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Applying the science of learning to teacher professional development and back again: Lessons from 3 country contexts

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ABSTRACT

Background: Evidence from the science of learning suggests that playful learning pedagogical approaches exist along a spectrum and can support student learning. Leveraging active engagement, iterative, socially interactive, meaningful, and joyful interactions with content also supports student learning. Translating these concepts into guidance and support for teachers is lacking.
Method: We introduce a tool designed to support teachers in implementing across the facilitation spectrum and leverage the characteristics that help children learn. Across three international contexts, we engaged with 1207 teachers and the tool was used 4911 times.
Results: Student age, the intended learning goal, and context influenced teachers' use of the tool, suggesting that contextualization is critical, even when basing programs on evidence-based, universal principles given by the science of learning.
Conclusion: Science of learning research must be effectively translated but we must use evidence from teachers and real-life classrooms to inform those studying the science of learning.

1. Introduction

Over the past few decades, researchers from across a variety of disciplines, including linguistics, machine learning, education, psychology, cognitive science, and others, have made tremendous progress in studying how learning occurs. Together, these insights have formed a new, interdisciplinary field coined the science of learning and this term was recently reviewed and operationalized in the pages of this journal [1]. This approach has led to a more comprehensive understanding of learning across the lifespan, but particularly during childhood [2–6].

Despite these insights, the translation and application of these findings to support children in everyday contexts remains lacking. However, while scientific insights have continued to accumulate, the challenges for education across the globe have remained. For example, according to the Sustainable Development Goal (SDG) 4 Scorecard, at least one in three counties showed backsliding, both in terms of teacher training at the pre-primary and primary levels as well as in learning proficiency [7]. Further, learning loss due to COVID-19 has resulted in children being behind, by eight months on average, of where they would have been without the pandemic and the impacts are only increasing inequalities [8].

Recent work from the science of learning has coalesced around a number of principles and pedagogical approaches that are effective for learning, but much work remains to be done in supporting teachers in implementing those approaches in the classroom. This paper explores these approaches and then investigates how teachers of children ages

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3–12 years across three country contexts (Bangladesh, Uganda, and Colombia) used a formative assessment tool designed to support their implementation of playful learning approaches in the classroom. This study helps us better understand how to support teachers in facilitation in their classrooms, taking a multi-context approach to look for similarities and differences across ages, learning goal differences, and country contexts. Finally, we explore how lessons from how teachers used the tool can be used to inspire research in the science of learning, arguing for a cyclical, rather than unidirectional, relationship between the science of learning and teacher professional development.

1.1. Playful pedagogical approaches

For decades, a false dichotomy between play and learning has done a disservice to the field of education and the implementation of pedagogy in the classroom [9–12]. This dichotomy is likely rooted in a narrow conceptualization of play. However, evidence from the science of learning [13,14] and teacher practice within the field of education [15] have suggested that play and playful practices exist along a spectrum, or continuum, that captures the differing roles of the teacher and the student. When thinking about the spectrum of play, three key elements emerge that determine where an activity falls along the spectrum: 1) the degree of children's agency, marked by choice and the ability to direct the experience, 2) the level of adult facilitation and 3) if there is a learning goal [16,17].

Free play is sometimes heralded as the "gold standard" of play, and in free play, there is no specified learning goal, nor adult scaffolding or control [18]. In free play, children maintain agency, decision-making, and direction. Children are free to play, or not play, with whatever materials are available. Guided play and games [11,12,19,20] still maintain children's agency, but adults scaffold and support the play and there is an intended learning outcome. In teacher-directed play [15], children maintain limited agency, but adults have a heavier hand in both directing and supporting the play context. Direct instruction is outside the scope of the play spectrum. It eliminates child agency and aligns with the idea that children must be taught new information directly.

In a meta-analysis, Alfieri [21] analyzed the literature to compare learning across free play, assisted discovery methods (equivalent to guided play/games), and direct instruction. Alfieri found, perhaps unsurprisingly, free play was least likely to help support learning goals. However, Alfieri also found that guided play methods outperformed direct instruction methods for obtaining a variety of outcomes. Since then, additional work has extolled the benefits of guided play/games in supporting learning outcomes across domains - including mathematics [22], spatial thinking [23], literacy [24–28] and creativity [29]. But, research also suggests that there are some contexts in which direct instruction is better suited to support learning, especially of scientific thinking content [30].

Importantly, much of the research exploring the impacts of playful pedagogical practices are based in Western contexts, but there is growing interest in and program implementation supporting playful learning globally with some suggesting that playful practices have the potential to help leapfrog education [31]. A recent report highlights this potential and suggests that there are three "levers" that are needed to align educational policy around playful learning with implementation: namely shifting societal attitudes, through educational policy and implementation, and city design with a focus on intergenerational spaces centering children's learning [32]. However, we would argue that a fourth lever is also critical, direct partnership, training, and support of playful learning practices through teacher professional development.

1.2. Characteristics that lead to learning

Hirsh-Pasek, Zosh, and colleagues [3] reviewed the science of learning literature and argued that the literature supports the idea that there are pillars of learning - or characteristics that maximize learning. They suggested that when humans are **active** (minds-on), **engaged** (not distracted), learning **meaningful** content (connects to the larger world, their previous understanding, and potentially their passion), and **socially interactive**, learning is maximized. A few years later, Zosh and colleagues [14,16] expanded this model to specifically examine how play naturally leverages these characteristics and also supports learning via **iterative** (e.g., testing hypothesis and updating understanding) thinking in a **joyful** (including sustained or momentary positive affect and/or surprise) context.

