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Adaptive Learning Technology in Primary Education: Implications for Professional Teacher Knowledge and Classroom Management

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The aim of this study is to explore the introduction of Adaptive Learning Technology (ALT) and inherent Learning Analytics (LA) in the classroom management and professionalism of teachers in a primary education real-life context. ALT is characterized by an inherent opportunity to personalize curriculum and learning experiences for each individual learner and to support teacher-facilitated learning. In this mixed methods study, we explore upper-primary teachers understanding of ALT application in real-life context, and we take a closer look at their experiences with ALT in their own context and practice through three different methodological lenses. The study offers insight into how teachers think and reason as they integrate ALT in their practice and addresses advantages and disadvantages of using ALT technology in primary education learning ecologies. The study also aims to discuss some more general implications of applying ALT and LA in primary and secondary level learning ecologies and concludes that automated system affordances and constraints can create new challenges for teachers, which exceeds teachers' digital competence and ability to make use of certain real and perceived affordances.

Keywords: classroom management, teacher professional knowledge, adaptive learning technology, learning analytics, design-based research, mixed methods research, one to one devices

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1 INTRODUCTION AND BACKGROUND

In a number of studies classroom management has been found to be a key predictor of student success (Hattie 2009; Marquez et al., 2016) and in one of our recent studies we found a significant correlation between teachers' classroom management abilities and their digital competence (Moltudal et al., 2019). In this article we will examine this further in light of teachers' perceptions of Adaptive Learning Technology (ALT) in real life contexts.

In Norway, digital competence has been one of five basic skills in school curriculum since 2006; this means that the use of technology should be included in all subjects and across subjects through primary, lower- and upper-secondary school (Krumsvik et al., 2020). One-to-one access to information and communication technology (ICT) and mobile devices has gradually increased in primary and secondary school, and it is assumed that approximately 80% of Norwegian pupils now have access to their own computer or tablet for use in school (SINTEF, 2019; University of Oslo, 2021). The usefulness of technology in school is contextual, and Cheung and Slavin (2013) suggested that educational technology should be perceived as a help, but not as a breakthrough. Learners seem to benefit from computer instruction (Cheung and Slavin, 2013), but it is uncertain how large the

scope of use should be (Cheung and Slavin, 2012) and under which conditions use is most expedient (Tamim et al., 2011).

Use of educational technology generally seems to have a moderately positive effect on learning and achievement, but research has also pointed out that it is difficult to adapt technology to the needs of each learner (Rosen and Salomon, 2007; Tamim et al., 2011; Cheung and Slavin, 2012; Cheung and Slavin, 2013). An ongoing and increasing trend in the domain of Computer-Assisted Learning (CAL) is Adaptive-Learning Technology (ALT) (Xie et al., 2019). Adaptive and personalized learning is one of the technologies explicitly mentioned across Norwegian policy documents and is defined by the Centre for ICT in Education as, "learning and teaching, in which digital resources are adapted on an ongoing basis, with the aid of algorithms to each pupil's measured level of skill and development" (UDIR, 2018, p. 11). The Artificial Intelligence (AI) community has for decades explored how technology could mimic professional thinking (Abbott, 1988) and the computer's potential as a digital tutor has been known and explored for a long time. ALT now makes it possible to tailor educational content and curriculum to individual student skill levels and to personalize their learning experiences by the use of algorithms, artificial intelligence and machine learning. Recent technological development allows for ever-new distribution methods for such technology, and in the future, there will be a spectrum of potential applications (Xie et al., 2019).

In a real-life educational context, however, the human–machine interaction will merely be a part of a larger learning ecology, wherein the teacher as a classroom manager is responsible for facilitating academic and socio-emotional learning within a larger context (Evertson and Weinstein, 2006; Emmer and Sabornie, 2015). In 2013, the Centre for ICT in Education in Norway developed a guide for classroom management in technology-dense learning environments and emphasized that "when the term classroom leadership is used, is meant in this context management of learning activities in all learning environments inside and outside the classroom, especially how technology is used on a large scale" (Centre for ICT in Education, 2013, p. 8). The Education Act and the Working Environment Act § 15-7 are clear on what can be expected of a teacher in general and classroom management in particular. And also recent Norwegian policy documents emphasise the possibilities and the challenges teachers face as they are expected to choose and apply digital technologies for teaching and learning activities and in their classroom management practices (UDIR, 2018). The official strategies for digitalisation, classroom management and leadership of learning processes in Norwegian schools particularly mentions adaptivity, the use of adaptive technology and learning analysis and asserts that teachers must know what is being measured, which learning and student views underlie the technology and how the technology facilitates learning for individual students and groups thereof (Ministry of Education and Research, 2017). In this study, we therefore aimed to explore how real-life application of ALT is experienced by teachers and how teachers reason as they introduce ALT systematically in their classroom management practices. The data material in this study was obtained from a larger study and collected through a Mixed-Methods Research (MMR) design within the framework of Design-Based Research (DBR). The overall aim of the study was to explore the ways in which systematic introduction of ALT in an upper-primary real-life context would affect student learning, teacher practices and the interaction between the two. This paper aims to contribute to the emerging body of knowledge related to the ways in which algorithm-based, data-producing and -driven educational technologies could affect teaching and learning ecologies, and which affordances and pitfalls they carry. The twofolded research question that drive this study is: How did upper primary teachers integrate ALT in their classroom management practices, and what was perceived by them as the benefits and challenges of the technology as they applied ALT in real-life contexts?

1.1 Conceptual and Contextual Framework

As implied by the research question an emic stance (e.g., Johnson and Christensen, 2017) is emphasized, and the study aims to explore real-life relationships between classroom management as a core pedagogical competence (Evertson and Weinstein, 2006; Emmer and Sabornie, 2015) and integration of technology in teacher professionalism (e.g., Mishra and Koehler, 2006; Koehler and Mishra, 2009) when ALT is applied. As such, we will further present some theoretical underpinnings between ALT, LA, classroom management and teacher professionalism in order to present the conceptual framework for the design of the study.

1.2 Classroom Management: Actions and Strategies Which Supports Learning

Internationally, Classroom Management (CM) as a field of research is generally defined as, "the actions teachers take to create an environment that supports and facilitates both academic and social-emotional learning" (Evertson and Weinstein, 2006, p. 4). Classroom management is thus not an end in itself, but rather a means for creating and maintaining an optimal learning environment, given the intended academic curriculum and social emotional skills and competencies (Brophy and Weinstein, 2006). Motivation is considered to be the moving force behind any action or behavior (Ryan and Deci, 2000) and can be represented as a continuum between the contrasting concepts of intrinsic motivation (i.e., activity that brings inherent satisfaction) and amotivation (i.e., the absence of motivation), which indicates that some extrinsic motivations are related to intrinsic motivation while others are related to amotivation (Ryan and Deci, 2000). Supporting basic psychological needs (autonomy, relatedness and the feeling of competence) and hence motivation is therefore described as at the core of CM (Evertson and Weinstein, 2006; Emmer and Sabornie, 2015; Deci and Ryan, 2016; Liu et al., 2016). The recognition that CM is perceived as a support for learning carries implications for success and assessment criteria and the choice of strategies, activities and tools applied in the learning context should therefore be considered integrated aspects of CM practice.

Hickey and Schafer (2006) described five types of actions teachers take to facilitate learning in their classroom: Engagement

(i.e., maximizing involvement in academic tasks), curriculum (i.e., defining the scope and sequence of instruction), relationships (i.e., interacting with and among students), development (i.e., changing behavior and cognition over time) and discipline (i.e., preventing and addressing behavior problems). Whether or not CM actions and strategies are considered to be purposeful could be understood as a contextual question, strongly linked to desired curricular- and socio-emotional learning outcomes and desired (corresponding) student roles (Brophy and Weinstein, 2006).

Some findings suggest that teachers interpret the use of ICT differently according to their individual professional understanding and identity, and that most teachers perceive content, pedagogy and technology to be separate and not mutually integrated (e.g., Roussinos and Jimoyiannis, 2019). Other studies indicate that teachers can use technology for their own "everyday survival," instead of facilitating learning (e.g., Gray et al., 2005; Shin, 2015). Generally, there seems to be a relationship between a teacher's digital competence and their CM skills and abilities (Moltudal et al., 2019), and professional development is emphasized as being important for educational integration of technology in a manner that benefit learners (Wang et al., 2014).

