



Number of books at home and student achievement: new insights from two assessment methods and their interplay with the home literacy environment

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Abstract

Considering the widespread use of the books-at-home index in empirical educational and social research, the goal of the present study is twofold: First, by considering two common variants of the books-at-home index (i.e., number of books for adults and number of books for children) and their relations to the home literacy environment (HLE), we aim to provide further insight into the mechanisms underlying the relation between the number of books and student achievement. Second, the use of two different assessment methods of the number of books (i.e., open-ended questions and photos of the number of books) allows for an initial evaluation of the reliability and validity of the use of questions. Analyses are based on cross-sectional data of 332 parents of elementary school students from Grades 1, 3, and 5 who participated in a web survey in Spain. Multiple linear regression models revealed that, when assessed via open-ended questions, the number of children's books – but not the number of books for adults – contributed to explaining grades in Spanish and math beyond child gender and parental education. The number of children's books was also a significant predictor of the HLE, which was unrelated to students' grades. Comparing results of the two assessment methods revealed high correlations among the number of books collected through open-ended questions vs. photos and a much higher response rate for the questions. Results point to the use of (open-ended) questions as a viable approach for collecting the number of books in empirical research.

Keywords Books-at-home measure · (Open-ended) questions · Image collection · Mobile online survey · Socioeconomic status · School grades

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1 Introduction

Social inequalities in student achievement are a major concern for education systems around the globe. In many countries, schools fail to compensate for differences in the families' socioeconomic status (SES) and to provide their students with equal learning opportunities, resulting in pronounced achievement gaps to the detriment of students from families with relatively low SES compared to their counterparts from socioeconomically more privileged families (Chmielewski, 2019; Liu et al., 2022; Sirin, 2005). In investigating social inequalities, researchers draw on a range of SES indicators, including the number of books at home. This indicator has proven its appropriateness for use in empirical educational research (e.g., Zuschlag et al., 2024) for various reasons. It is substantially related to other commonly used SES indicators, such as parental education or occupational status, suggesting that it captures core aspects of SES (Eriksson et al., 2021; Heppt et al., 2022). Moreover, it has continuously been shown to contribute to explaining differences in academic success, as reflected, for instance, in students' test scores across domains (e.g., Evans et al., 2014; Martin & Mullis, 2013), grades (Evans & Kelley, 2002), and even overall years of schooling (Evans et al., 2010). The relations between the number of books at home and student outcomes typically remain significant when considering other SES indicators and researchers have, thus, identified the number of books at home as a particularly powerful predictor of student achievement (e.g., Eriksson et al., 2021; Heppt et al., 2022; Tsai et al., 2017). Despite this finding and the widespread use of the number of books at home in empirical educational research, the underlying processes that help explain the relation between the number of books in the household and student achievement have rarely been examined. The present study, thus, aims to clarify how the number of books at home and the home literacy environment (HLE) – including family literacy activities and attitudes towards reading (e.g., Wirth et al., 2022) – relate to student achievement in Spanish and math. Building on prior work showing that the number of children's books better explains student achievement than the number of parents' books (Heppt et al., 2022; Pagel, 2016), we differentiate between books for these two target audiences. In doing so, we use a unique (cross-sectional) dataset from Spain that includes information from open-ended questions on the number of books for adults and for children and from photographs of participants' home libraries. This enables cross-validation of our findings and provides a basis for evaluating the validity and reliability of open-ended questions on the number of books at home.