Those viewing play as a spectrum argue that playful learning practices (including free play, guided play, games, and teacher-directed play) naturally leverage the characteristics that lead to learning [14,16]. Indeed, a 2020 policy report explores the potential of playful learning as an approach to promote 21st-century learning in schools (and beyond) using these characteristics as a foundation [33]. In other words, the authors use these characteristics of learning to ensure that "… we are teaching in ways most compatible with the ways human brains learn." [p. 12]. Implementing these practices in the classroom across varying contexts, ages, and in the service of different learning goals, does, however, create challenges.

There is ongoing work exploring how these characteristics and playful pedagogies can be a path for much-needed educational reform in the United States of America [33], but it is also important to better understand how these characteristics of learning, based in the science of learning and designed to be universal in benefits, are instantiated across global contexts.

1.3. Goals of learning

While concrete, content-based learning outcomes are typically the focus of academic testing especially in Western contexts, much work has been done recently to expand the conceptualization of what children need to learn. Children's education is typically responsible for supporting learning in areas such as literacy and mathematics, but studies grounded in the science of learning have focused on learning skills, such as executive function, as well as 21st-century skills (Fadel, 2008), for example, Golinkoff and Hirsh-Pasek's [34] 6 C's - content, collaboration, creative innovation, communication, critical thinking, and confidence.

This expansion of thinking about what children need to learn is certainly important, but it still tends to be focused on Western contexts and recent work suggests that researchers need to be more cautious about using a cultural lens when examining outcomes [35,36]. OECD [37] expands the conceptualization of learning outcomes to include knowledge (e.g., academic proficiencies such as literacy and numeracy and interdisciplinary knowledge such as science, health and nutrition, humanities, arts and culture, digital literacy), skills (e.g., 21st-century skills like communication, collaboration, creativity, critical thinking, leadership, problem-solving, and entrepreneurship), as well as attitudes and values (e.g., personal, local, societal, and global). Similarly, Fadel [38] proposed a 4-dimensional framework for education that includes character (e.g., mindfulness, curiosity, courage, resilience, ethics, and leadership), skills (creativity, critical thinking, communication, and collaboration), knowledge (interdisciplinary, traditional knowledge [e.g., math], modern knowledge [e.g., entrepreneurship], themes [e.g., global literacy]), and meta-learning [metacognition and growth mindset]).

Beyond context-specific differences, there may also be differences in intended learning outcomes based on the ages of the children in a classroom context. Teachers must also determine how to create lessons that support learning amongst their students. To date, we are not aware of research comparing intended learning goals across ages and country contexts while also investigating the pedagogies used to support those goals.

1.4. Challenges in implementation and assessment

While resources, training, and situations may differ across contexts, it is universal that teachers are in the position to select the learning goals that are important to them, determine how to teach the students in their classrooms, and evaluate how well they meet their curricular goals. The larger question becomes how can we, as a field, support teachers' use of evidence provided by the science of learning in their classrooms? How can we create tools or conduct training in ways that are based in science but are not so prescriptive that they can only be applied in limited contexts?

There are a number of challenges in both implementation and assessment of programs designed to help support teachers. In terms of implementation, simply sharing information about the spectrum of playful practices and descriptions of the characteristics that support learning is likely not enough to change teacher practice. Indeed, there are a number of review articles exploring the various challenges facing professional development of teachers [39–41] with Hill and colleagues [39] stressing that more research is needed at earlier stages of professional development design rather than simply evaluating a program's efficacy at the end. Sancar and colleagues [41] highlight that professional development needs to be attentive to a variety of factors including context, comprehensiveness, support and control, and others.

Danniels and colleagues [42] outline two main types of assessment that are commonly used in research and policy. Summative assessment/assessment of learning is based on outcomes (e.g., student test scores, outcomes at the end of a project) whereas formative assessment/assessment for learning focuses on ongoing assessment that occurs throughout the project that provides continuous feedback and opportunities for reflection and changes throughout the implementation of a project. Formative assessment has been used in teacher professional development across contexts and ages [42–44]. This suggests that one potential pathway for supporting teacher practice that is based in the science of learning literature is through the use of formative assessment tools.

Beyond determining the type of assessments that may support teacher practice, another consideration comes from the fundamental challenge of bridging theory and practice. In other words, the description of active, engaged, meaningful, iterative, joyful, and socially interactive states is just one piece of the puzzle. The larger challenge is determining how one could even assess the presence of these characteristics in their classrooms. Notably, these are internal characteristics, thus leading to additional issues of measurement. The literature supports the idea that leveraging these characteristics supports learning [14,16], but it is a challenge to determine how well each one of these characteristics is engaged for individual learners. Yet another challenge is that each of these characteristics is not a present/absent concrete state. Instead, their engagement is dynamic within a given context, changes over the course of a single lesson, and the characteristics interact with one another. This presents a challenge for both implementation and measurement.

