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A one stop shop? Perspectives on the value of adaptive learning technologies in K-12 education

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ABSTRACT

This study explored the value of Adaptive Learning Technologies (ALTs) in K-12 education by examining the advantages and challenges these tools create for teaching and learning from the perspectives of stakeholders involved in the use (Teachers), implementation (Teacher Support professionals), and development (EdTech professionals) of ALTs. We conducted qualitative thematic analysis on 25 stakeholder interviews using the Teacher Response Model as a guide for examining stakeholders' perceptions of the advantages and challenges of ALTs. Analysis resulted in three overarching concepts (i.e., learning management, student agency and engagement, and implementation challenges), under which themes regarding stakeholder perspectives on the advantages and challenges of ALTs could be organized and contrasted with one another. Learning management themes suggest that stakeholders perceive features such as real-time student data and tailored learning content as creating value for teachers by supporting efficiency in their learning management, however that value is impacted by stakeholders' concerns with ALT grading and data collection processes. Student agency and engagement themes highlight how certain user interaction features can create value or challenges for learners depending on whether the features were designed with students' developmental and competence needs in mind. Finally, the implementation challenges themes suggest that for ALTs to create value in K-12 settings, stakeholders need better alignment around their ALT implementation goals and expectations. We leverage these data to make recommendations for future research and development so stakeholders can maximize the affordances of ALTs for K-12 students and teachers.

Introduction

In recent years, adaptive learning tools (ALTs) have become widely used for managing student learning. Although reliable data are not available about the prevalence of ALTs, recent research suggests that these tools are commonly used in K-12 classrooms [1–5]. ALTs (e.g., Dreambox; [6]; ALEKS; [7]) tailor instruction and feedback to students' individual learning needs [8] and have been described as solutions for improving student learning efficiency [9]. ALTs became more prevalent, and more relied-upon, during the COVID-19 pandemic, as schools transitioned to remote learning [10,11]. The rapid adoption of ALTs for K-12 contexts is incongruent with the rate of research examining the value of these technologies for K-12 students and teachers [12]. Previous research on ALTs has focused on their impact on students' academic outcomes (e.g., [13,14]). However, teachers evaluate classroom technology more expansively, considering how tools provide value both directly to students and indirectly by aiding teachers with a variety of administrative and learning management tasks [15]. For this reason, research should examine the impact of ALTs for additional outcomes (e.g., teacher efficiency, student engagement, and classroom interactions) from multiple stakeholder perspectives.

How students and teachers are impacted by ALTs is dependent on two factors: the specific design features of the tool and how the tool is implemented in the classroom. There is limited research investigating how specific design features and implementation methods of ALTs result in advantageous or disadvantageous use cases of the tool. This study attempts to fill the gap in the research by bringing together professionals engaged in the development, implementation, and use of ALTs, to examine their perspectives on which features and implementation models of ALTs result in value for students and teachers. We leverage

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these data to make recommendations for how stakeholders can maximize the affordances of ALTs for students and teachers and provide avenues for future research and development.

What are adaptive learning technologies?

Despite the increased popularity of ALTs in recent years, in part due to the COVID-19 pandemic [10], there is no universally accepted definition of ALTs [8,16]. The term adaptive learning has been used by EdTech companies, researchers, and educators both to describe a general approach to learning as well as the digital technologies that facilitate this approach [12,17–19]. ALTs "take a sophisticated, data-driven, and in some cases, nonlinear approach to instruction and remediation, adjusting to each learner's interactions and demonstrated performance level and subsequently anticipating what types of content and resources meet the learner's needs at a specific point in time" ([8], p. 7; for similar definitions, see [17,20–23]).

For the purposes of this study, we adopted a definition of ALTs that is broad enough to include a range of tools while summarizing key themes in ALT literature. We considered ALTs to be tools that utilize at least one of the following approaches to adaptivity (see [17] for a similar approach): 1) adaptive assessments, which adjust the questions a student sees based on their previous answers [24], 2) adaptive feedback, which provides students with personalized support or scaffolding [20], or 3) adaptive instruction, where the tool collects data about student knowledge and creates a unique sequence of learning content [12]. We used this definition to select a group of participants with a comparable understanding of and experience with ALTs, which enabled us to compare and contrast the stakeholder groups.

Theoretical background

Our investigation of stakeholder perspectives on the value of ALTs relied on a definition of value from the Teacher Response Model (TRM), a research-based model of teachers' decision-making process for technology implementation in the classroom [15]. In contrast with the existing implementation frameworks and research, which consider value only in terms of students' constructivist, authentic learning and achievement outcomes (for a review, see [15]), this model conceptualizes the value of education technologies more broadly. Namely, TRM posits that teachers may also find value in technologies because they support a wide variety of their needs as educators, such as efficiency and effectiveness in their administrative tasks, classroom learning management, and communication with families. Kopcha and colleagues propose that a key component of teachers' perceptions of technology's value in the classroom depends on how well it helps them complete their various responsibilities, including routine work tasks and tasks that support students' learning needs. Using conceptions of value in the TRM, our research question explores what value (and challenges) teachers, teacher support staff, and EdTech developers perceive ALTs provide for both students and teachers.

Value of adaptive learning tools

To date, research on the value of ALTs has predominantly focused on students' academic outcomes [12], and studies have linked the use of ALTs to improvements for K-12 and higher education students in math [13,14,25], chemistry [26], biology [27], and world languages [13]. However, research suggests that relevant stakeholders consider factors beyond student academic outcomes when evaluating classroom technologies, such as benefits to student-teacher interactions and enhanced student engagement [28]. Recent research has provided mixed evidence about the impacts of ALTs on students' learning experiences; some studies have observed benefits for student engagement [3,29], while others report declines in important skills such as self-regulated learning [30]. More research is needed to fully explore the impact of ALTs on K-12 students' learning experience.

Another body of literature specifically explores teacher experiences with using ALTs in classrooms. Research suggests that these technologies can assist teachers in understanding students' learning progress [31], differentiating instruction [1], and providing responsive feedback to students [9]. However, researchers have also identified barriers that prevent teachers from maximizing the benefits of ALTs. For example, Bingham et al. [32] found that teachers lacked the preparation and professional development opportunities necessary to effectively use ALTs in their classrooms. Teachers may also have challenges interpreting and using student data collected by these technologies [1].

Research has shown that successful technology design and implementation requires support from stakeholders that are both inside and outside of the classroom, such as teacher support professionals (e.g., tech coaches, school staff; [28,33]) and EdTech developers [34]. Therefore, to maximize the benefits of ALTs and improve their design and integration in K-12 settings, it is crucial to understand and evaluate these tools from the perspective of stakeholders engaged in the development, implementation, and use of ALTs.

Current study

To address these gaps in prior research on ALTs, our study aims to apply the TRM's conception of value to address the following research question: What are the perspectives of teachers, teacher support professionals, and education technology (EdTech) professionals on the value of adaptive learning technologies in K-12 education? We employed the TRM as a guide to explore stakeholder perceptions of value by examining the advantages and challenges ALT design features and implementation methods create for both students and teachers. Our analysis features teachers' perspectives, as teachers are one of the primary end users of ALTs. Therefore, other stakeholder perspectives are provided in supporting or contrasting detail to teachers' sentiments. We used the TRM to explore notions of value in stakeholder interviews and generate findings and recommendations that can be used to refine the design and implementation of ALTs so they can better support both students and teachers.