2 Books at home and student achievement

In explaining social inequalities in student achievement, researchers frequently rely on resource- and investment-oriented approaches (e.g., Bourdieu, 1986; Conger & Donnellan, 2007). These theoretical accounts, such as the family investment model (Conger & Donnellan, 2007), suggest that parents can provide their children with different amounts and kinds of resources depending on their SES, which are, in turn, predictive of their children's school success. These resources comprise (1) economic

resources such as household income, (2) social resources such as social networks that can help gain access to valuable information, and (3) cultural resources or cultural capital. These latter include institutionalized cultural capital such as parental education level and objectified cultural capital such as the number of books at home (Sieben & Lechner, 2019). Following broad conceptualizations of SES, these different parental resources, including the books at home, have repeatedly been conceived of as indicators of SES (Engzell, 2018; Eriksson et al., 2021; Harwell et al., 2016; Heppt et al., 2022). Whereas parental education and household income represent more distal structural SES features, the number of books at home can be seen as a proximal process-oriented SES feature. As such, the books at home offer a source of learning stimulation that fosters literacy-related activities such as joint book reading or sharing reading experiences (Grolig et al., 2019; Martin & Mullis, 2013).

The number of books at home are thus also closely related to the HLE, describing the overall quality of a child's literacy- and language-related learning experiences at home (e.g., Grolig et al., 2019; Wirth et al., 2022). In operationalizing the HLE, researchers also frequently consider the number of books at home as part of this multifaceted construct, along with a wide range of literacy-related activities (e.g., joint book reading, library visits) and attitudes (e.g., attitudes towards reading; Burgess et al., 2002; Claes et al., 2024). Focusing primarily on parent-child interactions during infancy and early childhood and (later) achievement, this research highlights the early HLE as an important driver of children's learning gains (e.g., Burgess et al., 2002; Sénéchal & LeFevre, 2002). These beneficial effects are not restricted to literacy- and language-related domains, but have also been observed for mathematics (Anders et al., 2012; Niklas & Schneider, 2017; Wirth et al., 2022). Typically, the early HLE emerges as a significant predictor of children's skills, even when considering structural SES features, hence pointing to its mediating role (Niklas & Schneider, 2017; Volodina et al., 2024; Wirth et al., 2022). However, because many studies incorporate the number of books at home into the HLE measure (e.g., Anders et al., 2012; Niklas & Schneider, 2017), they cannot isolate its effect from literacy-related activities. Moreover, little is known on the interplay of the HLE during (elementary) school age and student achievement. This is astonishing considering that a multitude of studies corroborated the link between the number of books at home and student achievement throughout schooling but did not provide insights into the mechanisms explaining this relationship (Heppt et al., 2022; McNally et al., 2024; Tsai et al., 2017).

One of the few studies that focused on the HLE during school age used longitudinal data of British students from preschool up to age 16 (Sammons et al., 2015). The authors found that not only children's early HLE but also later learning-conducive activities in the family, including the frequency of joint reading activities, predicted students' grades in English, mathematics, and science. The number of books at home, however, was not considered in this study. By contrast, a study with German elementary school students investigated the role of different structural and process-oriented features of the family for predicting students' reading comprehension (McElvany et al., 2009). Controlling for structural SES variables, both the number of books at home and reading-related activities in Grade 3, such as talking about reading experiences or visiting the library together, turned out as significant predictors of students' later reading achievement. Whether the effect of the number of books at home was

mediated by reading-related activities and, thus, by other indicators of the HLE, was not investigated. Addressing this research gap, the present study aims at exploring the mediating role of the HLE in the relation between the number of books at home and student achievement by assessing both the number of books and the HLE separately and investigating their interrelations as well as their relations to student achievement.

3 Challenges of assessing the number of books at home

Assessments of the number of books at home typically rely on questions, asking participants to indicate the number of printed books in their homes based on pre-defined categories (e.g., OECD, 2024). Despite its frequent use in empirical research and its proven effectiveness, the books-at-home measure is not without challenges. Concerns regarding the quality of this SES indicator mainly refer to (1) its appropriateness and timeliness as part of the measure's validity and (2) its accurateness and, thus, its reliability. Discussions about the validity of the books-at-home measure center on which kinds of books accurately reflect a family's cultural resources in an increasingly digital age. In this respect, books aimed at different audiences (adults vs. children) and ebooks have received increasing attention (Heppt et al., 2022; Schwippert, 2019). Regarding the measure's reliability, questions arise about participants' ability and willingness to estimate the number of books at home accurately (Engzell, 2018; Iglesias, 2024), and whether sending in photos of the books at home might yield more accurate information by reducing estimation errors and social desirability bias. Theoretical considerations and empirical findings regarding the validity and reliability of different indicators of the number of books at home are described in the next two sections (for a detailed description of potential sources of measurement error for [open-ended] questions and photos, see Iglesias, 2026).