Similarly, play types exist along a continuum where there are stronger and weaker ways of facilitating free play, guided play, and teacher-directed play. While this creates a challenge for measurement, it also provides a benefit for implementation. By viewing these facilitation styles and characteristics as continuums of their own, teachers are afforded the opportunity to facilitate in a variety of ways– for example, ways that are suitable for their context, the lesson at hand, the children's age and educational needs, and their own strengths. Recently, Zosh and colleagues [45] suggest a framework that characterizes teacher practices that are likely to engage each of the characteristics to varying degrees within the classroom. For example, seating children in groups is a positive step towards promoting social interaction, but providing multiple opportunities for children to work together and with peers of varying abilities is even more likely to promote high quality social interaction. Relatedly, there are different ways of facilitating each type of play, which provides a number of opportunities for teachers to make small changes to maximize learning through play even within a single type of play (e.g., within guided play, increasing how children engage with the characteristics). Similarly, as reviewed by Parker and Thomsen [46], the term "play" is often not used when discussing pedagogical approaches after the age of about 8 years old. Instead, they review evidence suggesting that other more typical "pedagogical" terms such as active learning, cooperative and collaborative learning, experiential learning, guided discovery learning, inquiry-based learning, problem-based learning, and Montessori education that are related to learning through play and, to varying degrees, align with learning through play approaches and with the five characteristics of playful learning discussed here.

Finally, research in the science of learning has primarily come from Western contexts and, while implementation of these practices is starting to have global reach [31], it is critical to understand how direct practitioners - the teachers - approach these core principles of pedagogy. In other words, how do educators approach selecting learning goals, supporting the characteristics of learning in their classroom experiences, and facilitating playful pedagogies across ages - and how do these factors interact with an eye towards uncovering universals and differences across contexts?

Taken together, the larger question is how can we support teacher practice in ways that are grounded in the science of learning literature but that are actionable and observable for teachers across ages and contexts? And, more broadly, how can we create a feedback loop such that these types of professional development efforts can inform researchers from the science of learning to ask better questions that are rooted in practice (see Fig. 1)?

1.5. The current study

The purpose of the current study was to investigate teachers' approaches to supporting playful practices in their classroom across three country contexts. To do so, we created a formative assessment tool that was designed to support their facilitation of playful practices in the classroom. Importantly, we aimed to create a flexible tool with teachers' professional development and reflection at the fore (rather than

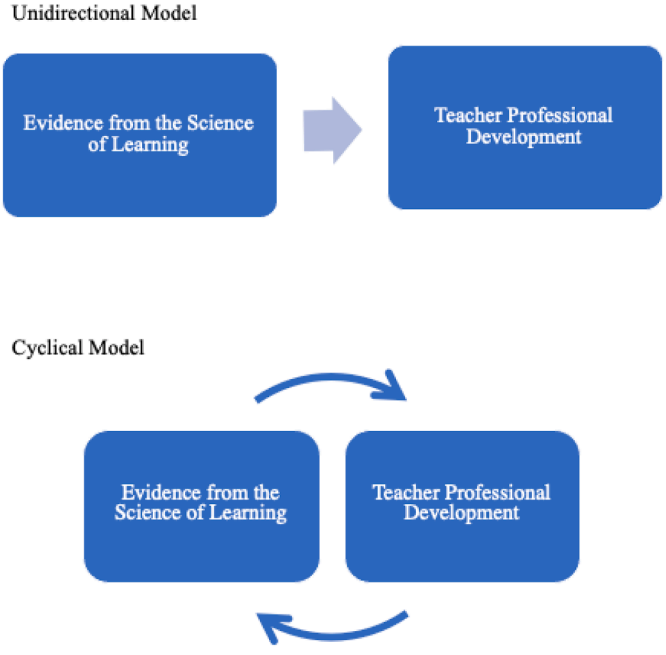

Fig. 1. Unidirectional vs. Cyclical models of the relationship between research and teacher professional development.

assessing teachers or measuring child outcomes). To do so, the tool allowed teachers to self-select a learning goal as well as the facilitation style and the characteristic of learning (actively engaging, meaningful, socially interactive, joyful, iterative) that they would like to examine in their classroom. The tool provided behavioral indicators that could be used by teachers to examine whether individual students, small groups of students, or the entire class were exhibiting the characteristics of learning as they engaged in playful learning practices.

Teachers were able to control their own data (enter and access) and we purposefully moved away from evaluative models that have the potential to negatively impact teachers based on their performance as well as limit the potential for teachers to select responses that they thought were "correct" so that they would look better to anyone monitoring their results. While this purposeful decision to use authentic formative assessment rather than accountability approaches [47] limited our ability to monitor changes in teacher behavior over time, we decided that the ability of teachers to use the tool with no concerns about repercussions would provide a higher likelihood of authentic use of the tool to support student learning.

Importantly, this work sought to investigate the use of this tool across three diverse country contexts: Bangladesh, Colombia, and Uganda. The countries were purposefully selected to represent different geographic regions and education systems. Colombia has a more central focus on play as a pedagogy in the early childhood education system [48], but has less of a focus on play in primary and secondary school contexts [49]. While play has largely been traditionally viewed as a leisure activity in Bangladesh, there is a shift occurring with the 2021 National Curriculum Framework emphasizing learning through play for pre-primary and grades 1–3 [50]. However, class size, teacher professional development, availability of play materials, and ambiguous perception of play based pedagogies have been identified as barriers to implementation in pre-primary classes [51]. While there is some recognition of learning through play in Uganda, it is important to note that there is no official guidance or policy about its use in schools and rote learning is the norm [52]. Further, Uganda identifies as having a low quality of education (e.g., low rates of literacy and numeracy, high dropout rate) and improving education has been identified as a priority in their national development plan [53]. Indeed, a recent analysis suggests that even for early childhood, the discourse and approach focus on survival rather than thriving and carers view cognitive development as fixed and innate [54].

Thus, we also sought to investigate how teachers across these contexts engaged with the tool to determine whether there were meaningful differences in their selection of learning goals, facilitation types, and characteristics. Learning how teachers used this type of tool can help provide guidance to anyone seeking to support teacher practice by determining areas of alignment and areas of misalignment across age and context.