1.3 Integrating Technologies in Professional Practices

Mishra and Koehler (2006) developed the Technological Pedagogical Content Knowledge (TPACK) framework in an effort to explain how teachers can integrate technology into their existing professional understanding in different ways. They proposed that, ideally, Technology Knowledge (TK) should be mutually integrated with teacher Pedagogical and Content Knowledge (PCK) (Shulman, 1986; Shulman, 1987) within a classroom/learning environment context. The mutual integration aspect implies that TK should also contribute to a renegotiation of professional identity and new interpretations of established PCK. However, research on the TPACK framework often fails to communicate the importance of context and contextual factors due to the complexity it adds (Rosenberg and Koehler, 2015). Teacher practices and professional knowledge and identities are established over time and are deeply rooted in their professional commitments, ideals, interests, beliefs, values, ethical standards and moral obligations. Professional development is thus not merely seen as a matter of acquiring knowledge and professional competencies or updating skills (Koehler and Mishra, 2009; Eteläpelto et al., 2014). A renegotiation of professional identity is thus a prerequisite for professional learning and development to take place. Some classroom managers fear the loss of control and authority in their classrooms when technology is used (Bolick and Cooper, 2006; Bolick and Bartels, 2015), while others are described as frontrunners or power teachers who integrate ICT beyond the abilities of the average teacher (Wasson and Hansen, 2014). Overall, it seems that teachers who are already effective classroom managers are more inclined to use technology in their classrooms than teachers whose classroom skills are weak (Bolick and Cooper, 2006).

1.4 Application of Adaptive Learning Technology and Learning Analytics in Classroom Management and Professional Practices

So far we have demonstrated that knowing student needs is a prerequisite for purposeful CM. However, even highly experienced teachers could face problems identifying learner needs and varying motivations at any given moment in learning processes (Deci and Ryan, 2016), Inherent affordances in ALT have the potential to provide important additional support to teachers and their CM actions and strategies beyond the previously mentioned automated personalization of curriculum for each individual learner. Dashboard access to real-time activity data could assist teachers in identifying the academic and socio-emotional needs of each learner. But if teachers are expected to make use of real-time data in their facilitation for learning they must be able to interpret and make use of the available information.

"Affordance" is a term used to describe the relationship between an object and the user thereof (Gibson, 1977; Norman, 1990; Norman, 1999). Specific technologies therefore afford specific learning activities, and the ability to perceive the educational potential in technology and the placement thereof into a pedagogical setting is an important component of TPACK integration. The TPACK framework emphasises the connections, interactions, affordances and constraints between and among content, pedagogy and technology (Mishra and Koehler, 2006), and it therefore contributes important perspectives related to classroom management and professional practices when ALT is applied.

Educational technology has been researched for decades, but emergent algorithm-based ALT systems have other affordances and constraints than more traditional educational technology. An effective adaptive learning system would theoretically maintain learners in a permanent state of flow, which could be achieved when their skills matched the difficulty of the activity—a balancing act between difficulty and boredom (Csikszentmihalyi, 2009; Gallego-Durán et al., 2018). A level of difficulty that exceeds learners' skills results in anxiety, while an activity that includes what learners already know leads to boredom. Thus, maintaining learners in a state of flow is associated with positive motivation. However, the use of digital tools and software such as ALT for educational purposes also produces large amounts of data regarding learner activity, academic development, level of competence, etc. The use of such data for educational interventions and the facilitation of learning has emerged under the term "Learning Analytics" (LA) (Lang et al., 2017). LA-driven interventions in teaching and learning seem to be in the infancy stages and have potential to either support current educational practices or to challenge them and reshape education (Knight and Buckingham Shum, 2017). In a systematic review Xie et al. (2019) noted that higher order thinking skills and communication have attracted

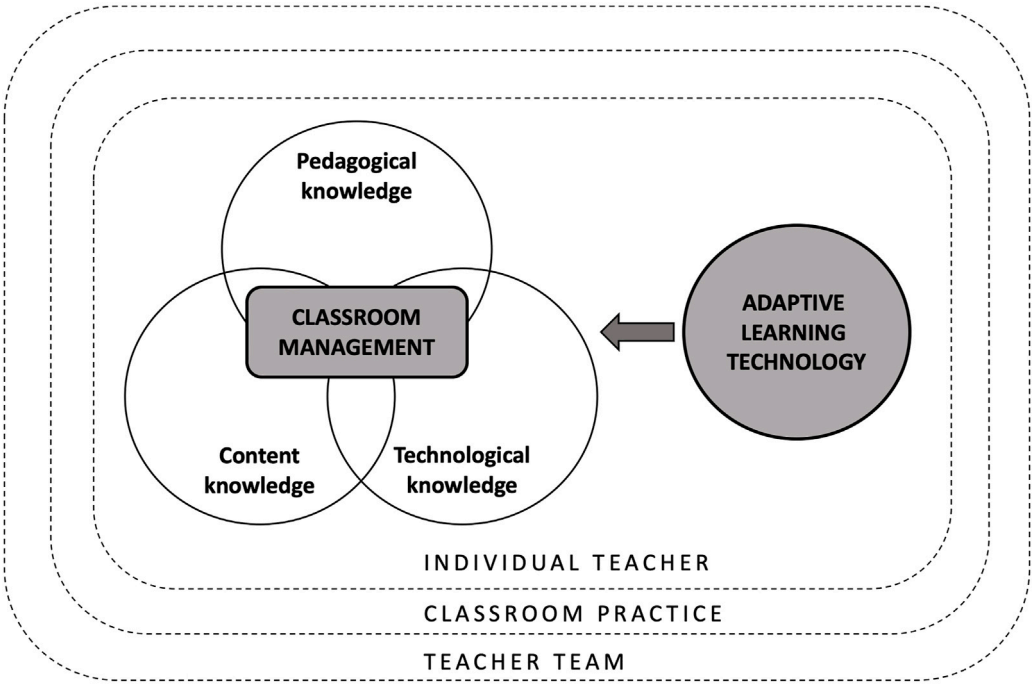

FIGURE 1 | The conceptual design of the study.

little attention in terms of learning outcomes and the process of adaptive and personalized learning due to the difficulty in measuring effectiveness and the limited types of learning. LA and ALT are said to have broad ethical and pedagogical implications (Slade and Prinsloo, 2013; Prinsloo and Slade, 2017), and algorithms may both ignore and mask key elements of the learning process (Knight and Buckingham Shum, 2017) in addition to making implicit claims about epistemology, pedagogy and assessment (Knight et al., 2014). (Knight and Buckingham Shum, 2017) have therefore raised concerns that LA and data-driven teaching and learning could potentially marginalize learners and educators by transforming education into a technocratic system, wherein learning is limited to concepts for which we can create analytics and excludes alternative learning engagement activities that may be difficult to computationally track, to the detriment of learners.

Thus far, ALT has mostly been studied in higher-education contexts (Xie et al., 2019), and little is known about how primary teachers develop their practices alongside their introduction of ALT. However, as noted by Knight and Buckingham Shum (2017) the use of ALT and LA technology must support the goals and values that are set for education, and it is therefore important to explore the benefits and challenges of introducing ALT in primary teachers real-life -professional practice and -classroom management. In the following methods and material section we will therefor present how the study was planned and conducted within the conceptual framework of classroom management, professional practice and systematic introduction of adaptive learning technology as illustrated in **Figure 1**.

However, an underlying and often-addressed challenge is that new educational technologies spread so fast that it is a challenge for formal educational research to keep up with real-life practices (Koh, 2016). Small-scale research and real-life interventions within the concept of Design-Based Research (DBR) could thus provide valuable contributions to educational research by providing first glances into new practices and suggesting further pathways into the complex relationship between technological development and educational change (Brown, 1992; The Design-Based Research Collective, 2003; Collins et al., 2004; Mishra and Koehler, 2006; Koehler et al., 2007). DBR designs also enable practice-based interventions that focus on the intertwining relationships between identity, renegotiation of identities and the practice of agency (Eteläpelto et al., 2014) and could lead to theoretical advances in the field of classroom management in terms of prototheory (Hickey and Schafer, 2006).

2 METHODS AND MATERIALS

2.1 A Real-Life Intervention as Context for Investigation

The learning context described in this article is Norwegian, and the core curriculum of. education in Norway describes good classroom management as being based on, "insight into the needs of the pupils, warm relations and professional judgment," and asserts that, "to create motivation and the joy of learning in the teaching situation, a broad repertoire of learning activities and resources within a predictable framework is needed" (UDIR, 2017, p. 16). Norwegian framework for professional digital

competence (PfDK) (UDIR, 2018) further describes classroom management and the ability to lead learning processes as central elements of teachers digital competence. A study from Rambøll (2014) found that classroom management was the topic that was ranked highest by Norwegian school principals and teachers, and teachers are expected to organize and lead teaching and learning activities in digital learning environments that are characterized by 'frequent transitions, and adaptive and parallel learning activities at different levels (UDIR, 2018, p. 8).