3.1 Choosing an appropriate indicator: number of children's books, number of parents' books, and number of ebooks

The importance of the number of books at home for explaining student achievement likely arises from conducive learning interactions surrounding the books (see Sect. 2). Therefore, for the books-at-home measure to be an appropriate, timely, and valid reflection of a family's cultural resources, it needs to be established that the indicator refers to books that are widely used and may actually serve as a basis for such interactions. In this regard, the role of books for children and ebooks have been discussed as potential extensions of the traditional books-at-home question which mainly refers to books for adults (Heppt et al., 2022; Schwippert, 2019).

As for the comparison of books for adults and books for children, one can argue that, for school-aged children, stimulating learning interactions are more likely to occur based on a child's age-appropriate books than on parents' books. Therefore, the number of children's books should be a particularly appropriate SES indicator in the school context (for a similar line of reasoning, see Heppt et al., 2022; Pagel, 2016). In line with this assumption, prior research highlights that greater accessibility of children's books stimulates parents to engage in more frequent interactions and

shared book-reading with their children (de Bondt et al., 2020; van den Berg & Bus, 2014). Moreover, the number of children's books has been shown to relate to student achievement (McNally et al., 2024; Shahaeian et al., 2018).

A study focusing on German elementary school students from Grades 2 through 4 assessed the number of both children's and parents' books and considered them as independent predictors of students' academic language comprehension (Heppt et al., 2022). Results revealed that both indicators significantly contributed to explaining students' academic language comprehension, mediating the relationship of structural SES features (i.e., parental occupational status and education) with student outcomes. Further analyses suggested stronger relations between both indicators of the number of books with language achievement than with achievement in mathematics, possibly because the learning-conducive activities and interactions surrounding books more directly bolster language skills than mathematics skills (Pagel, 2016).

As for the comparison between printed books and ebooks, concerns have been raised that printed books might no longer be a valid indicator of a family's cultural resources in an increasingly digital world where ebooks are becoming more prevalent (Balzer et al., 2025; Heppt et al., 2022; Schwippert, 2019). Yet, data for Germany indicate that only 6.1% of all book sales at the consumer publishing market in 2024 were ebooks (Börsenverein des Deutschen Buchhandels, 2025). Similarly, data for Spain suggest that out of 82.5% of elementary school children aged 6 to 9 who regularly read books, only 2.4% indicate to read ebooks, whereas 97.8% read printed books (Federación de Gremios de Editores de España, 2025).

Furthermore, research findings from Germany show a much greater proliferation of printed books than ebooks across age groups (Balzer et al., 2025; Heppt et al., 2022). Floor effects and large amounts of missing values have been observed for the number of ebooks, possibly limiting its predictive power. Consequently, the number of ebooks shows substantially lower correlations with other indicators of SES and, contrary to printed books for adults and children, does not contribute to explaining students' academic achievement. Overall, current research challenges the common assumption that increased ebook use undermines the validity of the traditional books-at-home index (e.g., Balzer et al., 2025; Heppt et al., 2022). Therefore, the analyses presented in this paper refer to printed books only.

