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Children's perspectives on self-regulated learning: A co-design study on children's expectations towards educational technology

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Abstract
Self-regulated learning (SRL) involves processes by which learners purposefully direct their cognitions, emotions, and behaviors towards the achievement of personal learning goals. Research has shown that young learners often struggle with SRL. Educational technology could be useful to support their SRL. However, it remains unclear how support mechanisms can be best adapted to the needs of children. Adopting a participatory design (PD) approach involving an intergenerational design team of six children (ages 10–12) and three adult facilitators, we explored children's perspectives on factors that facilitate or hinder their SRL, and what kinds of support they desire. The study consisted of three in-person co-design sessions (one per week) lasting about 90 min each over three weeks. The sessions centered on brainstorming needs, evaluating existing technology, ideating and designing paper prototypes of study-planner apps. Our findings indicate that children primarily voice the need for support to better organize their study and to keep focused on the learning task at hand. They also make it clear that SRL support systems must be designed to be attractive and fun. Children's subsequent evaluation of app features and the prototypes which they designed were consistent with these needs. Taken together, our study indicates that children can voice clear and consistent preferences for SRL support with educational technology. By including children in the design process, we can ensure that educational technologies effectively meet their needs, enhance their learning experiences, and promote self-regulation and academic success.

Keywords Participatory Design · Young Learners · Study-Planner App · Co-Design · Self-Regulated Learning

Extended author information available on the last page of the article

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1 Introduction

Educational technology advancements have significantly influenced the way young learners engage in the learning process, giving rise to new opportunities for learning. One of the key benefits of educational technology is the enhanced opportunity for self-study. Self-study has been defined as spending time and effort on gaining knowledge on a topic without direct guidance of the teacher (Baars & Viberg, 2022). This entails that the student would need to self-regulate their study process by planning their self-study (Breitwieser et al., 2023; Nobbe et al., 2024), monitoring their learning process and employing effective learning strategies (Hartwig & Dunlosky, 2012; Geller et al., 2018; Nobbe et al., 2024), as well as reflecting on the performed learning activities (Zimmerman, 2000).

Research has shown that young learners often exhibit deficiencies in their self-regulated learning (SRL) skills, particularly in areas such as planning, monitoring, and reflection (Bjork et al., 2013; Stone, 2000). Furthermore, there is a common lack of awareness among young learners regarding effective learning strategies and their practical application (Blasiman et al., 2017; Dirkx et al., 2019). This suggests that young learners could benefit from support in self-regulating their study process, provided that the support meets their needs and preferences. Therefore, this study explored children's perspectives on factors that facilitate or hinder their SRL, and what kinds of support they desire. In the following, we will first introduce an influential model of SRL and its relation to studying with educational technology, followed by an introduction to participatory design research that takes into account children's perspectives.

2 Literature review

2.1 Self-regulated learning with educational technology

Self-regulated learning (SRL) within the context of educational technology is underpinned by several theoretical frameworks that emphasize the active role of learners in managing their learning processes.

One foundational perspective is Vygotsky's Social Constructivism, which posits that cognitive development is inherently tied to social interaction and the use of cultural tools. Educational technology, in this regard, functions as a critical mediating tool, enabling learners to construct knowledge through collaborative activities and scaffolding provided by digital platforms (Vygotsky, 1962). Complementing this, the Cognitive Load Theory highlights the necessity of instructional designs that optimize cognitive resources by effectively managing intrinsic, extraneous, and germane cognitive loads. Educational technologies, such as intelligent tutoring systems and adaptive learning environments, are particularly adept at customizing content to match the learner's cognitive needs, thereby reducing unnecessary cognitive load and enhancing learning efficiency (Sweller, 1988;

Clark et al., 2006). These theoretical foundations collectively emphasize the critical role of cognitive and metacognitive strategies in effective learning.

Zimmerman (1989) defined SRL as the extent to which individuals are "metacognitively, and behaviorally active participants in their own learning process". It encompasses the processes by which students purposefully direct their cognitions, emotions, and behaviors towards the achievement of personal goals. Zimmerman's SRL model draws from social cognitive theory and outlines three distinct phases of the SRL process: forethought, performance, and self-reflection. At the forethought phase, learners meticulously plan their learning sessions by establishing clear objectives, and devising strategies to attain those goals. In the performance phase, learners actively engage in the learning task, continuously monitoring their progress and utilizing self-control strategies to maintain cognitive engagement and motivation throughout the learning process. Finally, in the self-reflection phase, learners assess their completed learning session, pondering their achievements and failures, and attributing outcomes accordingly (Zimmerman, 2000). This model underscores the significance of both cognitive and metacognitive processes in SRL, and establishes the relevance of supporting these processes.

In the context of Zimmerman's SRL model, cognitive processes are the mechanisms that enable learners to process information, solve problems, and apply knowledge during the learning tasks. These processes include selecting appropriate learning strategies, organizing information, and maintaining focus on learning objectives. For instance, when a student chooses to summarize a text as a means to better understand and retain information, they are engaging in a cognitive process that enhances their learning experience (Pintrich, 2004). On the other hand, metacognitive processes involve higher-order thinking skills that allow learners to plan, monitor, and evaluate their cognitive activities. These include setting specific goals, self-monitoring progress, and reflecting on the effectiveness of the learning strategies used (Winne & Hadwin, 1998). Together, these processes are essential in SRL as they enable learners to become more autonomous and effective in their learning endeavors, adapting their strategies as needed to optimize learning outcomes (Zimmerman & Schunk, 2011).