To be able to explore what happens when teachers integrate ALT into their classroom management practice and their leadership of learning processes a real -life intervention was developed and conducted. The case software explored in this study was Multi Smart Øving (MSØ) (Gyldenhal, 2020), an ALT software that is closely linked to a mathematics textbook, for basic mathematic learning that is in line with Norwegian curriculum. MSØ has been extensively used in Norwegian primary education for several years, and the main contribution thereof is variation and volume training. However, MSØ does not in itself afford deeper learning, practical mathematics or collaborative learning and should thus be combined with additional activities and methods for learning (Egelandsdal et al., 2019; Kynigos, 2019). The researchers and the case school had two joint aims for the intervention: to explore how systematically streamlining mathematical volume training at home with the use of ALT, specifically MSØ, would influence pupil learning and motivation; and to understand the interplay between MSØ, school culture and teacher practices. The local intention of the school was to determine to what extent and in what way the use of MSØ or similar software could expediently meet the overall goal of providing more time for practical mathematics and deep learning in mathematics, which is in line with the new curricula reform in Norway (LK20).

The intervention criteria were few, but real-life oriented: All pupils should have 1:1 access to a tablet with MSØ software at school and at home, and they should do tasks and activities that were adaptively provided by the software for a minimum of 15 min per day and 60 min per week as homework. All pupils and teachers had previously used the software program sporadically, and were therefore familiar with the main functions thereof before it was systematically used during the intervention. Since the main intention of the study was to explore real-life introduction of the technology, no additional professional development program was initiated.[1] The teachers were free to implement the use of the program, including dashboard data, in their own practice as they found in accordance with their own values and beliefs.

The MSØ software technology was developed in collaboration with Knewton and was thus built on the Knewton platform algorithms for task and level recommendations (Krumsvik and Røkenes, 2016). MSØ technology aims to facilitate learning on at least two levels, where ALT and LA technologies are mutually integrated. The first level is the activity and program feedback loop. This is the automated process wherein the program selects tasks and activities from a database that are tentatively adapted to a pupil's competence level at any given time. The pupil is provided with immediate feedback on whether the answer is right or wrong, and they are provided with symbolic stars and/or diamonds when they have reached certain levels within the program; an overview of the amount of time they have spent in the program, right and wrong answers, how many tasks they have given up on and how many stars and diamonds they have collected so far are also provided. The second level is the teacher feedback loop. This is a non-automated process by which the teacher can actively use empirical, real-time data from the dashboard to support facilitation of learning, either as a supplement to the program feedback loop or outside the program as an integrational part of the overall practice. Pupil activity in MSØ serves as empirical data that feeds the technology with information about the pupil, and thus, the software provides inherent access to data about the pupils as individuals and as a group. Empirical data generated by pupil activity is stored and systematized and is visually presented on a dashboard to which the teacher has access. In the teacher dashboard, pupil-registered levels of competence (i.e., levels 1–5) are color-coded according to traffic-light semiotics (red, yellow and green). **Figure 2** below illustrates the process and workflow of pupils and teachers who use MSØ. The classroom context element of the figure aims to highlight the fact that MSØ is not considered to be an isolated activity, but rather an integrational part of the existing learning ecology of each class. The dotted arrow line between the pupil interface and the teacher interface (in the figure) intends to visualize that the teacher feedback loop is not a part of the automated flow of the ALT system. The teacher must make active use of the data for further facilitation purposes.

2.2 Sample and Informed Consent

The case school and the participating teachers and pupils were selected through purposeful and partly theoretical sampling (Patton, 2015; Merriam and Tisdell, 2016). The case school was identified as an information-rich case, that was an early adopter and frontrunner (Wasson and Hansen, 2014) in educational use of tablets and other digital technologies. They had used tablets and other technologies for educational purposes over many years and the teaching staff at the case school was also familiar with the guiding principles of the Norwegian educational curricula reform, which was at the time not yet implemented (the data collection was carried out prior to August 2020). The real-life intervention was designed according to what the involved school leaders and teachers perceived to be real-life challenges facing the new curriculum and the guiding principles thereof. The study (aims and purposes, the intervention criteria, the mathematics test and the translation of survey items) was designed in collaboration with the involved teachers and school leaders, conducted at the upper-primary level, grades 5–7 (ages 10–12), in mathematics, and was approved by the Norwegian Centre for Research Data (NSD). Informed consent was obtained by parents and pupils prior to the intervention and data collection, and the pupils were orally provided age-appropriate

[1]No formal professional development was initiated before the intervention but results from the current study was used for professional development after the intervention (in line with DBR-purposes and axiology).

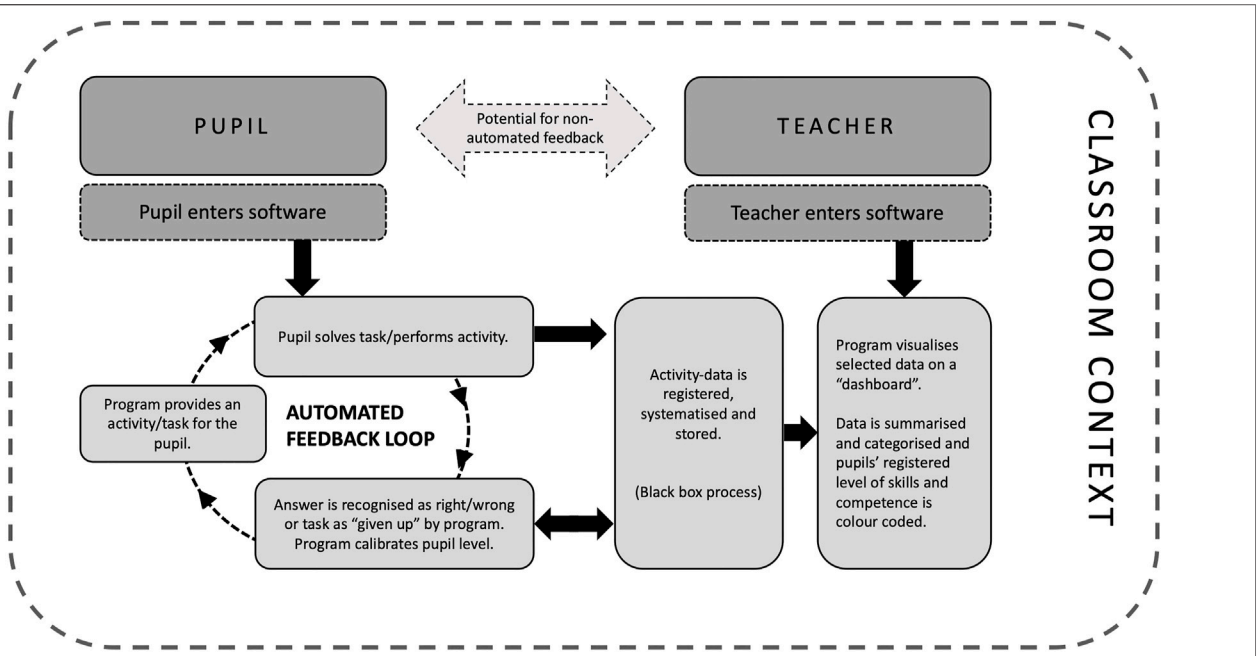

FIGURE 2 | Adaptive Learning Technology (ALT) step-by-step process.

information, in addition to the formal cover letter that was sent to their homes and signed by their parents. After implementing the ethical principle of informed consent, the total number of participants included 43 pupils and 3 teachers. In line with the NSD assessment, informed and active consent from the participants was repeatedly emphasized throughout the project.

2.3 The Design of the Study

The purpose of this study was to explore how the real-life introduction of ALT and the inherent LA-data access thereof would influence teacher practice and pupil learning within a real-life existing bounded system. The overall study design was planned to be a hybrid between a single case study (Yin, 2013; Merriam and Tisdell, 2016) and design-based research (DBR) (Brown, 1992; The Design-Based Research Collective, 2003; Collins et al., 2004) positioned within the logic of mixed research (Johnson et al., 2008; Johnson and Christensen, 2017; Johnson, 2017; Creswell and Guetterman, 2019). The iterative cycles/phases (The Design-Based Research Collective, 2003) of planning the intervention, introducing MSØ, systematic use of MSØ and evaluation of the systematic use were observed and informed by the use of a mixed-methods approach (MMR) (Fetters et al., 2013; Creswell, 2015; Johnson and Christensen, 2017; Schoonenboom and Johnson, 2017). The iterative nature of DBR and the integrational nature of MMR were combined in a partly planned and partly emergent mixed-methods research design (see **Figure 3**), where each phase of the study informed the next (Schoonenboom and Johnson, 2017). The QUAL-to-quan datasets from the four-week intervention were convergently collected within each phase, and they sequentially informed the next phase (Creswell, 2015). The design of the study reported in this article may be summarized as qualitatively driven partly planned and partly emergent mixed-methods research (Schoonenboom and Johnson, 2017; Johnson and Christensen, 2017) (**Figure 3**).

Findings regarding the ways in which ALT influenced pupil learning and motivation have previously been reported (Moltudal et al., 2020) and primarily included data from Phases 2 and 3. The following sections in this article will elaborate upon the methods, data collection, analysis and findings that directly involve the participating teachers in line with the research questions[2] and the previously described conceptual framework. This article could thus be read both as an isolated study described as a QUAL + qual multimethod study (e.g., Schoonenboom and Johnson, 2017), or be holistically read in the context of the pupil perspective of the study (Moltudal et al., 2020).