More specifically, this study examined the following research questions:

RQ 1: *What facilitation styles were selected by teachers across student ages and teacher learning goals and are these choices impacted by context?*

RQ 2: *Which characteristics of learning were selected by teachers across student ages and teacher learning goals and are these choices impacted by context?*

2. Methods

The data used for this investigation comes from a larger initiative, titled Teacher RePlay, which is examining the implementation of a set of tools designed to support teacher practice as well as include the voices of children in implementing playful learning pedagogies in school classrooms across contexts [55]. The data presented here focuses on teachers' use of the tool to support varying learning goals while utilizing facilitation styles across the spectrum of pedagogical practices identified in the science of learning literature with a focus on the characteristics of learning supported in that literature.

Data were collected across the three country contexts (Bangladesh, Colombia, and Uganda) in two rounds (Pilot 1: May - July 2022, and Pilot 2: September through October 2022). The design of the tool, training, and implementation of the pilot was an iterative process that brought together members of the research and implementation teams across all three contexts. It prioritized supporting teachers and in doing so, we purposefully limited the specificity of the data so that we could ensure a tool that centered authentic, no-risk professional development that could not be used in a negative way by school or district administrators. Critically, this project espoused a bi-directional design with researchers partnering directly with project teams and educators across country contexts and their feedback was central in the design.

2.1. Participants

In each country, we worked with a different set of pilot sites (see Table 1). To the extent possible, we recruited teachers from schools that had already received some training on playful learning through one of the education nonprofit organizations operating in their area, and enlisted the staff of these organizations as partners and collaborators in implementing the pilots. However, this was not always practically possible, as the training in playful learning did not always engage all teachers in a school, or was limited to teachers of younger age ranges. In each of the countries, we therefore recruited teachers with an interest in learning through play, whether or not they had been previously trained. We recruited teachers with students between the ages of 3–12 years (3–5 years of age, 6–9 years of age, 10–12 years of age) to explore if student age was a significant variable in terms of how teachers used the tool to support their pedagogy.

Informed consent was obtained for experimentation with human subjects. In Bangladesh, ethical review and approval was obtained from the National Research Ethics Committee of Bangladesh Medical Research Council (*Reg No.: 433 04 08 2021*). In Colombia, ethical review and approval was obtained from the Ethics Committee at Universidad de los Andes (Reg. No. 1440 de 2021 and 1681 de 2023). In Uganda, research ethical review and clearance was obtained from Mildmay Uganda Research and Ethics Committee (*Reg. No.: MUREC REF 2021-44*) and the Uganda National Council for Science and Technology (*Reg. No.: SS1022ES*).

2.2. Procedure

2.2.1. Framework and item development

As an intermediate step between generalized evidence from the science of learning and actionable behavioral indicators that could be used by teachers to observe how a student, group of students, or class, is engaging with a given lesson, we created The Learning through Play Experience Framework (LEF). The LEF interlays the characteristics of learning with the teacher facilitation styles to offer teachers a way of visualizing and setting expectations of children's experiences at every point of intersection (see https://osf.io/73epa/). The behavioral descriptors form the foundation of the Teacher RePlay behavioral items that provide teachers with specific ways of observing and registering children's responses and reactions during and after the playful learning activity (see https://osf.io/73epa/). Note that the characteristics of active and engaged were combined into "actively engaging" for simplicity for teachers.

It is important to note that the tool planning, framework, behavioral item development, and implementation of the pilots was a collaborative and iterative process that involved the research teams and teacher input from all three country contexts to ensure that the training, tool design, behavioral items, and implementation of the tool were relevant and useful for teachers across all country contexts while also based in evidence from the science of learning.

Table 1
Pilot participation across contexts.

	Bangladesh		Colombia		Uganda	
	Pilot 1	Pilot 2	Pilot 1	Pilot 2	Pilot 1	Pilot 2
Number of teachers participating	143	142	48	521	174	179
Average age of teachers (years) (SD in parentheses)	35.6 (8.8)	35.9 (9.1)	42 (10.2)	38.8 (9.4)	35.6 (9.6)	36.2 (9.6)
% female teachers	79.50 %	75.60 %	92.30 %	91.50 %	80.80 %	84.50 %
Pilot site partner(s)	BRAC Bangladesh; Government primary schools		Open call for interested teachers	aieoTU; open call for interested teachers	BRAC Uganda	
Locations	Gaibandha Sadar, Palashbari, Gobindagonj and Shaghata in Gaibandha district	Gaibandha, Rangpur	Bogota	Bogotá, Bucaramanga, Cali, Cartagena, Cúcuta, Florencia, Medellín, and San Vicente del Caguán	Kampala, Luweero, Wakiso	Luweero

2.2.2. Tool overview

The Teacher RePlay tool used a 4-step process 1) Reimagine, 2) Record, 3) Reflect, and 4) Children ReAct. In the Reimagine section, teachers were asked to mark the date, type of activity, number of children present, and number of children observed, as they prepared to start the learning through play activity. Teachers were also asked to set a learning goal for the types of skills the activity was intended to focus on, choosing among cognitive, social, creative, emotional, and physical skills [56]. During the Record section of the protocol, teachers were offered all of the behavioral items for the chosen facilitation style and characteristic(s), making it easy for the teacher to note the behaviors they had set an intention on eliciting during the activity. The Teacher RePlay items consisted of these observable behaviors, ranging from three to six per intersection of teacher facilitation and characteristic of learning. The toolkit's observation forms contained a total of 70 behavioral items, including 23 under free and teacher-directed play each, and 24 under guided play. As part of the Reflect section, the toolkit asked teachers to select: a) behaviors they were proud of eliciting during the activity; and b) behaviors they would like to focus on eliciting in the future. This latter step resulted in feedback (coaching tips) based on their selections, with advice geared towards improving their practice with specific emphasis on items of interest. Children ReAct was created for teachers to get input from students about their experience during the playful learning activity and is not the focus of this manuscript.