Some educational technology have been designed to support the cognitive and metacognitive processes involved in SRL. They provide learners with tools that enable them plan their study, track their progress, review their learning activities, and reflect on their strengths and areas for improvement in real time. These educational technology include study-planner apps, which equally provide a context to study SRL, and often include features such as study schedulers, progress trackers, feedback mechanisms, reminders, and analytics that offer insights into students' study patterns (see Baars et al., 2022; Biedermann et al., 2023). By actively monitoring their performance, students can identify their learning gaps, modify their strategies, and make informed decisions about their next steps. Additionally, study-planner apps could also facilitate the development of self-regulatory skills (Dabbagh & Kitsantas, 2013) by offering scaffolds and supports. In sum, using study-planner apps, students can enhance their self-regulation abilities by learning how to manage

their time effectively, set realistic goals, and seek appropriate resources to overcome obstacles in their learning journey.

An aspect of supporting SRL with educational technology which is under-researched is the understanding of the nature of support desired by learners. Although previous quantitative studies (see Baars et al., 2022; Breitwieser et al., 2023; Nobbe et al., 2024) have reported selective effects of app-based SRL support on SRL outcomes, it is unclear whether the support measures employed in the apps matched the perceived needs of learners, which is a prerequisite for long-term app usage (Amaefule et al., 2023). This persistent gap in knowledge points to the viability of an alternative approach to understanding the SRL process as it applies to developing educational technology to support SRL among young learners. Ensuring that SRL apps properly support the SRL process and are suitable for young learners requires a better understanding of self-regulation challenges and support measures from their perspective. One approach to filling this gap is by giving young learners a say in the development of such technology through participatory design.

2.2 Participatory design of educational technology

Participatory design (PD) is a user-centered design method that can support users in the democratic development of services and products. In particular, co-design, a form of participatory design, involves designers collaborating closely with stakeholder audiences to address design challenges (Walsh et al., 2013). While PD broadly includes any inquiry-related activity with end users (e.g., informing opinions), co-design implies that the end user is a direct collaborator in the design process (Walsh et al., 2013).

The significance of incorporating young learners' perspectives and involving them actively in the design process of educational technology cannot be overstated. Children particularly possess likes, dislikes, curiosities and needs which may not be obvious to adults, such as parents, teachers or developers of educational technology (Druin, 2002). Nonetheless, Druin et al. (1997) has noted that it is common practice for children's feedback to be sought long past the completion of the initial design stages.

The earliest notable involvement of children in the collaborative design of educational technology can be traced back to Druin et al. (1997). Druin and colleagues established an intergenerational design team of elementary school children and adult researchers aimed at creating new learning environments (i.e., KidPad) for elementary school children. Following the study by Druin et al. (1997), co-design studies involving children have focused more on other kinds of information technology, such as web interfaces, robots, diverse tools and games (see Druin et al., 2001; Arnold et al., 2016; Bilal, 2003; Bonsignore et al., 2013; Walsh et al., 2013; Yip et al., 2023), but see (Gelderblom, 2014; Yip et al., 2020). In all these instances, child participation was highly valued as a means to foster creation of more child-friendly technology.

In recent times, the adoption of PD in the creation of educational technology has mostly been observed among adolescent and adult participants within school

communities (Cumbo & Selwyn, 2022). For instance, Sarmiento et al. (2020) adopted a PD process that involved university students in the co-design of a learning analytics tool. Similarly, Mäkelä et al. (2018) engaged students in co-designing a school learning space while incorporating their perspectives into decision-making processes. Baars et al. (2022) equally reported involving researchers, students, and developers in the co-design and creation of a mobile application to support SRL (i.e., study-planner app). This trend in participatory design within educational technology highlights the growing recognition of its value in educational technology development, demonstrating its effectiveness in engaging various stakeholders, from university students to researchers and developers, in the co-creation of innovative tools for learning.

Despite the relevance of educational technology supporting SRL for children (e.g., study-planner apps), to our knowledge there is no study addressing their inclusion in the design of such technology. When considering studies involving the design of study-planner apps in older students, only Baars et al. (2022) was identified to have mentioned the utilization of co-design methods among university students, and the extent of involvement is unclear. This, therefore, further portrays the lack of research involving young learners in the design of mobile applications for SRL.

In summary, while co-design has gained traction in the design of educational technology, it has yet to be adopted in the development and design of SRL applications for children. This provides room for potential opportunities to incorporate co-design principles in exploring children's perspectives on SRL, and how this translates to designing more child-friendly applications for SRL. Additionally, considering that self-regulation is a process that relies on the learner's personal factors, it becomes paramount to work with young learners to understand what they think of their own self-regulation. Study-planner apps provide a pragmatic context to better understand SRL among children.

2.3 The current study

Co-design provides an effective way to improve technological innovation and to incorporate learners' needs in the development of educational technology, as evident in the aspect of learning analytics (Sarmiento & Wise, 2022). Most educational technology developed to support SRL have been informed by outcomes from experimental studies with little-to-mixed effects concerning the nature of SRL support that will be beneficial to learners (Nobbe et al., 2024; Schumacher & Ifenthaler, 2021; Wong et al., 2019a). One possible limitation of these quantitative studies is the lack of an adequate representation of relevant support from the perspective of young learners, especially children.