Method

Research design

The TRM's expansive definition of value encouraged us to take an interpretive qualitative approach to the research design to understand how those involved with a phenomena (ALTs) interpret and construct meaning around their experiences [35]. For our research design, this meant collecting a wider range of stakeholder perspectives regarding the value of ALTs compared to prior studies, without any specific hypotheses about which aspects of value would be salient for individuals in the three stakeholder groups. This also meant we would need to collect data in a systematized and open-ended way. For this reason, the research team utilized a semi-structured interview method for data collection to elicit participant perspectives in their own words. Thematic analysis was used to categorize and interpret varying perspectives to provide a rich narrative around the use and value of ALTs in K-12 education. The research design, study materials, and procedures were reviewed and approved by an Institutional Review Board.

Participant recruitment

Participants were recruited through our network of education professionals using media posts, snowball sampling, and cold calls via contact pages of EdTech company websites, professional websites (e.g., LinkedIn), and industry conferences (e.g., ISTE). We focused recruitment on five professions that would allow us to capture a holistic set of perspectives surrounding the development, integration, and use of ALTs

(i.e., teachers, teacher educators, school administrators, technology coaches, EdTech developers). Recruitment materials included a flier summarizing the study purpose, as well as a consent form for interested individuals to complete and return to the research team. The consent form included an overview of the study's purpose, the voluntary nature of participation, study compensation details, and secure data storage and confidentiality measures (i.e., information collected would remain devoid of identifiable participant details in publications or presentations).

Individuals who responded to our recruitment materials with a completed consent form were sent a brief screening survey (Appendix A). Individuals who indicated on the screener that they belonged to one of five relevant professions and reported experience with at least one adaptive learning tool were invited to participate in an interview.

We later grouped these professions into three broader stakeholder categories: individuals who use adaptive learning technologies in classrooms with students (Teachers), individuals who support the implementation of these tools in schools and districts (Teacher Support professionals), and individuals who design and market these tools (EdTech professionals). See Table 1 for details.

Sample

Our final sample included 25 participants, with 5 Teachers (20 %), 7 Teacher Support professionals (28 %), and 13 EdTech professionals (52 %). During the interview process, we identified a new relevant profession (teacher developers). This group of participants were initially recruited as EdTech developers, but they revealed during the interview that they had prior experience as K-12 teachers who had used ALTs in classrooms. We decided to include these participants in the EdTech professionals stakeholder group, since they had most recently worked with EdTech companies to develop and implement ALTs. Therefore, when looking at the distribution of participants across the three stakeholder groups, it is worth noting that three of the EdTech professionals also spoke from a teacher perspective. See Table 2 for participant details. Across the sample, there were 24 ALTs that participants had used. All platforms included one or more of the following features: adaptive assessments, adaptive feedback, or adaptive instruction (Table S1 in the Supplemental Material provides a list of all 24 ALTs and their functionalities).

Table 1
Description of participant groups.

Participant Group (n)	Description
Teacher (5)	
Teachers (5)	K-12 educators using ALTs in their classroom
Teacher Support (8)	
Technology coaches (2)	Individuals working at schools or within school districts to directly support K-12 teachers to implement ALTs in classrooms
Teacher educators (2)	Educators focusing on teaching pre-service teachers and contributing to the professional development of in-service teachers who teach about the use of ALTs in K-12 classrooms
School administrators (4)	Individuals working at a school or within a school district that utilizes ALTs across multiple classrooms
EdTech (13)	
EdTech developers (6)	Individuals working at an EdTech company to create ALTs
EdTech technology coaches (4)	Individuals working at an EdTech company or working as an external consultant who directly support or train K-12 teachers in implementing ALTs
Teacher developers[a] (3)	Teachers also working as an EdTech developer or as a technology coach for an EdTech company

Note. [a]Emerging category.

Data collection

Four researchers (Authors 1, 2, 3, 4) and one research collaborator conducted interviews from July to December 2020. Interviews were conducted using a semi-structured interview protocol designed with the TRM in mind to draw out participant perspectives on the advantages and challenges they have seen ALTs create for K-12 students and teachers (see Appendix B for full interview protocol). Utilizing semi-structured interviews as the data collection instrument aligned with the interpretative qualitative design of the study as it enabled researchers to approach data collection in a systematized way with a consistent set of questions for every participant, while also maintaining flexibility to rephrase, probe, or omit questions to elicit nuanced experiences and insights from each participant [58]. Interviews lasted one hour and were conducted over Zoom. Participants' audio and/or video were recorded over Zoom in accordance with the participant's preference, as outlined on their consent forms. Participants were sent a $25 gift card as compensation.

Data analysis

Interview recordings were transcribed by a third-party service (https://www.rev.com/). Dedoose version 4.12, a qualitative data management software, was used for coding and data management [59]. The transcripts were analyzed using thematic analysis, a qualitative methodology used to identify, organize, analyze, describe, and report patterns in a data set in rich detail [60].

Code development was an inductive process that was informed by the research question and the TRM. Researchers started the analysis by completing an initial review of the transcripts. The research team then collaboratively discussed emerging patterns in the data in relation to the research question and conceptions of value described in the TRM and collapsed patterns into potential categories and codes. This process resulted in an initial set of three code categories. The first category contained codes describing the FEATURES of ALTs (e.g., diagnostic data, gamification). The second category focused on the different IMPLEMENTATIONS of ALTs in classrooms (e.g., for differentiated instruction, for collaboration). The final category captured the different VALUE statements that participants made about ALTs (e.g., a certain feature or implementation that created an advantage or challenge for students or teachers using the tool).

The three coding team members (Authors 1, 3, 4), with guidance from the second author, independently applied these initial codes to two transcripts and made any necessary modifications to the codebook (e.g., collapsing or eliminating sparsely used codes). This process led to a more refined and condensed codebook that reflected the data in the transcripts and could be used across the entire dataset (See Appendix C). The codebook was stratified to include parent codes, which captured broader ideas (i.e., Data, Learning Content, User Interaction, Advantage, Challenge), and a series of child codes under them.

The three coders then independently coded the same five transcripts (20 % of the dataset) to test for inter-rater reliability (IRR). IRR is a statistical measurement that is used to gauge consistency in the application of codes across multiple coders. IRR was a necessary measure to use in our coding process due to the number of coders, the breadth of our codebook, and the volume of our dataset [61]. The coding process involved using the child codes as flags to identify which parent codes applied to specific excerpts. Reliability was calculated at the parent code level using Light's kappa to account for multiple coders [62], and 0.80 was used as the threshold for acceptable reliability [63]. The coding team documented areas of agreement and disagreement and worked to clarify the definition and appropriate application of parent codes with lower kappa values. The coding process was repeated for a second and third time until acceptable levels of kappa were obtained for each parent code. The final kappa statistics associated with each of the parent codes ranged from 0.808 to 0.957. Once reliability was established, each

Table 2
Participant information.