2.4 Fieldwork

An ethnographic approach to educational research is helpful when new elements are introduced and investigated (Schensul and LeCompte, 2013). The first meetings with the case school took place several months before the intervention was conducted, and the aim of observation days 1 and 2 was to understand the visions, aims, culture, and lifeworld of the case school as communicated by two of the school leaders. These discussions informed the subsequent design of the study and provided data and information at the school-leader level. Observation day 3 was dedicated to a plenum meeting with all (available) teachers at the upper and lower primary levels. This meeting served as an information meeting during which the preliminary study aims

[2]Hence the mathematical pre- and post-test, the survey pre- and post-test and the pupil focus group interviews are not further elaborated upon.

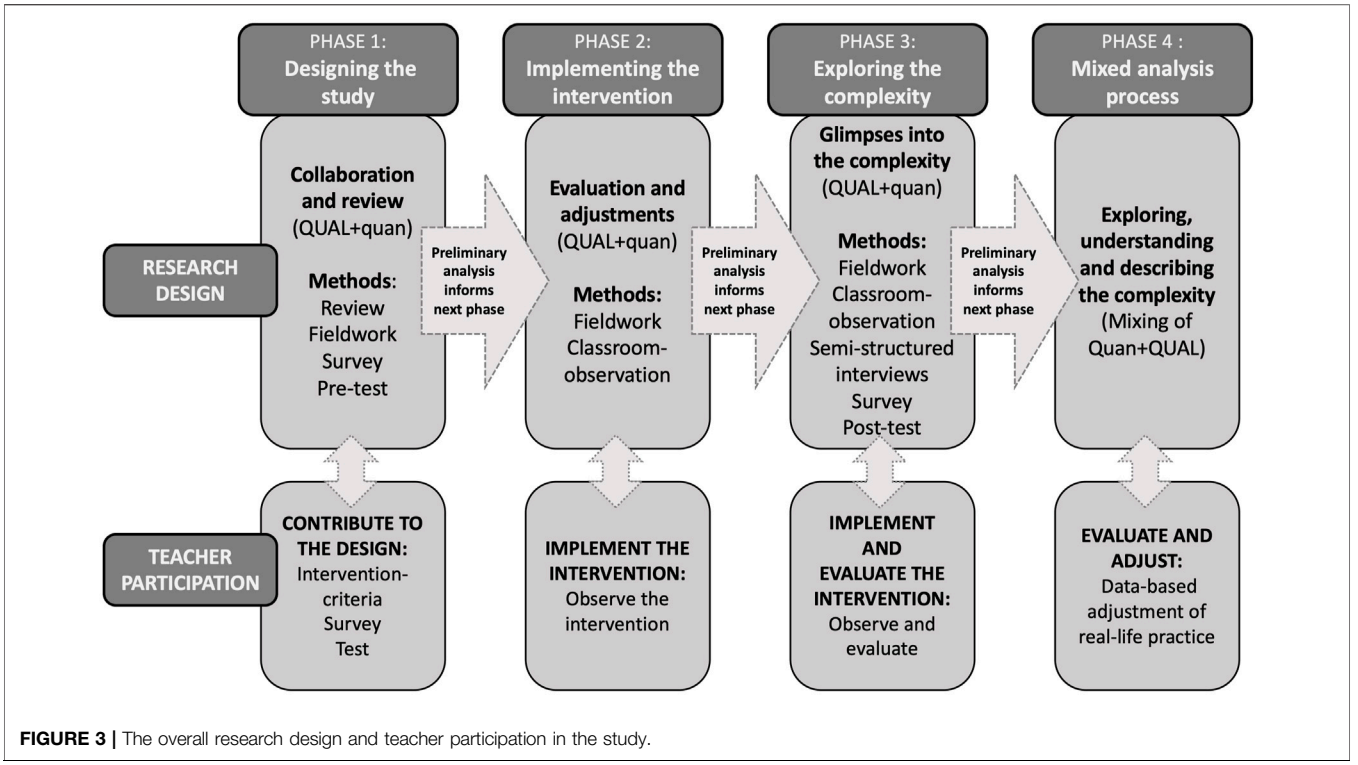

FIGURE 3 | The overall research design and teacher participation in the study.

were presented and the teachers were invited to share their (eventual) initial experiences with MSØ. Looking for patterns and inconsistencies confirming, supplementing, or contrasting the school leader level was also an aim. The fieldwork templates (throughout the entire project) included the following (expanding) text boxes: date, place/time, participants, researcher role, situation, methodological issues, topic, keywords/categories, preliminary findings/interpretations, did something surprise the researcher, topics for further investigation, supplemental information. In addition—each template had an own «supplemental analysis afterwards»-box, where preliminary analyses could be noted (and further developed) without editing the original data.

The participating teachers (n = 3) had previously worked together for a while, both as general colleagues and as an upper primary mathematics team, and as such, could be described as a culture-sharing group; thus, ethnographically inspired fieldwork provided a "detailed day-to-day picture of events [. . .] so that [we could] build a detailed record of their behaviors and beliefs over time" (Creswell and Guetterman, 2019, p. 474). Fieldwork among the participating teachers' team was conducted prior to the intervention (4 weeks) and during the intervention (4 weeks). Observation days 4 and 5 were dedicated to collaborative talks and discussions with the participating teachers (n = 3) to make sure they understood and agreed with the overall design of the study and their contribution to the intervention and the data collection (in line with informed consent and intervention criteria). But these talks also provided initial information about their practice, values and beliefs. A framework for the intervention was developed—that corresponded with the teachers' practical needs and professional integrity. The intervention started on observation day 6 (O6) and ended on observation day 14 (O14). Field notes written from O6 to O14 thus describe observed interaction and communication between the participating teachers or between participating teachers and other colleagues, considered relevant for the study's aims and purposes. The fieldwork was inspired by the design-based research axiology of researchers and practitioners working together to produce meaningful changes in real-life practice. Such cooperation requires researchers to be sensitive and attentive to practitioners' experiences and values. Conversations during the O1–O14 period thus contributed important insights into the teachers' lifeworld and shared culture.

2.5 Classroom Observation

Ethnographically inspired fieldwork (Fangen, 2010; Merriam and Tisdell, 2016) in the classroom was conducted during the intervention. The classroom observations included two sessions in each class ($2 \times 3n$) during a 2–3 week period (during the four intervention weeks); each session lasted 45–60 min. The first session protocol was the following: 1) chronological description of the class and transcribed representative snapshots (objective stance—during class and elaborated immediately after class). 2) What happened and what could this mean (subjective stance after class). The second session protocol was the following: 1) what to look for and things to further explore (informed by previous preliminary analysis). 2) chronological description of the class and transcribed representative snapshots (objective stance—during class and elaborated immediately after class). 3) What happened and

what could this mean (subjective stance after class). During both the fieldwork and the classroom observations the relationship between the researcher (i.e., the observer) and the participant(s) (i.e., the observed) could be described as "observer as participant" (Merriam and Tisdell, 2016). However, the researcher was also included in several everyday routines at the case school that occasionally provided her with a participant-as-observer status in the fieldwork settings. The participating status of the main observer could lead to potential bias and reactivity-validity threats (Maxwell, 2005). We therefore relied on multiple investigators (i.e., investigator triangulation) (Johnson and Christensen, 2017) throughout the emerging design of the study, the subsequent analyses and the interpretation and discussion of the findings.

2.6 Semi-Structured Interviews

Data related to the shared understanding of the teacher team was collected during the fieldwork process, but the fieldwork also revealed slightly differing opinions on the central themes. In order to further explore and understand individual teacher opinions, experiences and professional identities, one-on-one interviews were conducted (Kvale and Brinkmann, 2009; Merriam and Tisdell, 2016; Creswell and Guetterman, 2019). An interview guide created a common framework for the topics and categories the researcher wanted to discuss during the interview, such as their professional role as a teacher and their attitude toward and experience with MSØ; the interview guide was also informed by the preliminary analyses from Phases 1 and 2. To further explore their shared understandings and their differing opinions, clarifying and elaborating probes were both applied (Merriam and Tisdell, 2016; Creswell and Guetterman, 2019). Open-ended questions were emphasized, and the interview guide planned for an intended narrative structure wherein harmless and descriptive questions in the beginning would establish and maintain a natural flow in the conversation (Kvale and Brinkmann, 2009). The following topics were explored in the interviews (interview guide): Motivation for becoming a teacher—Why and how (and how long experience)? About own teacher role—Values, focus, attitudes etc. Perceived change in own teacher role over time (how and why?). Attitudes towards use of ICT in education in general. Attitudes towards MSØ specifically. Experiences with MSØ. Links between MSØ and own practice. How they perceive the academic and social learning environment in class. Aims for academic and social learning environment. How school culture is perceived. Follow up-questions were emphasized. All interviews were carried out in the same room at the case school and were audio recorded; this resulted in 160 min of recordings that the interviewing researcher later transcribed into 24 pages of text. The interviewing researcher also took notes from the interviews immediately after they were conducted, to record additional information about the interview process.