2.2.3. Training

We conducted two pilot tests in each country, with each pilot lasting approximately four weeks. Prior to the pilots, country research partners led training workshops to orient teachers to the toolkit and practice its implementation in their classrooms. Training workshops varied in duration in each country based on the academic calendar, teacher availability, and agreements with schools and programs serving as pilot sites for the toolkit: less than one day in Colombia, two days in Bangladesh, and three days in Uganda. Workshops were led by our country research teams, with optional remote engagement of the research team in the U.S. and Canada for question-and-answer sessions.

2.2.4. Testing

The Teacher RePlay tool was used across the three country contexts and participants were able to use either a paper version or a digital version of the tool. We offered both paper and digital app versions of the toolkit in the three countries and provided assistance to teachers in installing the digital app during the training. The majority of teachers in Colombia used the digital version exclusively (78 % in pilot 2), while in Uganda, most teachers (70 %) used the paper version exclusively due to the lack of access to devices. In Bangladesh, teachers either used paper exclusively (42 % in pilot 2) or both digital and paper versions (54 %). Data from paper tool administration was entered by members of the research team into a central database.

During each pilot, participating teachers were asked to administer the toolkit at least once or twice a week. The country research teams followed up with teachers through WhatsApp groups and site visits, addressing questions and concerns, providing support with the toolkit as needed, and encouraging more active use of the toolkit.

3. Results

3.1. Descriptive statistics

Across the three country contexts, the tool was administered a total of 4911 times (see Table 2). Due to logistical constraints, student age data was not collected during Pilot 1 or for those using the paper version of the Teacher RePlay tool.

3.2. Facilitation styles used across ages, country contexts, and domains

In order to better understand how teachers used the tool to support teaching across facilitation styles, we determined the number of times the tool was used to support free play, guided play, and teacher directed play regardless of student age and context (see Table 2). The tool was used to support all three facilitation styles to a similar extent (Free Play = 1597 administrations; Guided Play = 1789 administrations; Teacher Directed Play = 1525 administrations).

While age data was limited (approximately 25 % of the observations included age data), we then explored whether student age impacted teachers' choices of facilitation style. A chi-square test of independence demonstrated that student age significantly impacted teachers' selections, X^2 (2, N = 1153) = 13.86, p = .008 with guided play being a particular focus, especially amongst the two younger age groups and with some variation across country contexts (see Table 2). Additionally, free play was less frequently selected when students were in the oldest age group (10–12 years).

Next, we investigated whether country context impacted teachers' choices of facilitation style. A chi-square test of independence demonstrated that country context significantly impacted teachers' selections, X^2 (2, N = 4911) = 140.51, $p < .0001$. Teachers in Colombia focused on supporting their guided play practices more than teachers in the other two country contexts (see Table 2).

Finally, we explored whether the teachers' intended learning goal impacted teachers' choices of facilitation style (see Table 2). A chi-square test of independence demonstrated that learning goal significantly impacted teachers' selections, X^2 (2, N = 4905) = 197.50, $p <$ .0001. While all three pedagogies were used to support all learning goals, teachers more frequently selected teacher-directed play when they were supporting a cognitive learning goal vs. creative, social, and emotional learning goals. They were more likely to select guided play when they had a social, creative, or physical goal and were more likely to select free play when they were interested in supporting an emotional

Table 2
Overview of data collected regarding facilitation spectrum.

	3–5 years		6–9 years		10–12 years		Unclassified		Combined	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Facilitation Type - All contexts										
Free Play	132	29 %	138	29 %	46	22 %	1281	34 %	1597	33 %
Guided Play	199	43 %	218	45 %	78	38 %	1294	34 %	1789	36 %
Teacher Directed Play	131	28 %	128	26 %	83	40 %	1183	31 %	1525	31 %
Facilitation Type - Bangladesh										
Free Play	86	37 %	81	42 %	34	33 %	774	33 %	975	34 %
Guided Play	68	29 %	61	32 %	31	30 %	781	33 %	941	33 %
Teacher Directed Play	79	34 %	50	26 %	39	38 %	786	34 %	954	33 %
Facilitation Type - Colombia										
Free Play	35	18 %	15	11 %	6	12 %	16	12 %	72	14 %
Guided Play	120	62 %	83	60 %	22	43 %	66	49 %	291	56 %
Teacher Directed Play	40	21 %	40	29 %	23	45 %	53	39 %	156	30 %
Facilitation Type - Uganda										
Free Play	11	32 %	42	27 %	6	12 %	491	38 %	550	36 %
Guided Play	11	32 %	74	48 %	25	48 %	447	35 %	557	37 %
Teacher Directed Play	12	35 %	38	25 %	21	40 %	344	27 %	415	27 %
	Cognitive		Social		Emotional		Creative		Physical	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Learning Goal - All contexts										
Free Play	380	23 %	252	36 %	374	44 %	172	35 %	417	34 %
Guided Play	593	36 %	286	41 %	247	29 %	181	37 %	479	40 %
Teacher Directed Play	690	41 %	166	24 %	223	26 %	132	27 %	313	26 %

Note. The unknown column presents data that was collected without associated student age information (i.e., data collected during Pilot 1, and data from the paper administrations of the tool). The combined column combines the age-specific data with the age unknown data.

goal.