The current study addresses this gap in literature by utilizing participatory and co-design methods in addressing SRL, through the context of co-designing study-planner apps. This study goes beyond previous studies in two ways: firstly, by employing a co-design workshop that embodies the early phases of the design thinking process (Gestwicki & McNely, 2012), starting with empathizing, problem definition and

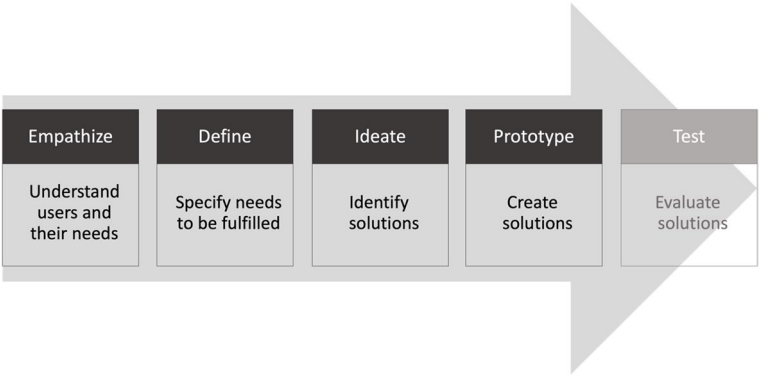

Fig. 1 The design thinking process. *Note*. The dark boxes indicate what aspects were considered in the current study. The gray arrow indicates that although the design thinking process can be iterative and non-linear, it involves a series of steps leading towards adequate solutions to user needs.

ideation which culminated in prototype generation (see Fig. 1); and secondly, by involving child participants in the design process to ensure that the resulting prototypes reflect their perspectives on SRL, as well as their preferences for SRL support.

Hence, this research was guided by the following research questions:

RQ1. What do children think they need for SRL support?
RQ2. What functions do children find relevant in a study-planner app to support SRL?
RQ3. How do PD methods help us better understand children's need for SRL support?

A prerequisite for the interpretation of the results is that the children report consistent SRL needs and requirements for study-planner apps. This was determined by triangulating the results of all three research questions (see Creswell & Miller, 2000; Yip et al., 2020).

3 Material and methods

In this study, we used a co-design approach (Walsh et al., 2013). We chose co-design as our method for this study considering the abstract and complex nature of SRL which requires a pragmatic approach of investigation. Also, advancements in human–computer interaction and child-computer interaction research have shown that PD techniques, including co-design, and workshops allow children to concretely express abstract ideas around complex topics due to the in-depth and rich engagement children are able to have (Yip et al., 2023). The co-design sessions in this study focused on designing and eliciting responses from children around their perceptions of self-regulation challenges and ideas for support.

Table 1 characteristics of the child participants

Name	Group	Age	Gender	School grade	Age of first smartphone	Study-planner app used
Laura	A	12	Female	6	10	Yes
Millie	A	11	Female	5	8	No
James	B	12	Male	7	8	No
Pamela	B	10	Female	4	6	No
Hans	C	11	Male	6	11	No
Edmund	C	12	Male	6	10	No

All child names are pseudonyms

3.1 Participants

Participants in this study were German-speaking school children in grades four to seven (ages 10–12) who used smartphones. Preference was given to ages 10–12 because they are considered both developmentally advanced enough to codesign and capable of providing insights from a child's perspective (Yip et al., 2020). This is also the age group targeted by the app being developed. Children were recruited through parent mailing lists in our institute's database, as well as the parent councils of two neighboring schools within Frankfurt, Germany. The parents and children were informed about the study through the informed consent forms which were attached to the e-mails. Following, 10 children were granted permission to participate in the study by their parents. Six out of the 10 children (3 female; grades 4–7) eventually showed up, and all of them participated in all sessions. An overview of participant demographics is provided in Table 1. The parent's consent form and the children's assent form were both obtained in-person right before commencement of the study. As recompense for their participation in all sessions of the co-design workshop, children received 30 euros Amazon gift cards. Ethics approval was obtained from the ethics committee of DIPF | Leibniz-Institut für Bildungsforschung und Bildungsinformation, approval number DIPF_EK_2023_02.

3.2 Context and procedure

The co-design workshop was conducted in a quiet, spacious room within our institute by a research team comprised of two undergraduate research assistants, one master's student and one postdoctoral researcher. The undergraduates and master's student acted as adult facilitators who worked in close collaboration with the children in three smaller groups. The postdoctoral researcher oversaw the assignment of children to the smaller groups, based on temperament and gender to ensure compatibility and diversity in the groups. We adapted the approaches used by Delcourt et al. (2022), Yip et al. (2020) and Bilal (2003), in determining the design of the current study, which reflects the early phases of the design thinking process (i.e., empathize, define, ideate and prototype).

The workshop entailed three in-person sessions lasting about 90 min each in total (Table 2). The structure of the design sessions was informed by best-practices for participatory and co-design involving intergenerational teams (Walsh et al., 2013). During the design sessions, participants interacted together using co-design techniques (Walsh et al., 2013) to explore and evaluate technologies (i.e., Study Bunny: Focus Timer (Study Bunny for short) & PROMPT apps), and create artifacts (i.e., paper prototypes). The Study Bunny app was chosen for exploration as it was deemed to contain relevant child-friendly features (e.g., animated rabbit mascot). The first two sessions were structured primarily as empathizing and defining sessions (Delcourt et al., 2022), while the third session was structured as an ideation and prototype generation session which included the actual design activity (Bilal, 2003; Yip et al., 2020). Different color sticky notes, A4 mobile phone paper templates, markers, and flipcharts were provided for the sessions.

Each of the sessions began with welcoming the children and refreshments (approx. 10 min) to aid the children and facilitators develop closer relationships. The sessions proceeded with an introduction of the major activity of the day by the lead facilitator to help prime study participants to think about the session's goals (approx. 15 min), followed by a break period (approx. 10 min). Afterwards, children practiced the main activity of the day in smaller groups of two children per group (approx. 40 min), and finally gave a presentation of the major outcomes of the day in the large group (approx.10 min).

