these data indicate? about:	***How** could these data and your pedagogical knowledge help you understand the situation?*	**What** decisions can these data help you make?
1) change in my context (new group of learners, change in course design or learning activities) 2) student needs/ perspective/ development 3) problems in teaching 4) outward pressure 5) professional development 6) ... + any other reasons or options	1) understand instructional change 2) evaluate my own performance 3) monitor the progress 4) identify areas of need 5) support conversations with parents 6)	Write down 1-2 specific questions that you would like to get an answer to	1) student work 2) student feedback 3) assessment data 4) process data (activity logs) 5) collaboration data 6) student background data 7) contextual data (curriculum, materials) 8) ...	1) data from electronic platforms 2) questionnaires or surveys 3) observation 4) conversations / interviews / discussions 5) exploring resources 6) sensor data 7) using apps 8) ... (CoTrack, EduLog, Prolearning, Menti)	1) knowledge of the students 2) progress of the students 3) engagement levels 4) skills development of the students 5) materials used and tasks employed 6) recurring mistakes or difficulties 7) your teaching 8) reaching the curriculum goals	1) set and assess progress toward goals 2) address individual or group needs 3) evaluate effectiveness of practices 4) assess whether student needs are met 5) reallocate resources in reaction to outcomes 6) enhance processes to improve outcomes	1) reflect on pedagogy 2) wait-and-see 3) take action, e.g., whole-class scaffolding, targeted scaffolding, and revising course design (adopt, adapt or reject a teaching method / material)

Based on: Hansen & Wasson (2016), Rolfe et al. (2001), Sergis & Sampson (2017), Schildkamp & Kuiper (2010), Lai & Schildkamp (2013), Marsh et al. (2006), Wise & Jung (2019)

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Appendix 5

Themes Emerging from the NGT and the Ranking of Ideas

Theme	Code	Ideas in Post-it Notes (in brackets: clarifications provided during the discussion phase)	Votes (voters)
Improvements to the model	**Links to materials**	(as many teachers are not up-to-date with modern learning theories, the model should provide) materials on the theories linked to the validated instruments	5 (4)
		(teachers need) materials on how to approach common problems (e.g., student motivation)	3
	Explanations	(the model should provide) leading questions, so that the teacher could find the self-analysis meaningful	4
	Technology	(the model should provide teachers with) a toolkit, including for data analysis (statistical data don't talk to teachers, they do not carry meaning for teachers; a fuller picture is needed)	4 (3)
		(the model should) provide info about the validated instruments	3
	Visualization	(the model should be) visualized as a problem-solving cycle	3
	Focus	the reasons/motivation step in the model should be systematized, better visualized (to make the focus clear)	2
Examples	**Examples**	(the model should provide) at least one concrete example	2
		(the model should provide) some examples about what has been researched and what results were obtained	4 (3)
		(the model should provide) some success stories about how such an analysis has improved the outcome	3
		(the model should provide) some use cases, as this would make it easier to relate to the process	2
Pro-inquiry attitude (and how this model could promote it)	**Possible benefits**	a teacher-inquirer could set an example and also inspire their students to define and add meaning to their activities	8 (7)
		the model could promote the development of teacher inquiry systems at schools	7 (6)
		(the model helps in) setting the teaching goals and systematically approaching all teaching steps	6
		(it helps to check) if my "gut feeling" is right (to validate this, the teacher might seek to collect some evidence)	3
		it is good that the model provides examples — this adds confidence that it is doable	2
		(the model could) convince teachers that the process is not that time-consuming	2
	The learning curve	a practitioner might not remember teaching theories, which diminishes their analysis competence (however, teachers might not have time and effort to study theories on their own, so maybe in-service training could be necessary)	4 (3)
		the focus should shift to learning (including the teacher as a learner — this would also help emotionally, to experience how difficult things might be when you do them for the first time and the teacher could then guide students being informed by their own learning strategies)	4
		teachers' learning skills (as somebody who teaches how to learn, the teacher should have good learning skills)	3