3.2 Choosing an accurate indicator: conventional questions vs. photographs of the number of books at home

As another potential shortcoming of the books-at-home index, researchers have raised concerns regarding its accuracy (Engzell, 2018; Iglesias, 2024, 2026; Jerrim & Mickelwright, 2014). Certain aspects might indeed compromise the measure's reliability. As most people will not know the exact number of printed books in their homes, questionnaire items usually rely on estimates. To facilitate estimation, respondents are typically asked to choose among several categories (e.g., "0–10 books", "11–25 books", "26–100 books", "101–200 books", and "more than 200 books") and items are frequently accompanied by visual aids, depicting shelves with a certain number of books. Yet, the use of predefined categories instead of an open-ended question may also have shortcomings (Iglesias, 2024). It not only reduces granularity and accuracy,

but may also increase effects of social desirability. Assuming that the possession of many books is considered favorable, respondents may not feel inclined to tick a category that falls toward the lower end of the range, even if this best reflects the number of books they have in their home (Iglesias, 2024).

It is difficult to empirically determine whether the assessment of the number of books at home via questions is impaired by such factors. Prior research that included different informants (i.e., parents and children) reported relatively low agreement, indicating that at least one of these information resources is of limited accuracy (Engzell, 2018; Heppt et al., 2022; Jerrim & Micklewright, 2014). As children's ability to estimate numbers is still developing during the elementary school years (Harel et al., 2007), parents are arguably a more reliable information source, at least for the number of parents' books.

Current technological developments in survey methodology may allow for a more adequate evaluation of the reliability of questionnaire items. Specifically, having participants take photos of all the books in their homes might result in more accurate data, which can be used for investigating the accuracy of questions on the number of books. Yet, this method bears its own potential threats to measurement accuracy (Iglesias, 2026; Revilla, 2022). Taking photos of all the books in the home may be arduous and time-consuming for participants and people might also be reluctant to provide researchers insights into their homes for privacy reasons. Corroborating this assumption, previous studies found that participants were less willing to capture photos during surveys than to answer questions, resulting in lower participation rates for the former (Bosch et al., 2022; Iglesias, 2024). Acknowledging the strengths and challenges of each format, the present study employed both methods, allowing for further evaluation of the reliability of the open-ended books at home question and to cross-validate the results.

4 Research questions and hypotheses

We aim to gain further insight into the relation between the number of books at home and students' school achievement, considering (1) the interplay between the number of books and the HLE and (2) different variants of the number of books at home (i.e., number of adults' books and number of children's books). Using different assessment methods (i.e., open-ended questions and photographs) for each of these variants serves as a basis for evaluating the reliability of the books-at-home measure. Including grades in Spanish and mathematics as dependent variables enables examination of the effects' generalizability across domains.

We address the following research questions, all of which are investigated using both open-ended questions and photos for assessing the number of books at home:

- (1) *Is the number of books at home (i.e., parents' and children's books) related to student achievement in Spanish and math beyond parental education?* Replicating prior findings, we expect the number of books to contribute to explaining student achievement both in language arts (i.e., Spanish) and in math, even when considering important confounding variables (i.e., gender, Spanish spoken at home;

Hypothesis 1 [$H1_{\text{question}}/H1_{\text{photos}}$]). Children's books can be considered more relevant for student learning and for initiating meaningful parent-child interactions than parents' books, suggesting incremental effects of children's books ($H2_{\text{question}}/H2_{\text{photos}}$; for similar findings, see Heppt et al., 2022).

- (2) *Is the number of books at home (i.e., parents' and children's books) related to the HLE?* Building on theoretical considerations that imply a close relation between the number of books and literacy-related activities within the family (de Bondt et al., 2020), we expect positive relations between the number of books and the HLE ($H3_{\text{question}}/H3_{\text{photos}}$). We expect these effects to be stronger for the number of children's books than for the number of parents' books ($H4_{\text{question}}/H4_{\text{photos}}$).
- (3) *Is the HLE related to student achievement in Spanish and math?* Prior research identified relations for both the early HLE (e.g., Anders et al., 2012; Niklas & Schneider, 2017) and the later HLE (Sammons et al., 2015) with achievement in language and math. Thus, we expect the HLE to show significant relationships to grades in Spanish and math ($H5_{\text{question}}/H5_{\text{photos}}$).
- (4) *Does the HLE mediate the relationship between the number of books at home and student achievement in Spanish and math?* Based on theoretical assumptions (e.g., Conger & Donnellan, 2007), we expect the HLE to mediate the relationship between the number of books and student achievement ($H6_{\text{question}}/H6_{\text{photos}}$). Research Question 4 will only be investigated if all necessary preconditions, namely the positive relations specified in Research Questions 1 through 3, are met.