ID	Profession	State	School Type	Grade Level[a]	Subject	ALTs[b]
Teachers						
1001	Teacher	WA	Private	7	Math	ALEKS [7]
1002	Teacher	WA	Private	6–8	Math	ALEKS [7], Dreambox Math [6]
1003	Teacher	WA	Private	4–5	Spanish	Conjuguemos [36], Duolingo [37]
1017	Teacher	CA	Public	8	Math	Dreambox Math [6]
1018	Teacher	WA	Private	3, 6–10	Math, English	ALEKS [7], Edmentum [38]
Teacher Support Professionals						
1007	Teacher Educator	OR	N/A	K-8	Math	Dreambox Math [6]
1014	Teacher Educator	WA	N/A	K-8	ESL	Lexia [39]
1008	School Administrator	WA	Public	K-6	Math, Reading	Khan Academy [40], iReady Learning [41], Moby Max [42], Freckle Math [43]
1010	School Administrator	WA	Public	K-6	Math, Reading	iReady Learning [41]
1011	School Administrator	WA	Public	K-6	SEL	Panorama [44]
1020	School Administrator	WA	Public	K-5	Math, Reading, ESL	iReady Learning [41], Imagine Language Literacy [45]
1009	Technology Coach	WA	Public	K-8	Math, Reading	Lexia [39], iReady Learning [41], Zearn Math [46]
EdTech Professionals						
1013	EdTech Technology Coach	PA	N/A	1–12	Math	Knowre Math [47]
1019	EdTech Technology Coach	CA	N/A	3–12	Reading, English	READ 180 and System 44 [48,49]
1021	EdTech Technology Coach	CA	N/A	K-8	Math	ST Math [50]
1027	EdTech Technology Coach	AZ	N/A	K-8	Math, Reading	SucccessMaker [51]
1005	Teacher Developer	MA	Public	9–12	Spanish	Conjuguemos [36]
1006	Teacher Developer	CO	Public	9–11	Math	Woot Math [52]
1025	Teacher Developer	IA	Public	K-6	English	Imagine Language and Literacy [45], Pictoword [53](
1004	EdTech Developer	CA	N/A	3–12	Math	ALEKS [7]
1022	EdTech Developer	CA	N/A	K-8	Math	ST Math [50]
1028	EdTech Developer	IL	N/A	K-8	ESL, Spanish, Reading, Math	Imagine Language and Literacy, Imagine Espanol, and Imagine Math [45,54,55]
1029	EdTech Developer	CA	N/A	K-6	Math, Literacy	Zearn Math [46], Lexia [39]
1030	EdTech Developer	OK	N/A	K-6	Math	Boddle [56]
1031	EdTech Developer	WA	N/A	K-8	Math	Maths-Whizz [57]

Note. [a]Refers to the grade level of students using the adaptive learning tools (i.e., for teachers, the grade levels taught using ALTs; for teacher support, the grade levels supported in using ALTs; for EdTech, the grade levels targeted by their ALTs). [b]Dates for each ALT are not provided as participants did not specify which version of the software they had used.

researcher took on coding a third of the remaining transcripts.

Once transcripts were coded, researchers (Authors 1, 2, 3, 4) started thematic analysis of the coded excerpts. This involved using the research question and the TRM as a guide to identify emerging and salient themes in the data regarding how ALTs create advantages and challenges for students and educators. In thematic analysis, salience of a theme is not necessarily dependent on how quantifiable the theme is, but rather on whether it captures something important in relation to the overall research question [60,64–66]. Of the stakeholder groups interviewed in this study, Teachers are one of the end users of these technologies, and therefore the most familiar with how the application of ALTs impacts teaching and learning. For this reason, the thematic analysis process involved first reviewing Teacher perspectives to develop the initial set of advantage and challenge themes, and then added Teacher Support and EdTech professionals' perspectives as support or contrasting details to further develop the themes.

This led to more finalized candidate themes reflecting stakeholders' perspectives on the advantages and challenges ALTs create for K-12 learning and teaching. The advantage and challenge themes were then cross-examined and sorted into three overarching concepts summarizing the areas in which common advantages and challenges of ALTs were cited by participants (See Table 3). These three concepts included learning management, student agency and engagement, and implementation challenges (See Figure S1).

A thematic map was created to test whether the ideas and data captured by the final three concepts reflected the dataset as a whole and were relevant to the original research questions. The thematic map was found by the researchers to be representative of the main ideas which emerged from the preliminary analysis of participant transcripts, while also reflecting the nuances of the less prevalent but salient ideas present in the transcripts. We have organized the findings in a way that brings advantage and challenge themes in conversation under these three concepts.

Results

Our results summarize stakeholders' perspectives on the value (i.e., advantages and challenges) ALTs create for K-12 teaching and learning. Themes are reported under the three concept areas that emerged from our thematic analysis: the advantages and challenges ALTs create for learning management, the advantages and challenges ALTs create for student agency and engagement, and the challenges of implementing ALTs. Representative excerpts that summarize the sentiments shared by participants for each theme are included throughout the results [60,67]. Additional excerpts can be found in Table 3.

Adaptive learning technologies, learning management, and deepening student learning

Learning management refers to tasks teachers complete to guide their pedagogy and help students achieve academic outcomes, including instructional planning, grading, analyzing trends in student learning data, differentiating materials to meet students' individual needs, and communicating with students about their learning. A key theme in stakeholder perspectives was that ALTs provide value by supporting teachers in completing learning management tasks efficiently through features such as adaptive learning content and real-time student data. However, teachers emphasized that instead of relying on ALTs for all of

Table 3
Summary of concepts, themes, and example excerpts.

Concept	Theme	Example Excerpts
Learning Management		
Advantage	ALTs provide value by supporting teachers in completing learning management tasks efficiently through features such as adaptive learning content and real-time student data	• "The nice thing is I don't have to be the one to come up with the problems. The tool does. Right? So it kind of relieves me of that a little bit and then allows me to use the classroom time a little more creatively" (T1001) • "[The] use of data to provide more targeted interventions is certainly one of the primary use cases, because… you can know what specific skills students are struggling with in a way that maybe you couldn't have known before" (ET1028)
Challenge	The type, quality, and presentation of data provided by ALTs makes it hard for teachers to utilize the data in their instructional decision-making	• "I just think it's unrealistic to think teachers are checking it every day, which is how a lot of things are advertised. I'm lucky if I can do a detailed check once a week because I have a million other things that I'm collecting data for, giving feedback on, and that's, frankly, still more reliable at this point than what a program's going to do" (T1018) • "Whenever [students are] faced with problems that they don't understand… they're going to put in guesswork. . .you're not getting really good data back because they're just trying to [wing it]…So [the ALT] can adapt, but then it's not adapting accurately" (ET1030)
Student Agency and Engagement		
Advantage	Features of ALTs (i.e., data reports, timely feedback, self-paced instruction, and gamified elements) can create value by enhancing students' awareness of their own learning and supporting students' engagement with the material	• "It's game-like….[and] they're getting rewards. Maybe they get a poster to decorate their digital bedroom. Maybe they get stars in the classroom. It's got to have sort of reward to it, gamified so that students are engaged" (ET1027) • "They have a sense of agency around their work . . . It's, 'These are the areas that I need to work on. This is where I've mastered. This is what I have left.' I think that's a really important part of it too, because if you cut that out, you're completely missing an opportunity to develop student agency" (TS1013)
Challenge	Certain gamification features and user interfaces that are too technical or too childish can lead to student frustration and even disengagement with learning in the tool	• "They wouldn't understand the questions. To them, it felt pointless . . . I think it was a little more childish for them, just the design and the format" (T1018) • "I've seen students on a program and they have some different choices and one of them is a games feature and they just stick on that one . . . I think because it's the most engaging part . . . Even though they're on a program they may not be getting to the meat of what the teacher really wants them to have" (TS1008)
Implementation Challenges		
Challenge	The design of certain ALT features, differing stakeholder expectations around the implementation purpose of ALTs, and a lack of ALT training and integration support for teachers creates a number of barriers for ALT implementation in K-12 classrooms	• "There's a whole range of issues that happen when you stick all your students in front of an adaptive learning tool without really checking and monitoring the back end to see 'Are they progressing? Are things growing well? What are they doing?'" (T1017) • "A concern . . . is just sort of the mindless adoption of things that I see happening in schools and districts where somebody makes a giant decision to use [an ALT] but maybe they don't know anything about it hardly, or the teachers aren't trained correctly" (TS1007)

their instructional needs, they used it to save time on certain learning management tasks and inform their instructional practices to deepen student learning outside of the adaptive platform.