2.7 Analysis

Since the aim of the study was to explore teachers integration of ALT and LA in real-life contexts we used the three different methodological lenses described to better understand teachers interaction with each other outside the classroom, teachers interaction with students in the classroom, and individual teacher beliefs and viewpoints. The data collection and hence also the analyses was thus carried out by the use of three different methodological lenses (fieldwork, classroom observation and interviews) as shown in **Figure 4** below. In an iterative, partly planned and partly emergent mixed-methods research design, each phase of the study has distinct characteristics serves a specific purpose. According to the fundamental principle of mixed research, the design of such a study should ideally combine methods with complementary strengths and non-overlapping weaknesses (Onwuegbuzie and Johnson, 2008), and the strength of mixed-methods research is the ability thereof to deal with diversity and divergence in markedly different ways (Schoonenboom and Johnson, 2017). On the one hand, researchers can either perceive divergence as the need for more research, a reanalysis or a more comprehensive theory; on the other hand, researchers can emphazise the value of elaborating upon convergences, contradictions and inconsistencies in mixed-methods results, which is in line with Mathison (1988). Convergences, contradictions, and inconsistencies in this study were embraced as part of the descriptive and exploratory purpose of the study.

The qualitative data from the study were multi-levelled, produced over time, and repeatedly preliminarily analyzed during different stages of the intervention and again after the intervention. The preliminary analysis that was conducted during the emergence of the study were documented in a visual and textual analytic memo (Saldaña, 2013), so the analysis and reasoning therefrom could be traced back to its origin, both in time and in context. The analytic memo thus contributed to *in vivo* coding (Silverman, 2019), thereby prototyping integration for further analysis. During the mixed analysis process (i.e., Phase 4), the fieldwork notes, observation notes and transcribed interviews were first analyzed using categories derived from the research questions and the conceptual framework. The categories were then refined using the analytic memo to preserve the relationship between data, context and phase. The design of the study is rather complex, but the application of multiple methods enabled the researchers to explore the integration of ALT from multiple perspectives (as demonstrated in **Figure 4** below). Mixing qualitative methods this way enabled the researchers to increase the ecological validity of the study (e.g., Bronfenbrenner, 1996, p. 29) and deepen the understanding, by applying a step-by-step analysis which will be gradually unpacked in the following **Section 3**.

To meet the research ethics requirement for anonymity, certain precautions were taken due to the one-case bounded-system sample of the study. Some contextual information has been deliberately omitted from the **Section 2**, and the data is presented in such a way as to not enable identification of the individual teachers (i.e., gender, age, etc.); thus, the names of the teachers are fictional and gender neutral in the forthcoming **Section 3**.

3 FINDINGS

3.1 Fieldwork Analysis and Findings

On the collaborative level of school culture and within the teacher team (see **Table 1** below), both teachers and school leaders

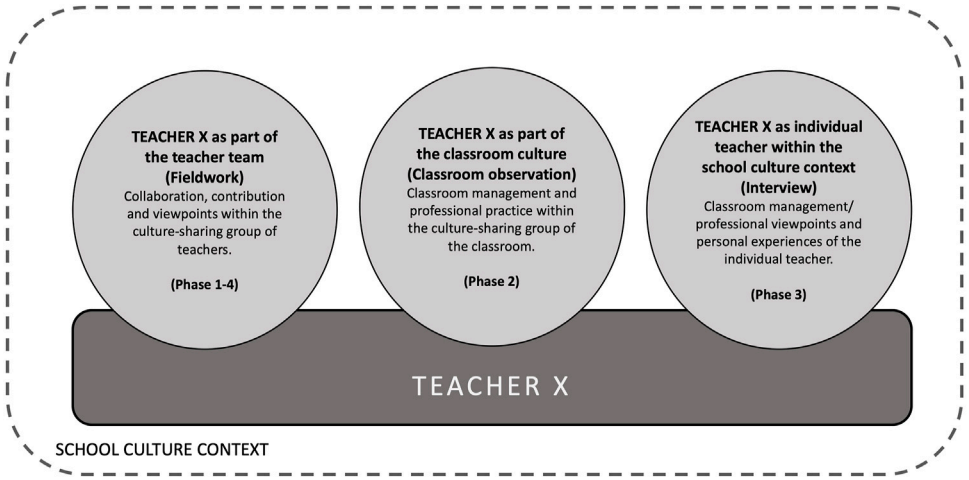

FIGURE 4 | Teacher data collection and analysis.

described a rather consistent practice, where deep learning, and pupils understanding and verbalizing knowledge and further questions to explore was emphasized. A safe and inclusive learning environment was repeatedly emphasized both as a means, but also as a prerequisite for deep learning and verbalizing to occur. The field notes were distilled based on patterns and contrasts in the teachers' emic ways of discussing both ALT in general, but also what they perceived to be potentially (ethically and practically) challenging in conducting the intervention. This implied that they had individual "profiles" regarding how they talked about and "framed" ALT, but also that their professional classroom management practices differed from each other. The first analyses of the field notes gave the impression that each of them emphasized and prioritized the different goals for classroom management somewhat differently, which in turn seemed to inspire an assumption that their individual priorities and judgment influenced the way ALT was integrated and experienced: Each teacher appeared to have an individual mental model about what was important to enhance motivation, learning, and a good learning environment (characterized by supporting basic psychological needs); accordingly, each had individual expectations of how and why using ALT could lead to benefits and challenges in their practices. The following **Table 1** provides an overview of the main patterns from the fieldwork notes which informed the classroom observations and semi-structured interviews about certain tendencies for further exploration.

3.2 Classroom Observation Analysis and Findings

The classroom observation notes were analyzed by using the five types of actions teachers take to facilitate learning in their classroom (Hickey and Schafer, 2006). This was done to identify general characteristics in classroom interactions, learning environment and classroom management practices. In addition, snapshots referring to ALT (either implicitly or explicitly) was registered as an own category to document whether or not ALT was a visible aspect of the classroom management practice. **Table 2** below presents the characteristics of each examined classroom practice as observed by the researchers.

3.3 Semi Structured Interview Analysis and Findings

Whilst the classroom observation findings in **Table 2** describe classroom management practices as they appear from the outside, the semi-structured interviews aimed to grasp (emic) teacher experiences and beliefs as perceived by themselves. In order to systematize the teachers' reasoning and experiences, the interviews were therefore first analyzed based on the following categories: General attitudes towards use of ICT in teaching and learning; initial thoughts on ALT; ALT experiences (advantages and disadvantages); use of dashboard data in own practice; dashboard data vs. own perception of pupils; and experience of school culture (the findings are summarized in the following **Table 3**).

3.4 Integrated Results

The three methodological lenses (fieldwork, classroom observation and interviews) and their corresponding main findings so far (**Tables 1–3**) provide three separate approaches which could bring us closer to understanding how the teachers integrated ALT in their professional practices, and what was perceived by them as the benefits and challenges of integrating ALT in their classroom management. In this integrated results section we will further integrate the findings, by voicing some of the reasoning and experiences provided by the teachers themselves. In the semi structured interviews the participating teachers elaborated on their views of their own teacher role and the desired pupil role in line with the school leaders' visions of an active, safe and inclusive learning community, and both fieldwork and interview data could easily leave an impression of a shared

TABLE 1 | School culture context and teacher team.