The goal of the first session was to gain an empathetic understanding into user needs. To achieve this, the following prompts were introduced: *"what helps you begin/continue studying?"* (Prompt 1; facilitating factors); *"what prevents you from beginning/continuing to study?"* (Prompt 2; hindering factors). Afterwards, a further prompt (Prompt 3; support needs) was introduced to initiate the second step which is defining and specifying user needs. Children responded verbally to the first and second prompts, and their responses were noted down by the lead facilitator on a flipchart. For the third prompt, the children were asked to imagine that they had a coaching robot which helped them reach their study goals, after which they were prompted to provide feedback on how the robot could have assisted them: *what would he*[1] *[fictional coaching robot] do/say to help you study better?* To encourage participation and create a conducive environment for idea generation in the first session (see Table 2), each of the three participant groups were instructed to come up with a name for their coaching robot, as a "building block suggestion" (Delcourt et al., 2022). Children provided written feedback to the third prompt on sticky notes, which they attached to the flipcharts in their respective groups.

The second session aimed at defining and specifying the user needs. Therefore, to consolidate the outcome of the first session, children were asked to explore a popular study-planner app for children (i.e., Study Bunny) and evaluate the inherent features by providing feedback on their likes, dislikes and justification (Walsh et al., 2013) thereof. Children provided written feedback on sticky notes, which they attached to

[1] Coaching robot is designated the pronoun "he" following a direct translation from German language, in which the noun Robot bears a male gender.

Table 2 Description of the study sessions

Design sessions	Activity/goal	Artifacts
Session 1	I. Question and answer session on facilitating and hindering factors in large group II. Coaching Robot game examining children's support needs in small groups	Flipcharts bearing: i. Children's comments concerning what factors facilitate or hinder their study ii. What support they would desire to achieve their study goals
Session 2	I. Exploration of the Study Bunny App in large group II. Evaluation (i.e., likes and dislikes) of the Study Bunny App in small groups	i. Flipcharts bearing children's feedback concerning what app features they find supportive or unsupportive ii. Facilitator notes bearing justification of feedback in free text
Session 3	I. Introduction to prototyping in large group II. Evaluation of the PROMPT app in large group III. Designing prototypes that meet children's study support needs in small groups	i. Paper prototypes of study-planner app design ideas ii. Written descriptions of target design features expressed in prototypes

the flipcharts in their respective groups. Additionally, their justifications were noted down by the respective group facilitator.

The objective of the third session was ideation and sketching of low-fidelity paper-based prototypes reflecting the children's preferences for study-planner app user interfaces. Considering that children were only exposed to the Study Bunny app thus far, we provided children with a balanced perspective for ideation by familiarizing them with some integral aspects of the app under development. The children were shown a 2-min video of the PROMPT app in which seven activities were being performed. These included: 1. Typing in a plan for when to study; 2. Memorizing the plan by reading it at least three times before proceeding to the next screen; 3. Further encoding the plan by selecting representative emojis; 4. Setting the time for a check-in pop-up notification which enquires on if study activity was performed as planned; 5. Responding positively to the check-in notification; 6. Skimming through some study tips in the app; 7. Changing the app background. Following a break period, they were prompted to draw app features and describe the purposes of the drawn features as was done in Bilal (2003). They were informed that they could draw up to three prototypes. Children drew the prototypes in the A4 smartphone templates provided, and described the features on the back side of the A4 smartphone templates.

3.3 Analytical approach

A qualitative approach was adopted in analyzing the study data. To answer the first research question (i.e., what do children think they need for SRL support?), we described children's comments concerning factors that *facilitate* or *hinder* their SRL, which we considered relevant for their SRL support needs. Next, we employed an inductive process to evaluate children's comments concerning *support needs,* as we were more interested in understanding children's comments and deriving novel insights concerning their perspectives on SRL rather than evaluating them against pre-existing theory. The inductive process involved affinity diagramming, which entails organizing children's comments into larger themes to generate meaningful and actionable insights (Harboe & Huang, 2015).

To answer research question two (i.e., what functions do children find relevant in a study-planner app to support SRL?), we explored children's feedback on their likes and dislikes. We evaluated their subjective justifications in relation to why certain app features are considered to be *supportive* or *unsupportive* for their SRL. Hence, the aim was to further concretize and delineate their needs in relation to a preexisting app, rather than to perform a usability evaluation of the said app.

To answer research question three (i.e., how do PD methods help us better understand children's need for SRL support?), we adopted a similar approach employed in Bilal (2003) by evaluating and categorizing children's statements and prototypes for SRL in terms of functionality, thereby enabling a deeper dive into their need for SRL support.

To ensure methodological rigor, we further validated the findings across all sessions by triangulating the study support needs (session 1 outcomes),

Table 3 Overview of factors facilitating and hindering children's study

Factors	Aspects
Facilitating	commencing at the right time, setting study goals, setting rewards, finding conducive environment and regulating smartphone usage/screen time
Hindering	having other engagements, distractions in the environment (e.g., music, persons), pressure to perform at school, urge to move about at school/home and smartphone being more appealing

supportive vs unsupportive factors (session 2 outcomes), and functionality clusters (session 3 outcomes; Creswell & Miller, 2000). In so doing, observations resulting from the three study sessions (i.e., children's comments, statements and prototypes) were further qualitatively evaluated for thematic convergence, as described in Creswell and Miller (2000). In other words, the triangulation process assessed the consistency in the themes derived from all three observations. Additionally, the third and fourth authors who did not initially plan or conduct the study acted as external reviewers by providing an independent check on the interpretations of the data, and determining the credibility of the findings (Creswell & Miller, 2000; Yip et al., 2020).

4 Results

The research findings are presented in relation to the three research questions of the study. Additionally, the outcome of evaluating all findings for consistency is described.