How adaptive learning content supports learning management

Teachers perceived ALTs to be valuable in their day-to-day practice because they were a source of reliably tailored and quality learning content (e.g., in-tool lessons, assessments, worksheets, videos, feedback, hints, and learning resources). This was summarized by an EdTech participant who has prior experience working as a math teacher:

I think one advantage of the program is it provides students with practice on non-routine problem-solving. When I was a teacher, worksheets could help them memorize, but being able to conceptualize the math, that's a lot harder to do. [The software] allows students to see math in different ways beyond the traditional, symbolic representations. Students can demonstrate their learning for me in a way that a [traditional] test couldn't. (TET1021)

Similarly, other Teachers in our study spoke to the value ALTs provide in giving them quick and easy access to learning materials and content for instruction, homework, and assessments. They also found value in the fact that EdTech companies designed the content to align with school curriculum or state standards, so teachers trusted that the content was not just accessible, but standards-aligned as well.

Grading was another aspect of learning management that all three stakeholder groups acknowledged was supported by ALT learning content. "My original motivation is to reduce my grading workload. So, I do use [ALT content] as homework quite a bit and the site grades for me" (TET 1005). Teachers expressed that ALT learning content features enabled them to refocus their time on providing students with individual attention and support instead of completing learning management tasks like creating and grading worksheets.

How adaptive learning data supports learning management

All stakeholders broadly discussed how ALTs make it easy for teachers to collect quick and consistent insights through diagnostic data (i.e., formative data on students' concept mastery) and behavior tracking data (e.g., time students spent engaging with the learning material in the tool). Teachers shared that these insights can support learning management by bringing their attention to "small learning changes that could happen day to day" (TET1025) that they might otherwise miss, and allowing them to easily communicate this growth back with students. Teacher 1006 explained how these insights from the diagnostic data help with their own instructional decision-making:

I would [use] it for pre-assessment data, 'What do my kids know right now?' I would use it for formative data, 'What do my kids know three lessons in?' Then I would use it as post data, whether it's a test or just checking in, 'What do kids know then?'… Formative assessments and formative data inform teachers on how to move forward.

We found agreement among Teachers that the data provided by ALTs served as formative assessments that could be used to guide their instruction.

All stakeholder groups frequently mentioned data reports from the tools' diagnostic content as a valuable feature that could support teachers in creating differentiated learning groups. While Teachers mentioned small group differentiation as an advantageous use of ALT data, this idea was more salient for Teacher Support and EdTech participants, who emphasized it as one of the main advantages of using ALTs:

I think educators are looking to use adaptive learning tools to differentiate in their classroom…Teachers are professionals. We should treat them like professionals and give them the tools, so their time can be more strategic and thoughtful. If you're not trying to meet everyone in the middle, and kids can get what they need, then you can spend your time with smaller groups of students as more of a coach than necessarily that sage on the stage. (ET1028)

EdTech professionals in particular perceived that data reports from adaptive tools save teachers the time and effort of making these groups themselves, and help students get the instructional support they need.

The limitations of adaptive learning data for learning management

Along with these benefits, stakeholders also expressed concerns with the type, quality, and presentation of data in ALT platforms. Teachers suggested that these concerns limited their ability to utilize ALT data for learning management.

Limitations in evaluating students' problem-solving processes. One challenge Teachers and Teacher Support professionals identified was that the type of data reported by ALTs does not always align with teachers' grading approaches. For example, some Teachers reported that some tools only provided information on students' final answers and lacked the capability to evaluate the steps taken by students. This limits Teachers' ability to understand students' problem-solving processes and assess students' conceptual understanding:

The challenges with these platforms are always based on the right answer as opposed to, well, what's the partial answer. Did you actually get the concept, and maybe all you did was make a computational error, which can easily be fixed by slowing down and taking more care when you punch a button. I think these platforms don't really catch that as well. (T1001)

Due to these challenges, Teachers felt that ALT data does not capture the whole picture of student learning. As a result, many Teachers reported struggling to effectively use the provided data to make informed learning management decisions. These concerns about the binary nature of data restricting teachers' learning management were not salient among EdTech participants, suggesting a disconnect between the design and actual implementation of ALTs.

Data reliability concerns. All stakeholders expressed doubts about the reliability of the data provided by ALTs. Teachers shared that ALT data can only be reliable if students are engaging with the tool in an appropriate way. For example, one Teacher expressed worries that the tools' gamification and behavior-tracking features might incentivize speed over thoughtful problem-solving:

I feel like some of the kids are like, 'Oh, I have to go fast because it's measuring me on my speed.' It's like, 'No, no, no. It's measuring you on the accuracy of your answers.' So, you have to slow down so you can give the right answer. (T1001)

EdTech participants echoed this concern, noting that variations in how students engage with the platform and respond to questions could negatively impact the suggested learning trajectory and the resulting learning data received by the teachers:

So especially for kids who are at younger ages… whenever they're faced with problems that they don't understand…they're going to put in guesswork. So when they have guesswork available or present, that's where, when you are adapting content to the learner, you're not getting really good data back because they're just trying to [wing it] …So it can adapt, but then it's not adapting accurately. (ET1030)

Their concern about students' interaction with the tool impacting the quality of their responses, and ultimately the learning data provided to teachers, was heightened during pandemic-related remote learning. Of particular concern were cases where ALTs were being used as a summative assessment tool to make more weighted decisions about a student's learning trajectory outside of the tool for that school year.

Teacher Support participants expressed concerns about students' scores being impacted by varying levels of support from family members while using adaptive assessments at home during remote learning. Additional help can result in misleading data about the students' knowledge due to the adaptive nature of the tools' algorithms:

Well, I always worry about, is it a true measurement of what they know? This year my concern was the kids were taking it at home…And it was during the school day, and it was still proctored by the teacher. However, there could be siblings or grownups there helping the kids answer the questions. So, we had to really think about that, when we looked at the results to see if these results match what we're seeing in the child's other testing areas in classroom work? (TS1010)

Ultimately, participants suggested that these concerns with data quality prevented teachers from utilizing ALT data to make informed instructional decisions. For example, some Teachers felt that any data from ALTs must be triangulated with other sources of learning data:

If their in-class data points and their ALEKS match then, okay, I'm like 'This makes sense.' That's a good validation, but if in-class, they're really struggling but in ALEKS, they're super successful, then there's an investigation there…So, I think that's a challenge. (T1018)

These extra data validation efforts reduce teachers' ability to take advantage of the time-saving learning management benefits that ALTs advertise. To address this concern, Teachers in our study mentioned wanting to have more capabilities to adjust or manipulate the adaptive path of a student and propose alternative content.

Challenges in interpreting data for learning management. Finally, Teachers reported struggling to interpret student data due to the amount of data provided and its presentation. Many Teachers expressed that the amount of data reported by ALTs can be overwhelming and is not always organized in a way that enables them to quickly gather useful insights.