Phase 1: Pre-intervention	**Collaborative meetings (6) with school leaders (2), the overall teacher colleague (1) and the teacher team (3)**
Aims and visions at the school-leader level	Goals of deep learning in every subject. Skills and competencies associated with inquiry-based learning and student understanding through active use of subject-specific language at school were emphasised in order to determine the extent and manner in which the program can be expediently used to achieve the overall goal of more in-depth learning and practical mathematics at school. Benefits and challenges related to the use of the program were both observed, and systematic exploration for future application and use in the local context was therefore desired
Two-pronged attitude at the teacher-colleague level	Teachers had differing experience with ALT. Lower- and upper-primary level math teachers had access to MSØ and had used it to varying degrees. Teachers expressed a two-pronged attitude towards the program: On the one hand, they liked it, but on the other hand, they did not. Teachers in the lower-primary level expressed uncertainty about how to implement it in their practice. The external motivational factors (i.e., stars, diamonds and quantitative scores) were addressed by a couple of teachers, who explained that students talked a lot about the rewards. General teacher attitudes were interpreted as seeing and appreciating the potential of the ALT technology, but also as being uncertain about how to make it work in their own practice. These findings informed further design as to the need to investigate how teachers described and perceived ALT and LA affordances
Shared and divided expectations at the participating teacher level (N = 3)	Teachers had varying experience with ALT before the intervention and described their previous use and application in a way that was interpreted that they integrated it differently. They expressed two-pronged attitudes toward the program that were similar to the rest of the teacher colleagues. They pointed to both advantages and disadvantages. All expressed a united commitment to the school's visions of deep learning and inquiry-based learning that emphasises student understanding by actively using subject language at school. They also expressed a united commitment to the intervention, even if they communicated varying expectations of results and outcome
Phases 2 and 3: During the intervention	**Observations at teacher's office, common areas and break room**
Observed practices and experiences at the participating teacher level	The teachers had frequent conversations wherein they updated each other on what they had done during the lessons and what they planned to do next. As they were busy with other things, these conversations became mostly spontaneous exchanges, with little time for deep reflection. However, two of the teachers (Sam and Kim) collaboratively analysed dashboard data and colour-coded scales on a few occasions, and they also discussed what the data outcome could imply in general. Absence and illness affected some pupils' activity levels in the program. The teachers discussed what implications such lack of activity could have on the results and how to deal with it. Issues for further exploration arose. The program needs a lot of empirical activity data to adjust to each pupil's level: How can a teacher handle low activity when activity is a prerequisite for technology function? Furthermore, the dashboard provides the teacher with information about the extent of student activity and thus gives the teachers an opportunity to exercise control: How do teachers relate to this opportunity?
Phase 4: Post-intervention	**Dissemination of findings and discussion with school leaders and lower- and upper-primary teachers**
Evaluation, discussion and adjustments at the school-culture level (i.e., participating teachers, teacher colleagues and school leaders)	Results from the intervention period were presented, and the interwoven relationship between classroom practice, learning, motivation and volume training in MSØ was addressed. Teachers and school leaders discussed implications for their future practice with an emphasis on how to adjust their local practice in future school development

understanding of what terms like "verbalized knowledge" and "safe learning environment" mean and what implications these terms should have on classroom practice.

> Sam: If the pupils are satisfied and want to attend school. If you can do that the rest, well it doesn't work itself out, but it is easier to get it right, at least. And to have a good relationship with the pupils. To see them and to care. Social competence and connection are very important. You can't do anything if the pupils fear you.
>
> Alex: I enjoy motivating others, and I like working with children. I have always been interested in how to teach and how to motivate, so I have always been thinking

TABLE 2 | Classroom practices.

Teacher	Classroom A: Sam	Classroom B: Alex	Classroom C: Kim
Curriculum: Topic and methods	Fractions and percentages. Individual work on tasks in ALT, textbooks and workbooks	Fractions and percentages. Collaborative work with complex problem-solving tasks on paper	Fractions and percentages. Collaborative work on practical (i.e., tactile) mathematics
Engagement strategies	Teacher seeks out pupils who appear to need help, models how to solve tasks and supports individual work	Pupils are encouraged to explain their thinking and reasoning in groups and during presentations. Teacher moves between groups and leads class plenum presentations	Pupils are encouraged to explain their thinking and reasoning in groups and in class plenum (i.e., step-by-step switching). Teacher moves between groups
Relationship strategies and classroom arrangement	Teacher facilitates individual work and silence (or whispering); seats two pupils together as learning partners, but seldom in active use	Teacher facilitates collaborative work and invites talking; seats 3–4 pupils together as learning partners in active use; invites subject thinking and supports collaborative work in small groups and class plenum presentations and supports and encourages pupils to explain how they solved the problem	Teacher facilitates collaborative work and invites talking; seats 3–4 pupils together as learning partners in active use; invites thinking and supports collaborative work in groups; supports and encourages pupils to explain how they solved the problem; and seems to have shared internal humour related to particular words and concepts
Development and discipline	Teacher facilitates a quiet, peaceful atmosphere and expects individual work effort. Music plays in the background. Pupils sit quietly and appear to complete their tasks; they sometimes ask for help from their teacher or learning partner, and they whisper when communicating	Pupils mainly engage in conversations, some more than others, which vary between being subject-oriented and non-subject-oriented. Teacher actively redirects conversations back to being subject-oriented. Teacher and students speak at normal volume when communicating	Pupils mainly engage in conversations, some more than others, which vary between being subject-oriented and non-subject-oriented. Teacher actively redirects conversations back to being subject-orientated. Teacher and students speak at normal volume when communicating
Rituals/structures for organisation and transformations	Clear routines and structures for transitions. Pupils respond quickly and efficiently	Clear routines and structures for transitions. Pupils mostly respond quickly	Teacher seemed to rely more heavily on intuition and have less-clear routines and structure for transitions. Pupils mainly respond quickly and efficiently
Integration of ALT	Teacher observed and (re)directed pupils use of MSØ when used. Emphasised pupils to set up calculations on paper	Pupils who finished collaborative tasks individually used ALT supplementary toward the end of the lesson	Sometimes referred to tasks, words and concepts in ALT when guiding the pupils. Little use during observation
Teacher emphasis	Individual thinking and "correct" form of problem solving	Variation between individual and collaborative thinking and ability to verbalise thinking	Variation between individual and collaborative thinking and ability to verbalise thinking

that I could be a teacher and aimed towards that and practicing classroom leadership.

Kim: The pupils should feel some sense of achievement and competence no matter their skill level. They should experience that they are learning something. Their work should have a purpose. [. . .] I have one main aim, and that is that everyone should dare to ask for help and dare to say that they don't understand something. You are supposed to be able to answer wrong without there being looks or giggling. I am super strict on that. Everyone should feel safe, and it should feel safe to make mistakes. So really, I am integrating the academic and the social aspect.

Sam described a static understanding of subject knowledge and voiced concern that "new" methods and application of digital tools could lead to poor working habits and thus diminish subject skills among pupils. Their classroom practice corresponded with their viewpoints and was characterized by more individualized learning practices where pupils were working on tasks and assignments in their books. Their classroom actions and strategies also demonstrated that they emphasized modelling approaches to mathematics perceived as "right" rather than "explorative."

Kim and Alex, on the other hand, both described collaborative and verbal learning as their preferred methods for learning. The semi structured interviews deepened the understanding of why they explicitly and consciously chose to facilitate collaborative learning in groups. Kim described their classroom practice as a result of their own professional development over time:

As a novice teacher I was very concerned with pupils "doing" things [and] doing the same. Even if the curriculum was somewhat adjusted for them, they should do all the textbook tasks they were supposed to do. If they had 99 right answers, I was still more concerned with them correcting the one wrong answer. That was the regime at my school at that time, and as a new teacher, you easily adapt to the existing practice. [. . .] Later [in a new job at a new school], I participated in a project where I saw other teachers work in other ways, and we started to work [in a] more practical [manner] in mathematics. [. . .] Learning is often hard, but I think it could be pleasurable as well. Some things

TABLE 3 | Semi-structured interview findings.

	Sam	Alex	Kim
General attitudes towards use of ICT in teaching and learning	Divided attitude. School must prepare pupils for the digital world, but is worried that it will "take over." Fear of less creativity and poor work habits when students can press a button instead of producing letters and numbers	Wants to test and try things, but also holds back. Does not want to practice extremes in any way. Tries to be loyal towards school leader initiatives	The topic in question leads the way. Some topics integrate well in analogue settings, while others integrate better in an ICT workflow. Use of ICT links to pupil's life-world and everyday life. Helps pupils who do not write well. Pupils are more active when stuck and seek help elsewhere on the web
Initial thoughts on ALT	ALT is basically a task generator with previously seen tasks and assignments. It provides variety, but the tasks and assignments just keep appearing	Was initiated by the school leaders, and Alex was okay with that. ALT is an easy way to get feedback regarding what pupils can and cannot do	The personalised levels and the adaptive technology itself are appealing. Lessens the pupil stigma of working on other books and/or resources than the rest if needed. When using MSØ everyone is just doing tasks on an iPad
ALT experiences: Advantages and disadvantages	Pupils do not have to write; they just press answers, and they do not use the program "right" at home. They are often guessing. Not being required to set up calculations leads to bad working habits. Fears less creativity	Is still questioning how much to use ALT in the future: What is its value? It is useful, but what do pupils learn from it? It requires time and space, at the expense of being able to verbalise. Afraid pupils just learn how to "hack" the system. Not being required to set up calculations makes it difficult to know what students are struggling with and how to help	Very positive in the beginning; still positive, but more aware of challenges and disadvantages. Not being required to set up calculations gives pupils valuable total amount of training; they simply think and solve the problem. ALT requires a lot of time spent in the program if the student is to be placed on the correct level in the program loop and on the dashboard. Displaces other working methods and focus areas
The use of dashboard data in own practice	It may seem like you have answers that you might not have. Also worried that I will settle for "good enough." Mostly use it to support pupils who struggle. In hectic everyday life, it can be tempting to rely on data, even if the value thereof is uncertain. Provides lots of data, but unsure if it should be used for anything	The program maps out what the pupils can and cannot do, but not what the underlying problem is. Use it to plan further teaching and learning activities for the whole group and for specific pupils	Do not generally want to use the required amount of time, so pupils are not always placed on the right level. Easy to become caught up with numbers and measures. Must be actively conscious about "what matters. Mainly use it as starting point for discussions with pupils
Are there similarities between dashboard data and own perception of pupils?	On very strong pupils: Yes. Otherwise a bit more difficult: Yes and no. Impressions do not always fit with the dashboard data	Feels the need to interpret. Might perceive the pupil to be stronger or weaker than the dashboard indicates	Yes, if pupils have spent sufficient time in the program. But my pupils seldom do, so the data must be used in combination with discussions and other ways of mapping pupils" levels
Experience of school culture	Generally willing to develop, share and change, but finding time is a challenge	Generally willing to develop, share and change, but finding time is a challenge	Generally willing to develop, share and change, but finding time is a challenge

> have to be drilled, but I think it is also important to verbalize and make use the knowledge. I am not so concerned with details, but more with the overall understanding.