5 Methods

5.1 Study information, procedure, and sample

The present analyses are based on data from the project “WEB DATA OPP: New opportunities to enhance or extend (mobile) web survey data and get better insights”, which investigates the acceptance, feasibility, and quality of innovative tools in web surveys. Given the widespread use of the books-at-home indicator in the social sciences, the main goal of this larger project is to examine the appropriateness and quality of using photographs for assessing the number of books at home (see the study protocol for detailed information; Iglesias et al., 2023). Data were collected in June 2023 using the Spanish Netquest opt-in panel, which offers participants rewards for each completed survey. The target group were parents of elementary school children in Grades 1, 3, or 5 in Spain¹ with the aim of exploring the link between the number of books at home and the concurrent HLE. Participation in the mobile web survey

¹ Elementary school in Spain comprises Grades 1 through 6. The target population was restricted to parents with children in Grades 1, 3, and 5 due to a change in the evaluation system that occurred during the academic year 2022–2023. From that time point onward, students in Grades 1, 3, and 5 received verbal evaluations (e.g., “insufficient”, “good”, “outstanding”) of their performance, whereas those in Grades 2, 4, and 6 continued to receive numerical grades. Including parents with children from all six elementary school grades would thus have resulted in limited comparability of students' grades.

was voluntary and only persons who provided informed consent at the beginning of the survey could take part.

To answer our research questions, we used data of participants who were requested to estimate the number of books at home (using open-ended questions) before uploading pictures of the books in their homes, ensuring that their estimates could not be biased by the photographs. The analysis sample comprised 332 participants ($M_{\text{age}} = 42.14$ years, $SD_{\text{age}} = 6.04$), 53% of whom identified as female and 47% of whom identified as male. One third (33.7%) of the sample had not completed any vocational training, 22.9% had completed vocational training, and 43.4% had completed tertiary education.

5.2 Measures

Participants were asked to provide information on their own and their children's demographics, their children's grades in Spanish and math, and literacy-related activities in their homes, amongst others, before answering open-ended questions on the number of books and submitting photos of the books in their homes. The median completion time for the survey was 10.1 min (the complete questionnaire can be found via <https://osf.io/54x7s/overview>).

5.2.1 Open-ended questions on the number of books at home

We used parents' information on (1) the number of books for children who do not read by themselves, comprising mainly picture books, (2) the number of books for literate children and youth, and (3) the number of books aimed at adult readers. For each of these categories, the number of books was freely estimated (i.e., no answering options were provided) and participants were instructed to exclude ebooks, school books, and magazines from their estimation. If participants failed to indicate the respective number of books, they were asked to indicate an approximate number. Visual aids were presented to facilitate estimations. These consisted of photographs of two full book shelves of the same width (74 cm) but containing a different number of books (34 vs. 77). An accompanying written note informed participants that the number of books that fits into a book shelf varies with the books' width. For all subsequent analyses, we summarized the number of books for children who do not read by themselves and the number of books for literate children and youth, using it as an overall sum score of children's books.

5.2.2 Photographs of the number of books at home

Parents were asked to take photographs of all the books in their homes (except for ebooks, school books, and magazines) using their smartphone or tablet. For the photos to be captured and uploaded during the survey, we used the open source software *WebdataVisual* (Revilla et al., 2022). Books could be captured in their storage places (i.e., shelves, beside lockers) but the title of each book should be fully visible. Participants were further instructed to remove any objects that might disguise the view of the books or that contained personal information. Photographs of an appropriate

and an inconvenient presentation of books were presented as visual aids. Participants could upload as many photos as they wanted and photos could be deleted and redone.