If they can give me a very quick, without a lot of clicks, overview of where students are, that's easy to read quickly, then I can hone in on the details if I need to. The reality is you can give me a million details but… I have over 200 kids now… So, if I can't get to it quickly, then I know it's there and I know it could help my students, but I humanly don't have the time to get to it. (T1018)

Additionally, Teacher Support professionals noted that teachers struggle with consolidating data gathered by ALTs with student data

from other sources (e.g., learning management systems, traditional classroom assessments), which requires additional time, effort, and sometimes IT support.

Challenges with varying data literacy skills among teachers were also discussed by Teacher Support and EdTech participants:

[The tool] has all these data points that you can use. Really great data. But if the teacher is not a teacher who's good at analyzing data, or doesn't know how that can inform further instruction, then there's going to be some stalling in the classroom. (TS1020)

Both stakeholder groups noted how they had often seen or heard of teachers struggling to effectively analyze and draw conclusions from the data provided by the tool. They felt that teachers did not have adequate support or opportunities to build data literacy skills, which made it more difficult for them to capitalize on ALT data reports for learning management.

Adaptive learning technologies and student agency and engagement

Across the interviews, stakeholders reported that features of ALTs (i.e., data reports, timely feedback, self-paced instruction, and gamified elements) can create value by enhancing students' awareness of their own learning and supporting students' engagement with the material. However, stakeholders also cited examples of these same features (e.g., gamification) leading to student frustration and even disengagement with learning in the tool when they are not designed with students' developmental and competence needs in mind.

How adaptive learning data, feedback, and self-pacing promote student agency

Teachers reported that ALTs provide value to students by allowing them to monitor and track their progress over time; this personalized feedback encourages students to become more aware and active participants in their own learning.

I love that they're getting that feedback too. It's not just feedback that I'm getting. They're able to see, 'oh, this is what I'm improving on. This is what I need more work with.' It really is helpful for students to just be more aware of their own learning. (T1003)

Teacher 1006 echoed this perspective and shared the value of students' increased awareness of their learning: "So many kids don't know what they don't know… [Now] they're able to come to me with more specifics about their own learning . . . All you want is kids to advocate for themselves. As a teacher, that is all I want." Teachers described how providing students with information about their own learning empowered students and helped facilitate productive teacher-student interactions.

Additionally, Teachers expressed that ALT self-pacing features enabled students to direct their own learning by revisiting concepts they need more practice on or continuing to build new skills. Teachers in our study said that self-pacing and increased choice in navigating learning content in ALTs builds students' self-directed learning skills, with one Teacher describing how the learning resources within ALTs allowed students to overcome learning roadblocks independently:

They were able to take a lot of ownership over it because when they got stuck . . . if I wasn't available in that moment to help with that concept . . . they could learn to look those things up on their own and start learning that . . . [it promoted] self-motivation and 'I can work through this'. (T1018)

Teachers also mentioned that self-paced learning features of ALTs provide students with some privacy in their work, which can help foster students' comfort with making mistakes or taking learning risks. Teacher Support professionals agreed, stating that students were able to focus on their own learning without being distracted by or comparing themselves to others:

[Students] didn't have to hide [that] they didn't know something… I feel like the feedback features of adaptive systems really helped students see them as nonjudgmental in many ways, and private…The value I think they get is privacy, which I think is important in learning. Learning is so public in a classroom. (TS1007)

Overall, stakeholders emphasized accessible learning data, timely feedback, and self-paced learning features as particularly impactful for building student confidence with directing their own learning.

How adaptive learning user interaction features impact student engagement

Stakeholders reported mixed perspectives about the value of ALTs for engaging students. While Teachers expressed positive views of games and interactive features for fostering students' excitement about learning, EdTech developers and Teacher Support participants mentioned concerns about gamified elements of ALTs overshadowing the actual learning content.

Some gamified features help students have fun while learning. All stakeholder groups described features of ALTs that foster student excitement and engagement as valuable. Teachers particularly noted the games and interactive animations built into ALTs, which they reported helped motivate students and allow them to have fun while moving through the learning content. Teachers were especially appreciative of these features during remote learning, when it was challenging to engage students or provide enjoyable learning experiences: "There's a live option which was super useful during remote learning in the spring where they were each able to be on a phone or a surface or whatever their laptop computer situation is. Then they can play a live game which was really fun" (T1003). The gamification of ALTs helped Teachers replicate the engagement and participation of in-person classrooms.

Teacher Support and EdTech participants also mentioned the benefits of ALT features for student engagement. EdTech developers highlighted particular design features, like interactive cartoon characters, that contribute to high student engagement: "The avatars that pop up on screen look like teenagers and they talk to you, and you can choose which one relates to you best. So, there are features that immediately engage kids, and I'm talking even the middle schoolers" (ET1027). EdTech developers also described the specific elements of the technology that help gamify the learning experience for students, such as rewards and encouraging animations. Although the stakeholder groups each emphasized different features of ALTs, all groups agreed that these features allow students to have fun while learning.

The limitations of gamification and content presentation for learner engagement. However, stakeholders also described challenges balancing student excitement and meaningful engagement in learning. Although teachers described the benefits of built-in games, some Teacher Support and EdTech professionals felt concerned about how some tools used rewards (e.g., coins) to incentivize students instead of providing meaningful feedback: "I think another area of concern is…the use of avatars…if students get a certain amount, they can buy a hat or something from their store. Students are just playing a video game at that point, and not learning" (ET1021). Teacher Support and EdTech participants expressed that although some of these features, in moderation, can build student engagement in ways that support their learning, an excessive number of gamified tasks may distract from students' primary learning goals.

During interviews, some Teachers reported on students' frustration with the user interface features and in-lesson graphics of ALTs. Specifically, Teachers reported that some content was presented in an overly-academic way, while other content was presented too simplistically. As one Teacher noted, "If a student was already intimidated by all the symbols and math language, then ALEKS is definitely not going to help them because it's even worse…it just kind of intimidates them more" (T1001). On the other hand, some Teachers reported that other ALTs presented content in a childish way, leading to disengagement with learning. "I think it was a little more childish for them, just the design and the format" (T1018). These experiences suggest that misalignment

between ALTs' designs and students' comprehension levels can contribute to frustration and disengagement with learning.

Adaptive learning technologies and implementation challenges

The design of certain ALT features, differing stakeholder expectations around the implementation purpose of ALTs, and a lack of ALT training and integration support for teachers creates a number of barriers for ALT implementation in K-12 classrooms. Teacher perspectives highlighted a gap in stakeholders' expectations for the tool and the reality of its implementation. Teachers discussed how EdTech companies and school administrators often present ALTs as a comprehensive solution for managing instruction and student learning. However, as one Teacher explained, these hopes for the tool do not match up with teachers' experiences in the classroom: "A lot of times, especially in my previous experience, they're sold to a district as 'This is a one-stop box. This will fix all your problems,' but it's not something that fixes everything" (T1017). Teachers emphasized that although they did experience some benefits from using ALTs, various design and implementation issues, such as those mentioned in the sections above, prevented the technology from being the marketed solution to their teaching and learning challenges.