Kim further described their own professional development over time as a constant (re)negotiation of what is important in each subject and topic, thereby indicating that the choice of methods and tools grows out of a content knowledge base that changes and adjusts over time—in an active interplay with their pedagogical and technological content base:

> Digital tools are, first and foremost, tools, and I use tools I consider useful for each purpose. Many of the boys, for instance, struggle with writing, and they believe that they are bad in subjects, when their writing issues are really the case. Digital tools open their world. They can seek and acquire information in new ways and present their knowledge in new ways.

The results so far demonstrates that even though Sam, Kim and Alex describe their overarching values and goals of the teacher role, the pupil role and education in general in similar ways, they practice their understanding differently. Whilst Sam explains developing subject knowledge mainly as a process of doing things the right way, Kim and Alex understands developing subject knowledge mainly as a verbal and collaborative process of exploration. This is an interesting starting point for further exploration of how they perceived the integration of ALT in their practice:

Working on tasks and activities in ALT systems like MSØ is mainly associated with individual processes of learning within a feedback loop of human-computer interactions. Despite mainly valuing collaborative learning processes, Kim was initially very

positive toward ALT and was also a driving force of applying the technology at the case school. Their initial engagement was explicitly linked to the sets of educational values and aims observed at the collaborative level (**Table 1**):

> It is not very cool to be the one who uses second-grade books when you are in sixth grade. In that sense, MSØ on a tablet facilitates equality and inclusion. You cannot see what other pupils are working on, and the adaptiveness of the system was something I found valuable.

Both Sam and Alex also initially found the promising theoretical adaptiveness of MSØ interesting and wanted to give it a try. Sam expressed a curious "let us see what happens"- attitude towards introducing ALT, while Alex reasoned somewhat differently—inking the integration to a more general understanding of the role as a classroom manager; trying to keep up with trends or "waves" without practicing extremes in any direction.

After using MSØ systematically for 2–3 weeks throughout the intervention, the three teachers had both positive and negative experiences with the program:

> Kim: I was very positive in the beginning. I kind of still am, but I have become aware that pupils have to do a lot of work in MSØ to prove a high level according to the color scale. I am not interested in spending that much time on MSØ, because I prefer more problem-based learning and so on, so my pupils might not reach their potential, color-wise, before we move on. If they have demonstrated their level to me, why should they keep working on lots of similar tasks just to get the "right" color?
>
> Sam: Many pupils like it because it is easy. They do not have to write, and the tasks just keep appearing, and they can get away with guessing. As a mapping and measuring tool, I like it, but I hope it further develops into even better tools. [. . .] It is easy to use, of course, for both pupils and teachers. But it has to be used right and I don't have either the overview or the time to do that.

The researcher encouraged Sam to comment on what they consider to be the "right use":

> The pupils have to draft the answers and not guess. They have to line up the equation and show their thinking. That is [. . .] getting more and more lost, and I feel that MSØ strengthens this aspect. You have to tell them to draft, and even when you do, they still just keep on pressing buttons [and] doing it all in their head because it is easier.

By linking the MSØ to "guessing" and poor work habits, Sam expressed an opinion that homework should reinforce good work habits and processes. This is in line with the previous notion that Sam explained developing subject knowledge mainly as a process of doing things the right way The descriptions and statements that MSØ is initially a "task generator" created the impression that Sam essentially perceived the program as a digitized workbook, which allows students to avoid or "skip" what they considered to be crucial processes and skills in the subject: Setting up calculations correctly and showing how they are solved by using mathematical language, numbers and symbols. These attitudes were also seen in Sam's classroom practice, which was characterized by individual thought and calculation processes and in which collaborative learning was not a priority. Sam also spent time modelling "correct" use of MSØ during classroom observations.

Kim expressed another, and almost contradictory type of attitude, in which MSØ was referred to as an aid that enables volume training, even for students who struggle with writing skills. Kim emphasized the writing of thought processes in a different way than Sam, in that the pupil's own understanding of what they do is more important than the tasks being set up and solved in the "right" way. Alex explained how they normally swapped between MSØ homework and paper homework that required pupils to draft and line up their equations. This allowed Alex to better understand how their pupils were thinking and to identify what each pupil is struggling with and thus, the best way to help them. Alex indicated that this was more difficult when all homework was done in MSØ, but that it was a general problem as well:

> Pupils who strive are often quiet and do not require attention. I feel it is important to help them, but I don't always know what the problem is. I have to find time for conversations, and I don't always have time for that with so many pupils. [. . .] This is [also] a general problem [. . .] when we don't use MSØ.

Alex further expressed uncertainty related to how much they wished to use MSØ in the future [after the intervention period] and explained this uncertainty according to educational priorities:

> How much time should you spend on it? What is its place and purpose? It is useful for feedback and mapping students' level of learning aims and so on? What are they really learning? Which understanding underlies what they can do? Have they just figured out the system? How to solve a task based on [several] repetitions, without [gaining] a deeper understanding of why the answer is right?

All three teachers explicitly linked their experiences with MSØ to their own classroom practices and educational choices therein. Although the intervention criterion was to use MSØ for homework, it became clear that beyond being a personalized "homework tool" for pupils, systematic use of MSØ also affected teachers classroom management practices in various ways. All three mentioned time and educational priorities as explanatory

factors when describing their experiences, albeit in different and slightly contrasting ways:

> Kim: It works well for math homework, because it is personalized, and pupils do not have to work more than 15 min; that is enough [time]. Some might solve four tasks while others solve 20. Fifteen minutes are 15 min, and the pupil who did four tasks might have done a great job.
>
> Alex: I am uncertain whether the pupils just figure out the system and what the program wants them to do. Using MSØ requires time and space, and if you spend much time on MSØ, it will be at the expense of something I find much more valuable: Using language to verbalize what you understand and know, what is challenging and so on, in interaction with others—to draw on specific experiences and not on constructed tasks.
>
> Sam: It provides me some information, but I am not sure if I dare to use it for anything. At the same time, it provides variation from working in textbooks or "flipped classroom." But basically, it is just a task generator. It might save me some time, but at the same time, you might think you have more information than you actually do. In everyday life at school with lots of subjects and things to think about, you might end up using it anyway.

Even though this last quote was Sam's view, it represented an ambiguity that was expressed by Kim and Alex, as well. They were all uncertain as to the extent to which they should rely on and trust the dashboard data at any given time, and they all had experiences wherein they had to make their own interpretations of the data—without quite knowing how to do so.

> Alex: It [the data] provides me with quick feedback. When they have done quite a few tasks and activities, you get feedback regarding what they can and cannot do. This is linked to concrete learning aims and formulations you can talk to them about, and that is useful. But it is difficult to know why some pupils score low. How have they been thinking? What is it they do not understand? Is it a misunderstanding?
>
> Sam: I mostly use data when I see pupils struggle; [I] use it to ask a bit, to talk to them about it and encourage them to work more on tasks they find difficult and [to] help them on their way. The dangers of using data is more in the opposite cases. "Look at you! You are doing fine. You do not need to do more of that". I have been thinking that several times. That is kind of dangerous.
>
> Kim: Since I normally don't use MSØ the way it is supposed to be used due to my own pedagogical priorities, I think the combination [of MSØ and practical collaborative methods] . . . well . . . [rephrases] What is good is that I can enter the color scale and tell immediately, "Wow, this pupil is in trouble," so it kind of works as a signal lamp, and then I can check it out. Instead of correcting books and equations, which the pupils have struggled with, it provides me an immediate hint to check someone out. That is really good.

The teachers all expressed that pupils were generally interested in knowing their color-scale score and comparing/rating stars and diamonds [provided by the program according to certain parameters]. The pupils did not have direct access to their scaled color coding through their own program interface, so they had to ask teachers to give them that information. The system "withholding" this information from the pupil dashboard thus created a scenario in which the teachers needed to determine which information to share with pupils and the extent to which they should contextualize the result.