Extraction of the number of books per photograph (i.e., classification of the information) was done manually by two trained researchers, following detailed guidelines (access to the classification guidelines via <https://osf.io/54x7s/overview>). A description of the coding procedure and potential challenges (e.g., determining whether photos met essential criteria such as being of sufficient visual quality for identifying the number of books) can be found in Iglesias (2026). Roughly 14% of all photos (i.e., 100 photos) that were captured within the larger project were double-coded (Iglesias, 2026). During the coding procedure of the photos, we identified (1) the number of books for children who do not read by themselves, (2) the number of books aimed at literate children and youth, and (3) the number of books aimed at adult readers for each participant². Analogously to the procedure for the open-ended questions, the number of books for children who do not read by themselves and the number of books aimed at literate children and youth were summarized and used as a sum score for the “photographs of the number of children’s books” in the subsequent analyses. As the two categories of books for children could not always unequivocally be distinguished in the photos, collapsing these two categories into one category seems a viable approach.

5.2.3 Parental education

Participants provided information on their highest educational qualification on an 9-point scale that ranged from *no studies* (coded as 0) to *doctoral or equivalent* (coded as 8). The scale was aligned with the categories of the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 2012), a globally recognized system for classifying educational programmes and qualifications, and was designed to capture educational trajectories and qualifications that are typical of the Spanish system of education and vocational training. Information on parental education was only collected from the parent who completed the questionnaire.

5.2.4 Child characteristics and home literacy environment

Information on child demographics, grades, and the HLE was collected for exactly one child per participant. Participants who indicated to have two or more children attending elementary school Grades 1, 3, or 5 were instructed to answer the questions for the child whose birthday would be next, ensuring a random selection of target children.

Demographic information Participants indicated whether the target child was a boy (54.2%) or a girl (45.8%). Parents further provided information on language use at home, indicating the frequency with which the target child speaks Spanish at

² An interrater reliability analysis of all double-coded photos, including participants from this group and from other groups in the same survey (for details on the experimental groups, see Iglesias et al., 2023), was reported in a separate paper to assess data quality (Iglesias, 2026). The results showed an average percentage agreement of 74%, and intraclass correlation coefficients (ICCs) ranging from -0.1 to 0.6 for counting and categorizing books, indicating low to moderate consistency between classifiers and highlighting the difficulty of analyzing photos of books at home.

home on a 6-point Likert scale ranging from *always* (coded as 5) to *never* (coded as 0). As Spain is a country with several official languages and classroom instruction sometimes takes place in one of the regional official languages (i.e., Catalan, Basque, Galician), many children grow up multilingually. Unlike in many countries where multilingualism is most prevalent among students with an immigrant background (e.g., OECD, 2023), many multilingual students in Spain are not from immigrant families. The vast majority of parents in the sample (81.3%) indicated that their children always speak Spanish at home.

Home literacy environment Building on an established instrument for assessing the HLE with preschool children (Wirth et al., 2022), our HLE measure included five items that referred to the frequency of literacy-related activities (e.g., shared book reading, library visits) and two that referred to reading motivation (e.g., reading as an important and joyful activity within the family). Where necessary, items were adapted for the age group of elementary school children (e.g., children's own reading activities). Items were answered either on a 6-point Likert scale, ranging from *several times a week* (coded as 5) to *never* (coded as 0), or on a 5-point scale, ranging from *very much* (coded as 4) to *not at all* (coded as 0) with higher values indicating a richer HLE. For subsequent analyses, we specified a latent variable of HLE with all seven items (see Table S1 in the Supplementary Material) loading on one factor (see Wirth et al., 2022, for a similar approach). A model allowing for covariances between the items (1) and (4) as well as between the items (6) and (7) resulted in a very good model fit (see Table S1: $\chi^2=9.85$ [$df=12$], $p=.629$, CFI=1.000, RMSEA=0.000, SRMR=0.000). The factor loadings of all seven items were significant ($p<.001$) and ranged between $\lambda=.45$ and $\lambda=.72$. The internal consistency of the scale was good ($\alpha=.80$, $\omega=.80$).