4.1 What are the SRL support needs of children?

4.1.1 Factors facilitating and hindering children's study

When asked about what facilitates their studying, children mentioned a number of factors (see Table 3). The factors describe aspects of their everyday experiences which they find enabling for studying. For instance, children mentioned that setting study goals and rewards were particularly helpful for them in commencing studying. When asked about factors hindering their studying, children equally mentioned an array of situations (see Table 3). The situations describe their everyday challenges in terms of starting or continuing studying, such as having other engagements or appointments. One comment strayed from the context and was, hence, excluded.

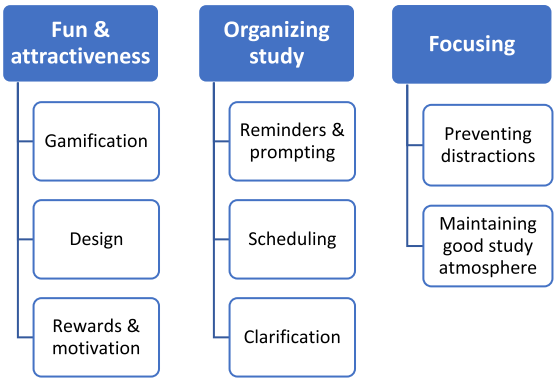

Fig. 2 Children's support needs and emerging themes *Note*. Left: Support needs identified by children in group B. These needs were generated in describing how a fictional coaching robot supports them in reaching their study goals. At the top-center in a white box is the name the children gave the coaching robot. Robot image is adapted with permission from Pixabay.com (Clker-Free-Vector-Images, 2023; CC BY 2.0). Right: Themes and subthemes resulting from evaluation of the support needs from all groups.

4.1.2 Factors relevant towards achieving their study goals

Three major themes (Fig. 2) emerged from the evaluation of children's support needs. Desire for assistance in *organizing study* appeared to be an important support need for the children. All groups expressed the desire thereof, through the subthemes of reminders and prompting (group C), scheduling (groups A, B & C), and clarification (groups A, B & C). Children also desired support in *focusing* on the learning task at hand, expressed through subthemes of preventing distractions (groups A & C) and maintaining good study atmosphere (groups A & C). Additionally, children emphasized the importance of designing SRL support to be adequately engaging. All groups expressed the desire for *fun and attractiveness* of SRL support processes and devices, through the subthemes of gamification, design, and rewards and motivation. We summarize these themes in relation to children's perspectives on SRL in the discussion section.

4.2 What functions do children find relevant in a study-planner app to support SRL?

Children provided feedback concerning their likes and dislikes of specific app features in a typical study-planner app. We highlight these under the sub-topics of supportive and unsupportive features, respectively, and discuss them in relation to children's perspectives on SRL in the discussion section.

4.2.1 Supportive features

Interaction with bunny and music Children evaluated the interaction with the animated rabbit mascot positively. They described the ability to personalize the animated rabbit mascot, by naming it, as nice and entertaining. Millie (group A) and Hans (group C) supported this positive evaluation by stating "It's nice to look at" and "I find it cool", respectively. Children also reported that the music feature, including being able to make a personal selection, was relaxing and helpful towards learning. Additionally, one child reported that the Happy Meter feature, in which the animated rabbit mascot gets happier the more one studies, was motivating.

To-do list and timer The To-do list feature was evaluated positively. In addition to being easy to use, it was regarded as being helpful in preventing forgetting when one had a lot to study. In James' (group B) words "one doesn't get confused with subjects". Also, the Timer feature was found supportive in regulating one's study progress. According to Pamela (group B), "one has definite ends [fixed study period], and can do other things afterwards".

Study tracker and flashcards Children evaluated the study progress tracker and flashcard features favorably. Laura (group A) described the flashcard as practical and helpful. While Pamela (group B) liked the quiz associated with the flashcards because of the possibility to get rewards.

Reward and reminder system The possibilities for obtaining, previewing and using rewards (e.g., store, carrots and coins, learning streak) were evaluated as fun, cool and motivating. The motivating function of the learning streak reward was indicated in Hans' (group C) comment "…will learn more regularly". Additionally, one child (Pamela; group B) described the reward associated with studying following the reminder function, as a motivation to do so every day.

4.2.2 Unsupportive features

Adverts Although children were eager to gain coins, they disliked the idea of achieving this by watching advertisement videos because it distracts them from learning. More so, Laura (group A) expressed this dissatisfaction by stating "it's not fair that you get more coins by watching through advertising than learning". Millie (group A) further expressed this dissatisfaction by stating "it tempts you to watch a lot of advertising instead of learning. Owing to similar concern, Millie also disliked the idea of going over to YouTube for music.

Lack of literal rewards and expensive reward items Millie (group A) longed for literal rewards such as "well done!" which were described as equally motivating. Concerning the reward items, Laura (group A) found it demotivating that they are mostly expensive and that one could not access certain functions without buying

them. Edmund (group C) had similar concerns about the rewards being expensive and one having to make a lot of purchases, "one must buy much…one can only use a lot of functions in exchange for money".

Suboptimal usability and aesthetics Millie (group A) expressed specific pain points such as difficulty while trying to close a function due to the size of the close button. Another issue was the range of color options available for the Study Tracker, which made differentiating the subjects based on the colors difficult. Furthermore, Millie (group A) "…partly in English although set to German", and James (group B) also expressed dislike for the language settings inconsistency, which leads to a limitation in understanding.

4.3 How do PD methods help us better understand children's need for SRL support?

We found the PD approach valuable in effectively exploring children's perspectives on SRL, as well as their SRL support needs. The co-design activities provided an enabling environment where the children felt comfortable to express their unique ideas on SRL, and what educational technologies supporting SRL, such as study-planner apps, should look like.