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Motivation	**Individual gains**	(teachers should have the) boldness to err and experiment (if a teacher fears to make mistakes and experiment, put himself/herself in a learner position, then they will never get this working) (it is very common that teachers are afraid of making mistakes or even inquire their own teaching because of the fear of finding out something negative about their own practice — it is imperative that we come out of this box)	8 (7)
		teachers become better aware of the components of learning and teaching	6
		(the model could lead to) a change in teachers' thinking and help the transfer from subject-centred teaching to learning-skills based teaching	6
		the model would help to teach more efficiently (to gain the same results with less effort)	5
		it should become clear if success in the analysis process has brought any benefits	4
		by planning and clearly formulating the teaching activities, the teacher sees better what the time is spent on	4
		focusing on how to get even better in my work	3
		(it is important that) the teacher is aware about the concept and motivated to become a teacher-inquirer	2
	Co-operation	(it provides) possibility to introduce the outcomes to my colleagues	1
		it would be good to compare your analysis with somebody (it is okay to assess your own improvement but also interesting to see the overall picture)	1
Social support	**Pair or group effort**	reflecting together in a study circle/group (this would help overcome insecurity, enhance synergy, study one class by different teachers for fuller picture)	6
		might be used in tandem — two colleagues inquiring and reflecting together, to each other	4
		would be good to find a partner who is also in this process	1
		propose the model for mentor–mentee pairs	1
The context, school culture	**Growth mindset**	it is important for the teacher to find motivation to become a self-directed teacher	4
		could be used as a basis for self-reflection and discussions with your boss (during developmental conversations)	3
	School culture	change in the organization culture, support from the school board (setting inquiry goals together, dedicating extra time for teacher discussions in groups, organizing in-service trainings)	7 (6)
		organization culture, empowerment of teachers	6

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Appendix 6

Teacher Diary Data from Practical Applications of the AMTI

AMTI steps	Teacher Researcher at School	Teacher Researcher at University
Motivation/ reason for inquiry	to develop professionally by introducing motivating and engaging teaching activities	a possibility for me to improve, I'd like to spot weaknesses that could condition the students
Purpose	to bring variety, and engage students, to see if engagement improves student results	to improve my course and teaching practice (make my classes beneficial for students)
Inquiry question	1) which activities do students find engaging? 2) does higher engagement get better results?	Would students report a good level of engagement in their course work? (preparation as well as in class)
Data needs	pattern and length of classroom activities; student perception of their cognitive, emotional, and behavioural engagement; assessment data	students' perceived engagement, what happens in the seminar
Tools	class activity logs; student surveys (every week, twice within a class) using mentimeter.com and research validated questions about engagement (6-point Likert scale, provided with the model); assessment data once a month	student surveys using Prolearning.realto.ch (with teacher predictions), teacher's own observations and notes; video data (from Zoom)
Sense making	to see the patterns, the teacher calculated the average engagement score for each activity; comparison of activity patterns and engagement data with assessment data	the teacher's observations and student responses were very different in two survey questions, so the teacher decided to discuss the results with her students during the next session (to make sense of it); video data (used later for course improvement)
Interpreting	emotional engagement seems to be the highest when the activity is built around an attractive item (funny poster, video, self-made illustration) and the lowest when students work on their own (listening or reading); behavioural engagement cannot be high during teacher-led activities and grows considerably when students can participate in a discussion or group activity; cognitive engagement does not probably depend only on the activity but also the information covered; however, the highest cognitive engagement can be seen when students listen/read to find new information (for a discussion or to find answers) and PowerPoint presentations seem to engage the least I find that the mere process of teacher inquiry already makes me better prepare and teach, as I want to get good feedback from students	one of the respondents had not realized the negative connotation of these two survey items, which led to these unexpected results; the discussion also revealed some aspects of concern my notes from the sessions help me in reflection and to remember what needs to be changed (like a reminder for myself) I intend to check the video data later, to check how much I deviated from the plan that I had in my head Zoom video data could also be analyzed to see how much each student and myself participated, and maybe identify patterns
Decision making	to raise student engagement, the activities should be built around an entertaining prompt and involve class discussions or group work (finding answers/solutions). In the future, I will try to validate these findings by using similar activities and find out how much the responses differ (as the novelty of the activity is gone). Maybe the engagement rate does not depend so much on the activity but on its novelty? I could also use similar activities with different students.	decision on course design: wait and see; decision on daily routine; change small things in daily routine and interactions with students (the teacher and the participants agreed on ways to adjust the situation) decision on data collection: Since I tend to plan too much content for a single session, I often have problems integrating the data gathering during the session and students need to do it afterwards. This creates problems related to the data collection, so I need to change this.
Suggestions for model improvement	practising teachers would probably NOT be able to link these findings to any theories	the terms "motivation" and "purpose" should be better explained; the concept "pedagogical knowledge" remained fuzzy and did not fit the prompts; reflection is not decision-making for me
Need for technology	there are many survey tools available, but in order to spend little class time on the survey, I wanted to use Likert scale questions, so I picked Mentimeter; however, the app does not allow for collecting respondents' names (to compare the survey results with their development); the Menti app provides session output but no session comparisons	the data from the first Prolearning session went missing; need technology to gather group work data (student engagement in group work)

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