Grades in Spanish and math Participants further provided the grades the target child received in Spanish and math in the second trimester of the school year from 2022 to 2023. Grades were assessed on a 5-point scale that ranged from *insufficient* (coded as 0) to *outstanding* (coded as 4), corresponding to the verbal evaluations provided by schools.

5.3 Analytic procedure

Structural equation models were computed in the *Mplus* 8.11 software (Muthén & Muthén, 1998–2019). All analyses were first conducted for the number of books for adults and for children as assessed with open-ended questions. Afterwards, all models were rerun with the number of books for adults and for children as assessed via photographs. In a first step (Models 1a through 3b), we examined whether the number of books contributed to explaining student grades in Spanish and math, controlling for child gender, language spoken at home, and parental education. We next modelled a multiple regression analysis for explaining the HLE, entering the sociodemographic background variables, parental education, and the number of books as predictors (Model 4). We used Wald-tests χ^2 (Wald, 1943) to examine differences between the effects of the number of books for adults and those for children on the HLE. Finally, we extended the models for explaining grades in math and Spanish by adding the HLE as predictor (Models 4a and 4b). Throughout, a latent modelling approach was

used for the HLE. Due to nonsignificant relations between the HLE and school grades (see Table 3 in the Results section), we did not examine whether the HLE mediates the relationship between the number of books and school grades.

Missing data Rates of missingness in our study varied. Grade in Spanish had 1.8% and grade in math had 0.9% of missing values. The number of books for adults and the number of children's books as assessed by open-ended questions had 18.4% and 11.4% of missing values (referring to the number of missing values after having asked respondents to indicate an approximate number of books if they did not indicate the exact number of books at home), while the number of books for adults and the number of children's books as assessed by photographs both had 72.3% of missing values. This large amount of missing values is mainly due to a relatively low response rate, with only roughly one third of the participants (30%) providing photos of their books when asked to do so³. Of these, some 30% encountered problems when capturing or uploading photos. Finally, the number of books identified from photos was further reduced during the classification process, since many books could not be clearly assigned to one of the three book categories, or due to the presence of confusing items in the photos (such as notebooks, magazines, or CDs; for a detailed description of technical problems and obstacles during the classification process, see Iglesias, 2026). Regarding other predictor variables, one item on the HLE scale had one missing value. We applied full information maximum likelihood (Enders, 2010) to deal with missing data on independent variables. Code files for data preparation and for the inferential analyses are available from the OSF project page: <https://osf.io/54x7s/overview>.

6 Results

6.1 Descriptive results

Means, standard deviations, and correlations of the study variables are displayed in Table 1. The average number of books at home for adults was higher when participants were asked to answer an open-ended question ($M=96.39$, $SD=200.19$) than when asked to upload photos of all their books ($M=72.92$, $SD=127.72$, $t=2.50$, $df=83$, $p=.007$). The number of children's books was substantially lower than the number of books for adults ($t=3.12$, $df=269$, $p=.001$ for open-ended questions and $t=1.32$, $df=91$, $p=.095$ for photos) and both assessment methods yielded similar results (question: $M=60.34$, $SD=60.10$, photos: $M=56.90$, $SD=73.14$, $t=0.58$, $df=90$, $p=.283$). The different indicators of the number of books at home were significantly and positively correlated, with an exception for the association between the number of books for adults as assessed by an open-ended question and the number of children's books as assessed by photos. The highest correlations ($r=.68$) emerged

³ We conducted additional regression analyses to explain the (low) response rates for photos compared to open-ended questions. The response rate for photos increased with participants' age, whereas education was a significant predictor of the response rate for the open-ended questions (Table S2). As none of the other predictors was significant, sociodemographic variables only play a minor role for explaining the relatively low response rate for the photos.