A two-pronged attitude towards MSØ was consistently addressed by teachers in the studied school contexts (and is represented in **Tables 1–3**). Both Kim and Alex expressed a consciously critical attitude toward what they perceived to be a somewhat narrow view of knowledge and competence in MSØ, and they were worried that the broader concept of knowledge (e.g., deep learning and verbalizing knowledge) could become a blind zone if teachers become too concerned with numbers and color coding:

> [Alex and I] were [both] really down after an MSØ half-year test. The results were much lower than we had expected. It did not at all reflect what we had seen during classes, but it is about another kind of competence. [MSØ] measured [its] own selections and interpretations.

The researcher asked, "Did it help that you talked about- and discussed these things?"

> Kim: Yes. It is really important that we have this common understanding about what matters in mathematics. National tests measure, and so do these half-year tests and other tests. If systems only look at numbers, we lose sight of what matters to us. Do you value a test someone has decided that your pupil should take more, or the process of learning during class and your local aims? To me, what matters more is what I see during class, but that does not necessarily look good on the color scale. [laughs].

4 DISCUSSION

Theoretical approaches indicate that the personalizing nature of ALT have the potential to reduce stigma and support inclusion in primary educational learning ecologies and to continuously personalize and adapt curriculum to pupils' level of skills and competence (Gallego-Durán et al., 2018; Xie et al., 2019). These are approaches that aims to support motivational and basic psychological needs (e.g. Ryan and Deci, 2000;

Csikszentmihalyi, 2009) which is found to be at the very core of classroom management (Evertson and Weinstein, 2006; Emmer and Sabornie, 2015; Deci and Ryan, 2016; Liu et al., 2016). The theoretically founded link between personalization and motivation is therefore a premise for the explicit focus on adaptive learning technology in Norwegian whitepaper strategies (e.g., UDIR, 2017; UDIR, 2018). Our findings indicate that all participating teachers acknowledged and appreciated the adaptive personalization potential of the technology (activity and program feedback loop), and they also liked that the technology could support inclusion by hiding visual stigmas, such as lower-grade textbooks and writing issues, and they emphasized the variational and motivational potential of the program; this is also why the teachers wished to use MSØ to personalize volume training at home and find a balance (between volume training and deeper learning) that "works."

However, even if such a combination works in theory, the participating teachers also faced continuous practical and ethical challenges when aiming to translate the promising theoretical contributions of ALT into practice. Since time is regarded as a valuable resource in education, it is natural for teachers to ensure that the use of their time is utilized in the best possible manner. All the participating teachers found that extensive use of MSØ in different ways created challenges for their own classroom practice, and as a result they were uncertain as to if (and eventually how often) MSØ should be used. This is not in itself a surprising finding. The usefulness of technology in school is generally perceived a contextual matter, and it is often challenging for teachers to identify under which conditions use is most expedient for each individual learner (Rosen and Salomon, 2007; Tamim et al., 2011; Cheung and Slavin, 2012; Cheung and Slavin, 2013; Rosenberg and Koehler, 2015).

As explored throughout the study, technology could in addition to the adaptive feedback loop also support a teacher's classroom management practice by providing the teacher with real-time data; information about pupil activity, competence level and knowledge gaps, thereby enabling teachers to make decisions based on data rather than assumptions (teacher feedback loop). However, our findings from the study implies that ALT and LA technologies could create and maintain educational blind spots unless teachers are sufficiently aware of the need to balance them out. Similar concerns have previously been addressed by researchers exploring implications of automated and data-driven educational technologies. LA and ALT are said to have broad ethical and pedagogical implications (Prinsloo and Slade, 2017), since the nature of algorithms may both ignore and mask key elements of the learning process (Knight and Buckingham Shum, 2017) in addition to making implicit claims about epistemology, pedagogy, and assessment (Knight and Buckingham Shum, 2017).

Data-driven teaching and learning technology could potentially transform education into a technocratic system, wherein learning is limited to those concepts for which we can create analytics and exclude alternative learning engagement activities that may be difficult to computationally track such as higher order thinking and collaborative learning activities (Knight and Buckingham Shum, 2017; Xie et al., 2019). If the technology algorithms are to be able to calibrate the adaptive technology and properly measure students' knowledge and competence levels, it must have access to sufficient and ongoing empirical input in the form of pupil activity. In other words, to provide personalization in line with theoretical aims of both the activity and program feedback loop as well as the teacher feedback loop, ALT must be used systematically and extensively, and an important pedagogical and ethical question is whether such extensive use is considered time well spent—in line with educational aims (Knight and Buckingham Shum, 2017).

A clear finding in this study is that the teachers describe the technology as promising, but that to use it fully their pupils must spend more time on solving tasks in the program than the teachers are willing to offer, due to their initial beliefs and pedagogical priorities. In that sense, our findings provide examples of how teachers experience the interaction between empirical input (i.e., the scope of use), the validity and reliability of the dashboard data. But our findings also indicated that in this specific study, the participating teachers consciously relied on each other and their shared understanding of "what matters" in the general school culture when they were tempted or felt obliged to use the technology beyond their initial beliefs and pedagogical priorities. In other school cultures this might not be the case, since some teachers use technology for their own "everyday survival," instead of deliberatly facilitating pupil learning (e.g., Gray et al., 2005; Shin, 2015).

Our findings somewhat contradicts the established view that classroom managers are critical towards educational use of technology because they fear the loss of control and authority in their classrooms when technology is used (Bolick and Cooper, 2006; Bolick and Bartels, 2015). Rather, the teachers expressed a constant search for new and better methods and technologies, both digital and analogue, that could support their goals and desires for pupil learning processes and outcomes. The teachers in our study were purposefully sampled because they were perceived general frontrunners and had included educational use of tablets in their teaching practices for several years. Their restrictive attitude towards MSØ/ALT is thus rather interpreted as an expression of their scepticism toward outsourcing educational assessments and judgment to a self-driven and automated system that only partially overlaps with their educational knowledge, values, and beliefs.

The driving research question of this article has been: How did upper primary teachers integrate ALT in their classroom management practices, and what was perceived by them as the benefits and challenges of the technology as they applied ALT in real-life contexts? Integrating technology in professional development and existing practices takes time (Wang et al., 2014; Roschelle et al., 2016), and four-weeks of systematic use of new technology might not be a sufficient amount of time for teachers to fully understand and make use of affordances, beyond the human–machine interaction. The relationship between affordances and constraints across the content, pedagogy and technology domains of the TPACK framework is complex, and even if teachers perceive the main affordances in the program

(i.e., TK), they might need additional time to integrate it with their PCK.

However, this study concludes that automated system affordances and constraints can create both new possibilities and challenges for teachers in their real-life practice. But the challenges discussed in this section are not merely related to teachers' ability to make use of technology for learning purposes and the integration of technology in teachers PCK. Our findings rather demonstrate some integrational issues regarding automated and data-driven ALT and CAL systems which exeeds teachers' ability to make use of certain real and perceived technology affordances. These issues are related to the intersection of real-life aims and purposes of education on one hand and automated built-in implicit claims about epistemology, pedagogy, and assessment on the other hand. Even teachers with lengthy experience in using educational technology and a dynamic subject knowledge understanding seem to encounter difficulties when interpreting automated algorithm systems into their classroom management practice.

Both pre-service and in-service teacher training and professional development would benefit from addressing ethical and pedagogical implications of ALT and LA in classroom management practices, beyond personal data issues. The findings from this study also revitalize the question of whether teachers should adapt their practice to a given software, or whether the software should be adapted to a given teachers' practice. We will therefore encourage technology developers to collaborate with in-service teachers to better adapt educational ALT and LA technology to teachers' professional practices and needs.

A limitation of this study is the small sample of participating teachers. However, the multi method design of the study and the lack of professional development support/intervention criteria enabled the researchers to explore the integration of ALT in existing classroom management practices and observe benefits and challenges of the technology as it could potentially unfold in similar real-life contexts. In that sense the study provide pragmatic and transferrable knowlege—relevant for teachers professional development and further research on educational use of ALT and LA. We thus call for larger research projects that address the relationship between teacher professionalism in primary and secondary education and the use of ALT and LA technology. The further development of educational technology will benefit from a broad knowledge base about the built-in strengths and challenges of algorithm-based learning technologies. Media and technology convergence makes it possible to develop and create ever-new programs and tools for applications, and teachers need transferable skills and competencies that are rooted in their basic teacher identity in order to achieve this reality. We believe this is particularly important since tabloid articles and sales pitches often describe ALT technology as being "self-adjusting" and easy to use.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because they contain information that could potentially identify the participants and thus compromise their anonymity. Requests to access the datasets should be directed to SM, moltudal@hivolda.no.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Norwegian Centre for Research Data. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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