3.3. Characteristics investigated across ages, facilitation styles, domains, and country contexts

Next, we investigated how teachers supported their playful learning activities through selecting characteristics of learning that they wanted to support in their classrooms. Teachers could choose from 1 or 2 characteristics that they were interested in observing every time they administered the tool.

We determined the number of times the tool was used to support actively engaging, iterative, joyful, meaningful, and socially interactive experiences for children (see Table 3). The tool was used to support all five characteristics but was used more frequently to support active engagement (48 %) and joy (46 %).

While age data was limited, we then explored whether student age impacted teachers' choices of characteristics (see Table 3). A chi-square test of independence demonstrated that age significantly impacted teachers' selections, X^2 (4, $N = 1791$) = 21.42, $p = .006$. Teachers less frequently chose joyful and iterative as student age increased (Joyful = 44 %, 41 %, 38 %; Iterative = 18 %, 12 %, 10 %) but were increasingly likely to choose actively engaging at the older age (Actively Engaging = 50 %, 46 %, and 58 %) (see Table 3).

Next, we investigated whether context impacted teachers' choices of

Table 3
Overview of characteristics selected for evaluation across age, learning goal, and context.

Baseline characteristic	3–5 years		6–9 years		10–12 years		Unclassified		Combined	
All Contexts	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Characteristic										
Actively Engaging	229	50 %	224	46 %	121	58 %	1796	48 %	2370	48 %
Iterative	84	18 %	57	12 %	20	10 %	668	18 %	829	17 %
Joyful	205	44 %	198	41 %	78	38 %	1774	47 %	2255	46 %
Meaningful	117	25 %	158	33 %	59	29 %	678	18 %	1012	21 %
Socially Interactive	108	23 %	90	19 %	43	21 %	583	16 %	824	17 %
# Unique Observations	462		484		207		3758		4911	
	Cognitive		Social		Emotional		Creative		Physical	
Characteristic	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Actively Engaging	855	51 %	191	27 %	446	53 %	208	43 %	665	55 %
Iterative	283	17 %	100	14 %	183	22 %	81	17 %	181	15 %
Joyful	782	47 %	247	35 %	386	46 %	186	38 %	650	54 %
Meaningful	439	26 %	150	21 %	133	16 %	147	30 %	141	12 %
Socially Interactive	201	12 %	287	41 %	73	9 %	105	22 %	158	13 %
# Unique Observations	1663		704		844		485		1209	
	Bangladesh		Colombia		Uganda					
Characteristic	*n*	%	*n*	%	*n*	%				
Actively Engaging	1649	57 %	282	54 %	439	29 %				
Iterative	496	17 %	128	25 %	205	13 %				
Joyful	1659	58 %	229	44 %	367	24 %				
Meaningful	387	13 %	255	49 %	370	24 %				
Socially Interactive	320	11 %	229	44 %	275	18 %				
# Unique Observations	2870		519		1522					

Note. The unknown column presents data that was collected without associated student age information (i.e., data collected during Pilot 1, and data from the paper administrations of the tool). The combined column combines the age-specific data with the age unknown data.

characteristic when using the tool (see Table 3). A chi-square test of independence demonstrated that country context significantly impacted teachers' selections, X^2 (4, $N = 7290$) = 627.09, $p < .00001$. Teachers in Uganda were less likely to choose Actively Engaging (29 %) compared to teachers in Bangladesh (57 %) and Colombia (54 %). Similarly, teachers in Uganda were also less likely to choose Joyful (24 %) compared to those in Bangladesh (58 %) and Colombia (44 %). Teachers in Colombia were more likely to choose meaningful (49 %) compared to teachers in Uganda (24 %) and Bangladesh (13 %).

Finally, we explored whether the teachers' intended learning goal impacted teachers' choices of characteristics (see Table 3). A chi-square test of independence demonstrated that learning goal significantly impacted teachers' selections, X^2 (4, $N = 7278$) = 576.67, $p < .00001$. When teachers had cognitive, emotional, creative, or physical skills as learning goals, they were more likely to select actively engaging and joyful, but when they had a social skill in mind, they were more likely to select socially interactive and joyful.

4. Discussion

Effectively translating findings and theories about the science of learning from journal pages and conference presentations for teachers to effectively use in their classrooms is rife with challenges. First, evidence from the science of learning has to be effectively translated and contextualized such that interventions or trainings do not rely upon jargon and are relevant to the intended participants. Second, it is important to recognize logistical constraints and concerns facing teachers. For example, teachers often report that they do not have enough time to accomplish their everyday goals [44,57,58], so adding additional requirements is often a higher burden than researchers realize. Additionally, with high-stakes testing and power structures creating vulnerability for teachers [44], it is important to recognize that participating in programs could create risk for teachers.

Here, we report the results of a program designed to support teachers in implementing playful learning in their classrooms across three country contexts. We used their use of this tool as a valuable source of data to gain insight into their perspectives of supporting children's learning through playful activities. Importantly, the design and implementation of this tool happened through partnerships between researchers and country partners, with iterative design based on actual use by and feedback from teachers as a core feature of the program.