Children sketched a number of low-fidelity user interfaces (UI) reflecting what features they desired in a study-planner app. Among these features included games (4x), flashcards (2x), timers (2x), timer and stopwatch combination (1x), avatars (2x), stores (2x), reward tracker (1x), progress tracker (1x), color set for subjects (1x) and legible close button (1x; see Fig. 3). These UI features represented their most desired requirements for SRL support technology.

Furthermore, children described a number of functions which the UI features were intended to perform. For instance, Laura (group A) sketched a flashcards folder (Fig. 3; second prototype under organization function) for the purpose of providing a better and more organized overview of the grouping of flashcards. These functions formed the basis for categorizing the UI features into six distinct functionality clusters: organization; reward; play; avatars and usability; timer (Fig. 3), and are discussed in relation to the implications for designing educational technology supporting SRL in the discussion section.

4.4 Are children consistent in their SRL needs and requirements for study-planner apps?

Children's support needs, supportive vs unsupportive factors, and functionality clusters were further evaluated for thematic convergence. The outcome of the triangulation process indicated consistency between all three observations. That is, we found that children expressed distinct support needs which guided both their positive vs negative evaluations of features within a typical study-planner app, and their design of related UI features to meet these needs. For instance, the support need of *focusing* on learning task was expressed both in

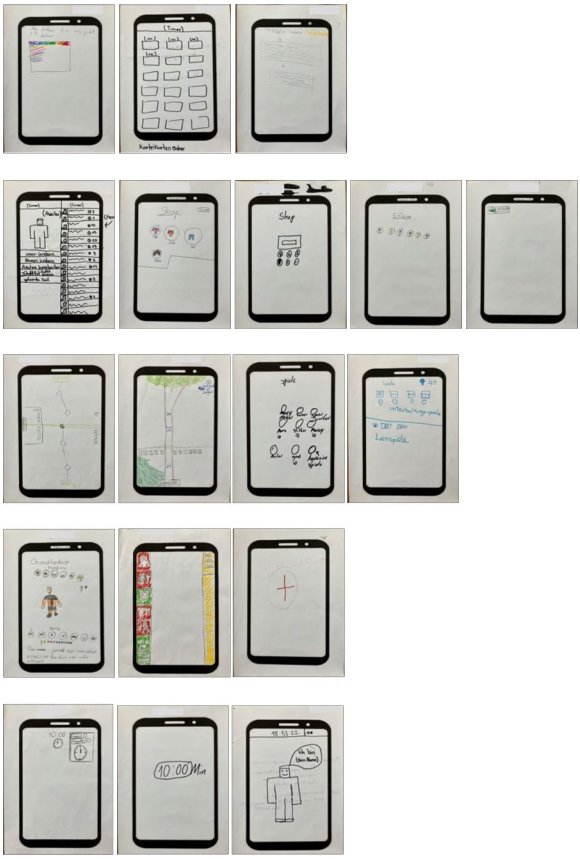

Fig. 3 Overview of paper prototypes and functionality clusters. *Note*. In parentheses to the right are the support needs, indicating the convergence of support needs, relevant functions, and functionality clusters.

children's positive evaluation of the timer and to-do list features in the Study Bunny app, their negative evaluation of the advertisements, and their subsequent design of timer and stopwatch UI features (see Fig. 3). Another example is the desire for *fun and attractiveness* of SRL support processes or devices, which was expressed in their positive evaluation of the interaction with the Bunny feature, their negative evaluation of areas of suboptimal usability, and their subsequent design of more intuitive and game UI features.

In sum, these outcomes also suggest that children are able to communicate their needs and requirements in a consistent manner through co-design. Recommendations for designing a child-friendly study-planner app are made based on the established convergence between the outcomes in the discussion.

5 Discussion and conclusion

The findings of this study hold significance for the design and development of educational technology, particularly study-planner apps, targeted at children. By placing children's voices at the forefront of the design process, we can ensure that these applications effectively meet their needs, enhance their learning experiences, and promote self-regulation and academic success. We will discuss the results in two steps, starting with children's perspective on SRL in general. We will then discuss the implications for the design of educational technology that supports SRL and summarize the relevance of the PD approach.

5.1 What did we learn about children's perspectives on SRL challenges?

The study outcomes demonstrate that children have unique perspectives on SRL challenges which they voiced consistently. These challenges were also specific to certain phases of Zimmerman's (2000) SRL model. The SRL model by Zimmerman emphasizes the relevance of metacognitive (e.g., planning, monitoring, reflection) and cognitive (e.g., distributed practice, summarizing, self-testing) strategies in the different phases (forethought, performance or reflection) of the SRL process. These strategies are relevant for various aspects of learning, including goal setting, task management, monitoring progress, maintaining motivation, and enhancing comprehension and retention (Baars et al., 2022; Breitwieser et al., 2023; Dent & Koenka, 2016; Devolder et al., 2012; Nückles et al., 2020). Children's perspectives consistently reflected the importance of these SRL strategies, as could be seen in their reported SRL support needs (i.e., focusing on learning task, organizing study, fun & attractiveness), and the Study Bunny app features which they perceived as relevant for SRL. These perspectives are discussed in relation to the SRL phases in the following paragraphs.

In connection with the *forethought phase*, children mentioned a number of factors which they considered supportive for initiating self-study. These factors included planning and scheduling study, and setting reminders, which are akin to the metacognitive and cognitive SRL strategies involved in establishing clear objectives, and the means to their attainment. Research has shown that children who received support in planning their study outperformed a control cohort in a subsequent vocabulary test (Breitwieser et al., 2023). This underscores the importance of planning as a metacognitive strategy in supporting SRL. Additionally, Nobbe et al. (2024) reports the effectiveness of the cognitive strategy of distributed practice (i.e., spaced learning), which entails scheduling and maintaining regular study intervals as opposed to condensed study practices. The value attached to these resources was also reflected in children's positive evaluation of corresponding features (i.e., To-do list, reminder function) in the Study Bunny app. The expressed need for support in organizing their study speaks to the relevance of SRL strategies involving planning, such as goal setting, in the forethought phase of their learning.