Teachers also discussed the implications of this disconnect between expectations for ALTs and teachers' real experiences with them. For example, one EdTech participant with teaching experience explained that issues arise when the use of ALTs in classrooms is mandated without teacher buy-in: "With Imagine Learning, my district pretty much told me [as a teacher] not to be involved…That's my apprehension, is teachers aren't involved enough to know what's going on in the app and what students are actually learning" (TET1025). Overall, Teachers described experiencing challenges implementing ALTs when they had differing expectations for the use and purpose of ALTs compared to administrators.

In addition to Teachers' concerns, all stakeholder groups mentioned experiences where teachers did not use the tool enough for students to realize the benefits. EdTech professionals spoke to the need for ALTs to be implemented with fidelity— meaning the tool is used in the classroom for the appropriate amount of time, for the appropriate kinds of instruction, and with teachers monitoring student progress and using the data to inform their pedagogy. For example, one EdTech professional discussed how, when tools are mandated without teacher buy-in, teachers do not always use the tool with fidelity:

They would say, 'This district doesn't have much fidelity to the instructional model.' …There are times where teachers just really aren't interested in using that… And my concern is the kids are missing out on this and you're still paying for it… especially in the struggling district or area where people hadn't come around to the idea that this might be worth their time and worth it for their students as well. (ET1019)

Many stakeholders were concerned that teachers do not use ALTs with fidelity, particularly in classrooms where teachers did not see the value of or were resistant to implementing these tools. Overall, all stakeholder groups mentioned significant concerns about implementation contexts where the expectations of EdTech developers and school administrators do not align with teachers' actual classroom needs. EdTech developer 1019 stated that the result of these administrative disconnects is that "kids are missing out on [the benefits of ALTs]."

Discussion

Education research journals have seen an increase in the number of articles focused on the design, implementation, and evaluation of ALTs for effective learning [68]. However, much of this research has focused on students in higher education [14,26,27] with a small amount of research examining K-12 settings relative to the popularity of ALTs in those settings. Even more rare are comprehensive studies of the advantages and challenges of these technologies from the perspective of the education stakeholders involved in both the design and implementation of these tools [12].

This study aimed to address this gap by conducting interviews with Teachers, Teacher Support staff, and Education Technology professionals to develop a comprehensive understanding of their perceptions of the value they associate with the use of ALTs in K-12 education. Thematic analysis of stakeholder perspectives surfaced advantage and challenge themes which were categorized under three overarching concepts: learning management, student agency and engagement, and implementation challenges. This categorization of themes under concepts allowed for a thorough cross-comparison of stakeholder perspectives on the advantages and challenges of ALTs.

In this section, we present our findings in conversation with current ALT literature and offer recommendations (See Table 4) for how practitioners in education and EdTech fields can further improve and integrate these tools in K-12 classrooms.

Multi-faceted approach to improving teachers' learning management with ALTs

Stakeholders' perspectives were consistent with other findings in the literature that cite real-time student learning data and quality tailored content as key features of ALTs that support teachers' learning management [1,31,69]. However, while other stakeholders cited efficiency in learning management as the value-add of ALTs, Teachers noted that by allowing for more efficient learning management, ALTs truly provide value by giving them more time to focus on developing approaches for deepening student learning outside of the platform. These findings build on existing theory [15] and related research [1,9,28,31] in recognizing that stakeholders both inside and outside of the classroom think expansively and consider intermediate factors besides students' academic outcomes when assessing the value that technologies bring to classrooms.

Teachers in our study also noted that some ALT learning management efficiencies are undermined by concerns around how the tools grade, collect data on student learning, and present learning data back to teachers. To address these learning management concerns, and other concerns presented in our results, we use this section to discuss design and implementation model recommendations for stakeholder consideration. For example, to address these learning management concerns, developers can modify ALT learning content and data features in the following ways. Developers can create content that enables students to demonstrate the process behind their responses and makes this process visible to teachers, which can build teachers' trust in the system's assessment of students' conceptual understanding. Another way is to contextualize student scores using metadata (i.e., student response time, guessing behaviors) to help address teachers' ALT data reliability concerns [70]. Further, Teacher stakeholders also expressed frustration that they are unable to intervene when they observe a mismatch between the student's proficiency and the content suggested by the technology. Developers could consider giving teachers more options to manage the trajectory of students in the tool. Finally, developers can provide in-tool training to help teachers interpret student data and prepare them to make informed instructional decisions.

Along with changes to the design of the tools themselves, our findings also suggest a need for increased professional development opportunities for teachers. Stakeholders in our study echoed the call for more accessible and relevant teacher development opportunities, specifically previous suggestions to create targeted training around understanding and interpreting data dashboards in ALTs [1,31]. Teacher educators, technology implementation specialists, school administrators, and EdTech coaches should all consider crafting professional development opportunities that better prepare and support teachers to interpret the data provided by these tools to inform their instruction.

Table 4
Findings and recommendations.

Finding	Recommendations for Stakeholders
Learning Management	
ALTs' learning content helps teachers with learning management tasks. This saves time for teachers and students, allowing them to use classroom time for more engaging activities.	**All Stakeholders** Consider the benefits of ALTs not just for student learning but also for managing teachers' administrative tasks
Although ALTs' data features have potential to provide teachers with insight into students' learning progress and help them make informed instructional decisions, challenges with ALTs' grading methods and external factors that impact student responses and data quality limit the benefits for teachers . Additionally, some teachers need data literacy support to help them interpret data from ALTs.	**Teachers** Continue to validate data from ALTs with other diagnostic data sources on students' learning **EdTech Developers** Design grading algorithms to better align with teachers' own grading approaches (e.g., giving credit for partial answers) Enable teachers to adjust, manage, interrupt, or otherwise manipulate the learning trajectory of students in ALTs Tailor data visualizations to be accessible for teachers' varying data literacy levels Provide in-tool trainings to help teachers' interpret student data displayed by the platform Help teachers assess the reliability of student data (e.g., providing a reliability score based on student response metadata) **Teacher Support Professionals** Provide teachers with professional development and resources to increase their data literacy Support teachers in understanding how to best use ALTs for making classroom decisions (e.g., creating instructional groups)
Student Agency and Engagement	
ALTs' data and self-pacing features help promote students' self-awareness and self-directed learning skills.	**Teachers** Support students in understanding and interpreting ALTs' learning pathways, data reports, and scores
ALTs provide students with a more private medium to learn concepts, practice, and receive feedback.	**Teachers** Find ways to utilize ALT student data insights to provide students with discreet feedback
ALTs' user interface and games allow students to have fun while learning. Teachers especially found engaging elements and gamified features useful during remote learning .	**Teachers** Incorporate ALTs into remote or hybrid learning settings to support student engagement
ALTs that overly rely on gamification, and those with less user-friendly interfaces, can become distractions from learning.	**EdTech Developers** Limit gamification features to those that will actively support students' engagement in learning content Ensure that activities and user interfaces are appropriately designed for the intended age range
Implementation	
ALTs are often adopted by schools or districts without support or input from teachers. The lack of teacher buy-in can lead to implementation choices that don't maximize learning benefits for students (e.g., using the tool too much or too little).	**EdTech Developers** Provide specific coaching and resources for teachers around beneficial implementation models Teacher Support Professionals Ensure that ALTs are aligned with teachers' goals and abilities before making school- or district-wide technology decisions

Design to support student engagement and agency in learning

Stakeholders in our study echoed findings in the literature that suggest that accessible learning data, timely feedback, and self-paced learning features of ALTs can create value by enhancing students' awareness of their own learning and engagement with learning material [30]. In particular, stakeholders in our study suggested that self-paced learning features of ALTs enabled students to focus on their own learning without being distracted by or comparing themselves to others. Relatedly, teachers can consider utilizing ALT student data insights to provide students with discreet learning feedback outside of the tool as well.