Teachers used the tool to implement across the spectrum of facilitation styles, with teachers across ages and country contexts using the tool to support playful activities across ages. Notably, there were some context-specific differences in how the tool was used, with teachers in Colombia using the tool to support guided play more frequently than supporting the other two facilitation styles. This likely aligns with the focus in Colombia on guided play as a pedagogy that is supported by national standards [59]. Similarly, there were some effects of context on which characteristics were selected. While actively engaging was selected with great frequency (relative to the other characteristics) across all three country contexts, teachers in Bangladesh had a strong secondary focus on supporting joyful engagement in their classrooms while teachers in Uganda and Colombia were more varied in their selections. Teachers across all three country contexts were less likely to focus on iterative experiences in their classrooms.

This work also found that teachers across all three country contexts were interested in leveraging all five characteristics of learning in their classrooms, but that there were some characteristics that were selected more frequently (e.g., these characteristics may have been of higher interest, were perceived to be easier to observe, etc.). Across country contexts, teachers were most likely to select active engagement and joyful except when they had social goals in mind (in which case they most frequently selected joyful and socially interactive).

4.1. Bi-directional approaches are necessary

While this work informs our understanding of a real-life implementation of a teacher professional development program that was designed using a framework based in the science of learning, the argument here is that these results should be used to inform future study of the science of learning across ages, domains, and contexts. Too often, there is a unidirectional relationship that goes from researcher to educator, but the findings presented here (and elsewhere in the scientific literature) also offer important insights for future research based in the science of learning. Thus, we propose that this relationship should be bidirectional (researcher *and* teacher) rather than unidirectional (researcher *to* teacher) and responsive to the contexts in which programs are implemented. For example, the finding that different facilitation styles were selected more frequently across ages, domains, and country contexts suggests that a one-size fits all training program or professional development opportunity likely will not meet educator needs unless it is designed to do so and allows for individual personalization (as it was here).

Thus, **it is important for researchers to center and prioritize the experience of teachers and students**. For example, while learning science might be able to provide insights into how children learn generally, the educational systems that exist in reality include challenges such as teacher shortages, challenges in retention, training, working conditions, social status of teachers, workloads, access to professional development, gender equality and general working conditions [7,60]. These are immediate contexts that impact the educational experience - thus, this partnership between researchers and teachers needs to include insights from both perspectives.

Evidence is also still needed within the science of learning to uncover the efficacy of each facilitation style for different learning goals, in different settings, for different learners. While evidence tends to suggest that guided play is an optimal approach [11,21], research also finds that guided play is a difficult pedagogy to implement, even amongst well-resourced educators [57,58,61]. A recent meta-analysis highlights these points. Skene and colleagues [62] investigated the impact of free play, guided play, and direct instruction on supporting children's learning across a variety of skills (e.g., math, shape knowledge, task switching, vocabulary, etc.). They found guided play had some relative benefits over direct instruction and free play, but these effects were not universal across skills. They also noted that the way guided play was operationalized and implemented varied across studies, which again speaks to the idea that support and scaffolding is needed when implementing guided play. Additionally, this work also highlights an area where teacher input can help move theory forward. As the field explores the impact of pedagogical techniques and refines theory, it is critical that educator voices are included so that these theories have real-world validity.

Further, implementation of the science of learning in the real world also leads to multiple questions that the field needs to answer moving forward. For example, class size, student age, teacher training, class resources, cultural values, and student ability are all factors that could potentially influence how effective different pedagogies could be in the classroom. It could be the case that guided play is most effective in all cases, but it could also be the case that it is more or less appropriate depending on any of those factors.

In this study, teachers used all of the characteristics, but used the tool most often to evaluate joy and active engagement. This suggests that teachers may potentially be interested in fostering joy in their classrooms and that this is an unmet need. Active engagement was also a characteristic of interest, whereas iterative, meaningful, and socially interactive experiences were less preferred. It will be important to understand why these differences arose. It may be that teachers are either more confident in these areas or that they do not feel as if they are as important for learning. Alternatively, it could be that teachers were less familiar with one or more of those characteristics and did not feel

comfortable selecting them - indicating a need for additional training and support. Given that only 17 % of the uses of the tool, across ages and country contexts, focused on iterative and socially interactive experiences suggests that these may be relatively underutilized in the classroom despite evidence from the science of learning suggesting that they can be powerful tools for learning. Future research is needed to understand what factors may be standing in the way of utilizing all of the characteristics across highly variable classroom settings.

In this study, we prioritized educator privacy and this design choice resulted in an inability to collect student-specific performance data. Future studies must also address short-term and long-term impacts of interventions–both on teacher practice as well as student outcomes. Finally, additional research is needed to better understand how teachers perceive evidence from the science of learning and whether these perceptions influence the efficacy of training designed to improve their engagement with the characteristics of learning.

Together, we argue that, too often, the relationship between the science of learning and teacher professional development is unidirectional and prioritizes translating evidence from the science of learning *to* influence education. Here, we suggest that while this is an important first step, lessons can also be learned from creating a cycle such that information garnered from educators (both within the context of professional development implementation and in general) needs to feed back into the cycle, and that this approach represents an important piece of the puzzle that should guide those studying the science of learning.

Those interested in supporting playful learning in classroom settings may benefit from insights generated by related work that incorporates insights from neuroscience into teacher training. A recent review suggests that existing work in this area, while limited both in number and methodological issues, is promising and, like the argument presented here, suggests that there remains a number of open questions about how to effectively share the science of learning with teachers [63]. Dubinksy and colleagues [64] also make a key distinction that "knowledge of neuroscience guides teachers in choosing appropriate pedagogies, pragmatically informing teaching" [p. 267] rather than teaching teachers specific content or curriculum. Privitera and colleagues [63] also highlight some additional considerations for translational work including, like stressed here, that ideally, training would be collaboratively established between scientists and educators, that educators are seen as partners and their expertise is recognized and that the science is not "dumbed down" beyond what makes it accessible to non-researchers, and that the limitations on teachers' time is considered in developing teacher training. Our tool was designed with these best practices in mind, but is not without its limitations. Our goal was to not only help teachers to consider appropriate pedagogies but also build on those selections and directly serve as an in-classroom, personal support to implement those pedagogies.