In relation to the *performance phase*, children mentioned a number of factors which they considered supportive for managing their self-study. In the performance phase learners engage in the learning task and rely on metacognitive monitoring to keep track of their progress, as well as cognitive learning strategies to stay focused and motivated on the task (Zimmerman, 2000). Subthemes arising from children's comments on their support needs represent key functions through which the relevant metacognitive and cognitive strategies for the performance phase could be actualized. These include clarification or summarizing of learning resource, preventing and managing distractions, as well as accessing rewarding and motivating resources. In line with previous research, using motivational regulation strategies has been shown to positively impact students' learning effort, which in turn led to achievement of better exam grades (Schwinger & Stiensmeier-Pelster, 2012). Additionally, the detrimental effects of distractions on learning, especially in digital environments, have been highlighted in previous studies (see Biedermann et al., 2021). Children's understanding of the relevance of these SRL resources is equally reflected in their positive (e.g., study tracker, timer, flashcards, reward system) and negative (e.g., adverts) evaluation of features in the Study Bunny app. The expressed need for support in remaining focused and engaged with a learning task during learning, speaks to the relevance of SRL self-control and monitoring strategies, in the performance phase of their learning.

As regards the *self-reflection phase*, children equally mentioned a number of factors which they considered relevant for assessing their self-study. These factors were reflected in the subtheme of maintaining a productive learning atmosphere through testing and querying. In the self-reflection phase, self-regulated learners assess their strategy for a learning task, revising their understanding of their own thought processes, and establishing reasons for their achievements or shortcomings (Zimmerman, 2000). Dent and Koenka (2016) have emphasized the relevance of self-reflection in the SRL process, pointing out that this contributes towards a composite measure of SRL which is more informative of a learner's metacognitive engagement. Children's expression of the relevance of this phase can be derived from their evaluation of relevant features (e.g., study tracker) in the Study Bunny app. Children's expressed desire for support in tracking and assessing their learning success, portrays the perceived importance of strategies to evaluate their SRL and reflect on their learning gains in the self-reflection phase of their learning.

Furthermore, findings from the study indicate that although children's perspectives on SRL support converge with conventional SRL literature, they actually diverge in terms of their areas of emphases. To date, the major areas of emphases for most SRL support investigations using mobile applications, have bordered on mode of delivery, dosage and timing of SRL interventions (see Breitwieser et al., 2023; Nobbe et al., 2024). While these might be important and promising for efficient SRL support, they do not adequately take into account other subjective factors that might have motivational and volitional implications for SRL, especially among young learners. Moreover, considering that these SRL support interventions are provided through mobile applications, factors potentially affecting children's acceptance of these applications and engagement with them, becomes even more imperative for

the success of the SRL support. Previous research indicates that the extent of satisfaction (i.e., perceived enjoyment) of using similar SRL support app was central to children's intention for sustained usage (Yip et al., 2023). Children in the current study further reiterated the importance of subjective factors promoting engagement by laying emphasis on the relevance of gamification and aesthetic design of SRL support systems. This was further expressed in their positive (e.g., interaction with bunny and music) and negative (e.g., suboptimal usability & aesthetics) evaluation of features in the Study Bunny app, as well as the prototypes which they designed (see play function, avatars & usability in Fig. 3).

Taken together, our findings suggest that children's perspectives on SRL support align considerably with conventional theoretical models, such as Zimmerman's (2000) SRL phases. However, they additionally extend pre-existing conception of SRL support by laying further emphasis on the need for SRL support processes that take the learner's key subjective factors into account.

5.2 What are the implications of our findings and the PD approach for designing educational technology supporting SRL?

The study findings provide insights into the intricate relationship between children's perspectives on SRL and their design of educational technology to support the SRL process. It is evident that children's perspectives on SRL align with Zimmerman's (2000) established SRL model. This alignment showcases the natural affinity of children towards metacognitive and cognitive strategies, which form the bedrock of SRL support across its distinct phases. These strategies play a pivotal role in various facets of learning, such as goal-setting and progress monitoring (Baars et al., 2022; Breitwieser et al., 2023). Additionally, the co-design activities indicate that children are able to communicate their perspectives on SRL, and contribute towards the design of apps to support the SRL process. This further buttresses the relevance of PD techniques in investigating complex topics concerning children (Yip et al., 2023), and designing child-friendly educational technology supporting SRL.

PD techniques offer actionable insights into children's perspectives on various aspects of their interaction with digital technology. Through its emphasis on uncomplicated and collaborative endeavors (e.g., sketching low-fidelity user interfaces), complex issues in technology design can be more effectively explored among children (see Yip et al., 2023). In the current study, the PD technique of co-design was pivotal in understanding children's perspectives on SRL and need for SRL support, based on their expressed preferences and desires for specific features in a study-planner app. The identified features, including games, flashcards, timers, avatars, and progress trackers, served as a tangible representation of their most desired requirements. Also, children's descriptions of the intended functions behind these features, highlights their expectations for study-planner app features that support enhanced study organization, user engagement and usability.

Furthermore, the study reveals specific elements within each phase of SRL that children find crucial for effective self-regulation. For the forethought phase, children emphasized the significance of planning, scheduling, and setting reminders, mirroring the metacognitive and cognitive SRL strategies involved in establishing

clear objectives and the means to achieve them. This was equally reflected in certain organization, timer, and avatar function UI features which they designed, enabling them to make personalized plans and allocate different study durations to different subjects. This is in tandem with previous research showing a positive impact of structured planning on subsequent learning outcomes (Breitwieser et al., 2023).