Stakeholders also brought up particular issues that limit these benefits. Specifically, design and interactive elements that are too childish, pedantic, or improperly gamified run the risk of disengaging learners and prompting a focus on speed and rewards over gaining conceptual understanding of the material. Therefore, developers should consider limiting gamification features to those that will actively support students' engagement in learning content, and ensure that activities and user interfaces are appropriately designed for the intended student age range.

Similarly, the fact that many ALTs do not allow students to demonstrate the process behind their response (e.g., check for right or wrong responses) can sometimes prompt learner disengagement and guessing behaviors in students frustrated by small mistakes. Stakeholders in our study echoed concerns from other practitioners (e.g., [71]) that instances of low student engagement lead to inappropriate learning tracks in the adaptive system, minimizing the technology's supposed benefits. As stated above, designing content so that students can demonstrate their response process and enabling teachers to modify students' learning content in ALTs can help address these concerns.

Design human-centered learning systems that facilitate meaningful learning experiences

Our findings also suggest that better alignment is needed between teachers and other EdTech and education stakeholders around the role and value of ALTs. Stakeholders described how disconnects between the design of ALTs, their adoption by schools and districts, and their actual use in classrooms lead to implementation models where students were missing out on the purported benefits of having ALTs as a classroom learning tool.

These disconnects may arise from a gap in stakeholders' expectations for ALTs. Some stakeholders in the education and EdTech fields have high expectations for the potential benefits of ALTs for teachers and students, and even consider them a one-stop shop for classroom teaching

[72]. However, our findings suggest that teachers who have experience with ALTs tend to have more moderate expectations for their usefulness, viewing ALTs as helpful but limited supplements to their own teaching practice (see also [4]). Recognizing these discrepancies and listening to teachers' perspective would help other stakeholders such as EdTech developers and teacher support staff focus their efforts on maximizing the features and implementation models that work best in the classroom instead of trying to meet teachers' every need with one tool.

Limitations and future directions

The study had limitations that should be noted. Firstly, this study used a definition of ALTs for the purpose of selecting participants, but acknowledged the need for an established definition shared by researchers and practitioners. Without a shared definition, it can be challenging to reliably explore the value of ALTs across diverse stakeholders. The need for an operational definition of adaptivity also meant that this study generalized findings across a set of ALTs with varying features, and across stakeholders who have seen these tools implemented in a variety of K-12 settings. This limits the application of the recommendations offered. Future research could develop more robust and specific findings by building on the work done in this study to identify features that are unique to ALTs, and enable its adaptive functionalities, and investigate the value these particular functionalities create for students and teachers.

Secondly, the study relied on the perspectives of key professional stakeholders involved in the design and implementation of these tools to infer the advantages and challenges experienced by students. This may have resulted in a limited understanding of students' experiences with ALTs. Further research could explore students' perspectives on the value of ALTs for learning and compare student perspectives to those shared by stakeholders in this study.

Finally, it is worth noting that our Teacher sample was largely from private schools, which could limit the generalizability of the findings to other implementation contexts. Further research is needed to explore the perspectives of teachers from a wider range of educational settings and to understand how ALTs are perceived and used by teachers in other contexts.

Conclusion

The use of ALTs in K-12 classrooms has gained attention in educational research journals, but there is a need for comprehensive examination of the advantages and challenges these technologies facilitate for teaching and learning from the perspective of education stakeholders involved in their design and implementation. This study aimed to address this gap by using the Teacher Response Model as a guide for exploring stakeholder perspectives on the value of ALTs. Thematic analysis of stakeholders' perspectives found that their evaluation of advantages and challenges of ALTs focused on three main concepts: learning management, student agency and engagement, and classroom implementation. Our findings suggest that while teachers do find value in using these tools to support their learning management tasks and students' engagement with learning, they also struggle to effectively utilize these tools due to some challenging design features and implementation approaches. We also found that teachers in our study did not view ALTs as a one-stop-shop solution to meet the individual needs of students. Our approach to generating these findings was enriched by bringing together the perspectives of stakeholders involved in the full lifecycle of the development and use of these technologies, and this work generates recommendations that can ultimately advance the next generation of these tools and the ways they can be used to better serve the needs of teachers and students.

Declaration of generative AI and AI assisted technologies in the writing process

During the final revisions of this manuscript the first author used OpenAI ChatGPT-3 in order to improve readability of a few individual sentences and adjust the language of certain headings throughout the paper. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Riddhi A. Divanji: Conceptualization, Methodology, Resources, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Project administration. **Samantha Bindman:** Supervision, Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Allie Tung:** Resources, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Katharine Chen:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Lisa Castaneda:** Conceptualization, Writing – review & editing. **Mike Scanlon:** Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.caeo.2023.100157.

Appendix A

Pre-Interview Survey Questions

1. Please enter your ID number provided by foundry10.
2. Please select your profession (check all that apply):
   a. Teacher
   b. Teacher educator
   c. Tech coach
   d. EdTech developer
   e. School administrator
   f. Other (please specify)

3. What adaptive learning tools have you used (e.g., Lexia Learning, Dreambox Learning, ALEKS)?
4. [if 'Teacher' is not selected in question 2] What features does a tool need to have to be considered an adaptive learning tool? Please select all that apply.
   a. Data-driven system that collects real-time data or collects data on more than one occasion
   b. Does more than just check for the accuracy of an answer
   c. Adjusts instruction based on each learner's interactions and performance
   d. Anticipates the learner's needs and presents relevant learning content
   e. Other (please specify)
5. [if 'Teacher' is selected in question 2] What features does the adaptive learning tool you use have?
   a. Collects real-time data or collects data on more than one occasion
   b. Does more than just check for the accuracy of an answer
   c. Adjusts instruction based on each learner's interactions and performance
   d. Anticipates the learner's needs and presents relevant learning content
   e. Other (please specify)
6. Are there features of adaptive learning tools that are particularly beneficial for student learning? If so, what are those features?
7. Are there features of adaptive learning tools that are particularly beneficial for educators? If so, what are those features?
8. Are there features of adaptive learning tools that concern you? If so, what are those features?
9. What kinds of student data beyond learning performance does the tool that you use collect and allow you to see? Please select all that apply.
   a. Student identification numbers
   b. Dates of birth
   c. Race
   d. Socioeconomic status
   e. Standardized test scores
   f. Attendance records
   g. Disciplinary records
   h. Health records
   i. Learning disabilities
   j. Homework completion
   k. Inter and intrapersonal skills
   l. Affective dispositions
   m. Student goals and interests
   n. Other (please specify)
   o. Do you have experience working with adaptive learning tools during remote learning?
   p. Yes
   q. No
   r. Other (please specify)

Appendix B

Interview Questions
Introduction

1. Can you describe what you do for work?
2. Can you describe your experience with adaptive learning technologies?

Definition

1. Can you define what adaptive learning means to you?
2. Can you provide examples of adaptive learning tools you know of or have used?