Another area of consideration is that professional development may not be linked directly with curriculum and instead, as it was here, focus on pedagogy. This requires teachers to apply what they learned in professional development trainings to their unique contexts, curriculum, children, and expectations of the educational systems [65]. This tool was created such that teachers of students ages 3–12 years, across subject areas, and in very different educational systems could potentially benefit, but this design choice still required teachers to do the work of determining how general principles could apply in their own unique settings. This is yet another reason for researchers to partner directly with educators as teacher perspectives likely varied from the outset. For example, existing work in Uganda suggests that early childhood educators may view intelligence as innate and have a decreased sense of agency in supporting children's cognitive development [54]. Better understanding those existing frameworks and perspectives is critical for anyone trying to implement professional development in classrooms.

4.2. Limitations

It is important to recognize that student outcomes were not queried as a part of this project. This decision was made purposefully as the intent was to create a formative assessment tool whose sole purpose was to support teacher practice and did not run the risk of teachers being penalized in any way. However, this decision comes with tradeoffs in that we are unable to say whether students in classrooms where playful activities were happening were more successful than students in classrooms in which traditional instruction was happening. Our work is not alone in facing this limitation [63] but it is critical that future work is able to measure impacts rather than assuming positive outcomes without evidence. It will also be important to consider impacts on a variety of scales. Anecdotally, a teacher participating in our pilot shared that they noticed much reduced levels of absence in their classroom once they adapted more playful approaches in the classroom. Thus, future work should consider academic outcomes as well as other outcomes on things like engagement, behavior, attendance, and attitudes towards education and learning.

Similarly, we were unable to track individual teacher performance over time. Future research should investigate both short-term (e.g., learning from a single lesson in which teachers were more successful in implementing playful learning vs. lessons using more traditional, directed instruction) and long-term effects (e.g., students' outcomes over a longer period of time when teachers have been trained in and more frequently use playful pedagogies in their classrooms vs. teachers that use more directed methods) on student and teacher performance and engagement. It will be important, however, for researchers to keep in mind the potential harms that could be generated by collecting this type of data (e.g., impact on the career and/or reputation of participating teachers, creating a high stakes testing situation).

Another limitation is again due to the open-ended nature of the tool. By designing a tool that had teacher choice as a central design principle, we are unable to know the motivations behind teachers' selections. It could be the case that some teachers selected facilitation styles with which they were both familiar and comfortable while others may have selected facilitation styles with which they had less familiarity.

The scalability of this kind of tool is not without challenges. Here, researchers and the project team partnered with teams in each country context to ensure that the behavioral descriptors, coaching tips, and training materials were appropriate for their contexts. This required numerous meetings and frequent communication among all members of the country teams as well as with the project leads and scientific teams. Further, there were numerous costs involved including translation and design costs for both the tool and the trainings offered as part of the pilot. While a general tool that does not have such a high level of adaptation may be equally as useful (e.g., materials are translated but there are fewer country context specific examples given in the tool), it is an open question what level of adaptation is needed to ensure benefits and to limit costs.

5. Conclusion

While the last few decades of research from the science of learning have helped uncover ways that the brain is designed to learn, it is critical that we 1) do not ignore the richness of the contexts in which learning occurs and 2) partner with and prioritize the experiences of educators and children in research or/and implementation of the next generation of science of learning research.

Research data

Data are available upon request.

Ethical statement

Informed consent was obtained for experimentation with human subjects. In Bangladesh, ethical review and approval was obtained from the National Research Ethics Committee of Bangladesh Medical Research Council (*Reg No.: 433 04 08 2021*). In Colombia, ethical review and approval was obtained from the Ethics Committee at Universidad de los Andes (Reg. No. 1440 de 2021 and 1681 de 2023). In Uganda, research ethical review and clearance was obtained from Mildmay Uganda Research and Ethics Committee (*Reg. No.: MUREC REF 2021–44*) and the Uganda National Council for Science and Technology (*Reg. No.: SS1022ES*).

CRediT authorship contribution statement

Jennifer M. Zosh: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Angela Pyle:** Conceptualization, Methodology, Investigation, Writing – review & editing, Funding acquisition. **Nikhit D'Sa:** Conceptualization, Methodology, Investigation, Writing – review & editing, Funding acquisition. **Carina Omoeva:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Sue Robson:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Martin Ariapa:** Conceptualization, Validation, Writing – review & editing. **Mauro Giacomazzi:** Conceptualization, Validation, Writing – review & editing. **Gopal Dey:** Conceptualization, Validation, Writing – review & editing. **Eduardo Escallón:** Conceptualization, Validation, Writing – review & editing. **Carolina Maldonado-Carreño:** Conceptualization, Validation, Writing – review & editing. **Kazi Ferdous Pavel:** Conceptualization, Validation, Writing – review & editing. **Rafael Contreras Gomez:** Software, Validation, Formal analysis, Data curation, Writing – review & editing, Visualization. **Brian Dooley:** Software, Validation, Formal analysis, Resources, Data curation, Writing – review & editing, Visualization. **Eleanor Newsome:** Validation, Formal analysis, Data curation, Writing – review & editing, Visualization.

Declaration of competing interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tine.2024.100225.

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