For the performance phase, children pinpointed the relevance of factors supportive in monitoring progress, and maintaining focus and motivation during self-study. Children's emphasis on resource clarification, distraction management, and access to motivating resources demonstrates a keen understanding of strategies crucial for effective task engagement. This was reflected in certain organization, timer, and play and reward function UI features which they designed, enabling them to keep track of their study progress, and stay motivated through the various reward and gamification resources. This outcome mirrors research demonstrating the positive impact of motivational regulation on learning effort and subsequent exam grades (Schwinger & Stiensmeier-Pelster, 2012).

For the self-reflection phase, children identified factors pertinent for assessing their self-study. Children's recognition of the relevance of this phase is evident in their design of certain reward, organization and timer UI features which would enable them to access and evaluate the magnitude of progress they made within given timeframes. Due to the importance of evaluating one's strategy and process on a learning task, previous research advocates the relevance of self-reflection for metacognitive engagement (Dent & Koenka, 2016).

In summary, our findings not only reaffirm the alignment between children's perspectives on SRL and established theoretical models but also expands the existing conception of SRL support. The outcomes emphasize the critical role of learner-centric factors, advocating for a more personalized and holistic approach to support young learners in their SRL process. This understanding offers valuable guidance for the design and implementation of digital SRL interventions, ensuring they resonate with the unique needs and preferences of young learners.

5.3 Limitations

While our study provides valuable insights into children's perspectives on SRL and their specific support needs, it is important to acknowledge certain limitations.

Firstly, the sample size consisted of six children, which, while sufficient for the participatory design approach employed, may not fully represent the diverse range of perspectives within the broader population of young learners. Additionally, the study focused on children aged 10–12, and the findings may not be entirely generalizable to younger or older age groups. Furthermore, the study focuses on the use case of a smartphone app for individual SRL support among children, which acts to limit its scope within the broader contextual framework of SRL.

Secondly, the study primarily utilized in-person co-design sessions, which may have introduced some degree of social desirability bias, potentially influencing the expressed preferences of the participants. Nonetheless, in-person sessions allow for a deeper level of engagement in comparison to online co-design. Moreover, online co-design is still in early adoption among children (Fails et al., 2022). Additionally,

equitable interactions are an implicit concern in participatory design research involving adults and children (Yip et al., 2017). In the current study, the adults relatively played more significant roles in facilitating the sessions (e.g., by prompting) than the children, which may create power imbalances.

A final limitation of this study is the omission of the social aspects of SRL theory. While our research primarily focuses on the cognitive and metacognitive aspects, it is important to acknowledge that social context plays a significant role in SRL, as highlighted by updates to Zimmerman's model (see Zimmerman, 2000; Zimmerman & Cleary, 2009). This limitation underscores the need for future research to integrate these social dimensions to provide a more comprehensive understanding of SRL.

5.4 Future directions

Despite the aforementioned limitations, our research underscores the significance of involving children in the design process of educational technology to cater to their specific SRL needs, and provides a foundation for further exploration in this critical area.

Future studies in the realm of SRL should consider several key avenues for exploration. One of these avenues is expanding the participant pool to encompass a more diverse range of young learners across various age groups would enhance the generalizability of findings. This could shed light on potential developmental variations in SRL perspectives and support needs. Additionally, employing a mixed-methods approach that combines qualitative insights from PD sessions with quantitative assessments could provide a comprehensive understanding of SRL in children.

Investigating the long-term effects of incorporating children's preferences into the design of educational technology for SRL is also crucial. Understanding how such tailored interventions impact learning outcomes and self-regulation skills over time would offer valuable insights for educators and designers. Also, exploring how app developers should precisely implement the emanating design solutions from the current study is a promising venture. Lastly, examining the potential influence of cultural and socio-economic factors on SRL in children, based on data from the broader social and learning environment, would contribute to a more holistic understanding of how diverse backgrounds may shape learning preferences and support requirements.

5.5 Conclusion

In conclusion, our study illuminates significant insights into the realm of SRL from the perspective of young learners, particularly children between the ages of 10–12. By adopting a participatory and co-design approach, we engaged an intergenerational team comprising both children and adult facilitators, allowing us to glean nuanced and authentic perspectives on SRL and its associated support needs. Our findings underscore the prominence of factors such as organizing study, and focusing on learning task in shaping the SRL experiences of these young learners. In addition, the role of fun and attractiveness of SRL support processes or devices in promoting engagement was also highlighted. Notably, the consistency in children's expressed preferences throughout the design process highlights the robustness of their perspectives, and relevance

of PD techniques. This consistency further advocates for the importance of integrating children's insights into the design of educational technology aimed at bolstering SRL.

Furthermore, outcomes of the current study bring to light a crucial distinction in the areas of emphasis between the children's perspectives and conventional literature on SRL support using mobile applications. While previous investigations on SRL support technology (e.g., Breitwieser et al., 2023) predominantly focused on delivery modes, dosage, and timing of SRL interventions, children place significant emphasis on psychological factors, such as enjoyment and aesthetic design, highlighting their pivotal role in enhancing SRL. This insight underscores the importance of tailoring SRL support processes to learners' individual preferences and motivations.

This study confirms that children's observations align with the phases within Zimmerman's SRL model, and offers practical implications for the development of tailored educational tools. We hope to provide a foundation for future research in this area, advocating for the active involvement of children in shaping their own learning experiences.

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Data availability The study data and materials will be made available on request.

Declarations

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