Design

1. What features does a tool need to have to be considered an adaptive learning tool?
   a. Data-driven system that collects real-time data or collects data on more than one occasion
   b. Does more than just check for the accuracy of an answer
   c. Adjusts instruction based on each learner's interactions and performance
   d. Anticipates the learner's needs and presents relevant learning content
2. Are there features of adaptive learning tools that are particularly beneficial for student learning? If so, what are those features?
3. Are there adaptive learning tool features that are particularly beneficial for educators? If so, what are those features?
4. Are there features of adaptive learning tools that concern you? If so, what are those features?
5. What kinds of student data beyond learning performance does the tool collect and allow you to see?
   a. Student identification numbers
   b. Dates of birth
   c. Race
   d. Socioeconomic status

e. Standardized test scores
f. Attendance records
g. Disciplinary records
h. Health records
i. Learning disabilities
j. Homework completion
k. Inter and intrapersonal skills
l. Affective dispositions
m. Student goals and interests

Necessity & Application

1. Why are you using this tool in your classroom? Or, for what purposes can educators adopt adaptive learning tools?
   a. Instruction
   b. Remediation
2. How did you find out about the adaptive learning tools?
3. Do you see a gap in how these tools are marketed to teachers or districts and how they are actually used in the classroom?
4. Do you have any apprehension about the application or classroom implementation of adaptive learning technologies?
5. Were there any implementation challenges? If so, what were these challenges?

Student Value

1. What do you think students' general perceptions are of the adaptive learning tool you use?
2. What type of feedback have students given you regarding their use of these tools?
   a. What, if any, emotions have you seen students express when using adaptive learning?
3. Do you believe that students understand that the system is adapting to their learning? What kind of indicators illustrate this?
4. How has the use of this tool impacted student learning outcomes?
5. Has the tool impacted the way students interact with one another in the class?
6. Who has access to student data collected by these tools (e.g., outside vendors, parents, students)?

Pedagogy

1. What are ways your teaching has changed as a result of using adaptive learning?
   a. Has it allowed for more focused support? If so, how?
   b. Has it allowed for more data on the effectiveness of lesson plans? If so, how?
   c. Has it allowed changes to assessment practices? If so, how?
   d. Has it allowed for more equity in teaching? If so, how?
2. What kind of data does the platform give you regarding student learning?
   a. How do you use the data provided?
3. Has the tool impacted the distribution of instructional time, one-on-one time, and homework time you have?
4. Has the tool impacted the way students interact with you in the class?

COVID and Remote Learning

1. COVID-19 has led to an increase in school closures and distance learning. What role, if any, have you seen adaptive learning technologies play in student learning during this crisis?
2. Have you seen any changes in demand for adaptive and personalized learning technologies since the COVID-19 crisis?
   a. How are you supporting teachers and staff in their use of these technologies? Did anything about teacher use of the technologies during the crisis surprise you?
   b. How are you supporting students and parents in their use of these technologies?
3. What challenges have students faced in using adaptive and personalized learning technologies during this crisis?
4. What challenges have parents experienced as they help their children learn through these technologies?
5. Have you received any interesting student/parent feedback as a result of the use of personalized or adaptive learning during this time?

Appendix C

Codebook

Code	Definition
FEATURE (Code Category)	
Data Feature (Parent Code)	Use for excerpts referring to the different data points the tool collects, utilizes, and presents to the different users
Data presentation	The tool produces reports or dashboards showing student-level or classroom-level performance
Diagnostic	The tool provides a snapshot or ongoing assessment of where students are at in their understanding of different topics
Prediction	The tool provides data making predictions about students' future learning performance/outcomes in that school year or throughout their K-12 journey
Behavior tracking	The tool collects data on how students are interacting with the tool and has various features to track/flag certain behaviors (e.g., flagging students who click through the tool too quickly, cheating, tracking how long students have spent working with the tool)
Learning Content Feature (Parent Code)	Use for excerpts referring to the type (e.g., worksheets, quizzes), quality, or presentation of the tool's learning content, including learning problems, feedback/hints, and learning instructions
Assessments	The tool provides assessments (baseline and/or formative) of students' learning, concept mastery, or understanding of a topic
Curriculum/standards- aligned	The learning content is aligned to some grade level standards, curriculum, or standardized assessments. (e.g., the tool presents students with information based on the grade level they are actually in or grade level they are performing at)
Feedback, hints, and resources	The tool helps students answer a topic/question they are struggling with by providing in-the-moment feedback, suggestions, or hints or by directing them to additional learning resources (e.g., textbook, videos)
Decomposition	The tool breaks topics down into parts and works the student through step-by-step
Adaptive instruction	Learning content is based on the student's performance data (e.g., baseline or formative assessment data). This includes branching, adjusting the topic, difficulty level, or format (e.g., word problem, multiple choice) of the learning content based on data
User Interaction Feature (Parent Code)	Use for excerpts referring to the design features of the website and learning content and how that impacts users' interactions with the tool
Engagement	The format, design, display, and/or mechanics of the tool's content plays a role in students' interest, ability, or motivation to focus/engage with the learning content (specifically) or learning (more generally)
Gamification	The tool uses game mechanics (e.g., rewards, points, levels, goals) and/or cartoon characters to appeal to students and/or to adapt sequencing
Self-paced	The student can approach topics at their own pace. Students can move through content asynchronously
Remote learning access	The tool is accessible inside and outside of the classroom or class time
User interface	The design characteristics of the website itself that determine the accessibility and usability of the tool (e.g., the look and feel of the website, the reports and data visualizations, navigating the fields and buttons on the website)
IMPLEMENTATION (Code Category)	
Data Implementation (Parent Code)	Use for excerpts referring to the way users and/or designers claim users utilize different data points presented by the tool
Identify learning gaps	Using the data provided by the tool, the teachers can identify students in need of additional support or remediation, and identify larger classroom-level learning gaps
Differentiated instruction	The teacher uses the data to provide learners with individualized learning paths. The individualized path can involve using the data to inform how students engage with the tool (i.e., the teacher has the agency to select specific topics for the student to cover within the tool), or to inform how the students learn in the classroom (e.g., small instructional groups based on performance in the system)
Track	Using data provided by the tool to track students over time (e.g., "diagnostic growth", tracking student pre/post assessment change)
Communicating with families	Data or reports by the tool are shared with families
Communicating with students	Teachers use data or reports by the tool to talk to their students about their learning
Learning Content Implementation (Parent Code)	Use for excerpts referring to how the tool's learning content is used in classrooms
Primary instruction	The tool is used to introduce students to new concepts that they haven't been taught before (e.g., a student uses the tool to progress beyond grade level and be introduced to more advanced topics)
Skill building	The tool is used as a supplement to help students practice concepts they have already been taught in order to gain mastery or proficiency
Remediation instruction	The tool is used to re-teach concepts to students who are behind (e.g., helping students reach grade level, closing students' learning gaps)
User Interaction Implementation (Parent Code)	Use for excerpts referring to how the features/design of the website and/or learning content impacts implementation of the tool
Individual work time	Students spend time working on computers by themselves
Collaboration	Students use the tool to work together
Time limit	Tool is used for a set amount of time
VALUE (Code Category)	
Advantage (Parent Code)	A benefit of using the tool that is actually experienced or a hypothetical advantage
Student advantage	Positively impacts student learning or student engagement with content, peers, or teachers
Teacher advantage	Positively impacts teachers' ability to support students, their classroom management, or their own instruction
Challenge/Concern (Parent Code)	A challenge of using the tool that is actually experienced or hypothetical challenges
Student challenge/concern	Negatively impacts student learning or student engagement with content, peers, or teachers
Teacher challenge/concern	Negatively impacts teachers' ability to support students, their classroom management, or their own instruction

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