Table 1 Means, Standard Deviations, and Manifest Correlations of the Study Variables ($N=332$)

Variable	<i>M/%</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Number of books for adults (Q)	96.39	200.19	0	2,300									
(2) Number of books for children (Q)	60.34	60.10	0	450	.44**								
(3) Number of books for adults (P)	72.92	127.72	0	802	.68**	.48**							
(4) Number of books for children (P)	56.90	73.14	0	324	.20	.68**	.43**						
(5) Child gender (girl)	45.8				.02	-.07	.09	-.05					
(6) Spanish spoken at home	4.63	1.02	0	5	.01	-.05	-.21*	-.16	.03				
(7) Parental education	4.55	1.62	0	8	.21**	.19**	.28**	.29**	-.01	-.04			
(8) Home literacy environment	2.75	1.03	0	4.71	.16**	.21**	.12	.18	.07	-.02	.20**		
(9) Grade in mathematics	3.15	0.91	0	4	.12	.16**	.14	.23*	.12*	.06	.18**	.10	
(10) Grade in Spanish	3.22	0.85	0	4	.13*	.17**	.06	.13	.23**	.03	.23**	.08	.64**

Note. Q = *open-ended question*, P = *photos*. Spanish spoken at home: 0 = *never*, 1 = *less often*, 2 = *once a week*, 3 = *several times a week*, 4 = *daily*, 5 = *always*. Parental education: 0 = *no studies*, 1 = *elementary school*, 2 = *first stage of the secondary education*, 3 = *secondary education*, 4 = *professional training*, 5 = *short-cycle tertiary education*, 6 = *bachelor or equivalent level*, 7 = *master or equivalent level*, 8 = *doctorate or equivalent level*. Number of books for children is the sum score of (1) the number of books for children who do not read by themselves and (2) the number of books for literate children and youth

* $p < .05$, ** $p < .01$

when different assessment methods (open-ended question vs. photos) were used for assessing the same kinds of books (i.e., for adults vs. for children).

The different indicators of the number of books at home showed positive relations with parental education, the HLE, and with students' grades in math and Spanish. More correlations were statistically significant when the number of books for adults and those for children were assessed using open-ended questions than when using photographs. The HLE was unrelated to students' grades in math and Spanish. As expected, gender was significantly correlated with grades in math and Spanish, with girls outperforming boys (for a meta-analysis, see Voyer & Voyer, 2014). Children's Spanish use at home was unrelated to all study variables except for the number of books for adults as assessed by photos. This finding likely reflects the multilingual societal context in Spain where many students speak several languages (e.g., Spanish and Catalan) regardless of immigrant background. It thus diverges from findings from other countries, where multilingual students – often from immigrant and socio-economically disadvantaged families – tend to lag behind their monolingual peers academically (e.g., Hoff, 2018; OECD, 2023).

Distributions for the different books-at-home indicators were positively skewed. In particular, this was the case for the number of books for adults as measured by both open-ended questions and photos with a few people reporting about or providing photos of very high numbers of books. We refrained from excluding outliers for two reasons: First, the overall number of cases identified as outliers based on the commonly used 1.5 x interquartile distance rule was relatively large (19 and 12 cases for the number of adults' books as assessed by open-ended questions and by photos, respectively). Second, and most importantly, none of the outliers can unequivocally be identified as an error outlier. They fall in a range of 250 to 2,300 books for the open-ended question and of 194 to 802 books for the photos. The person who reported the highest number of books was also the one who had most books as measured in photos, thus corroborating the written information. As robustness checks, we reran all analyses after (1) collapsing the continuous data into commonly used categories (see, e.g., Heppt et al., 2022) when assessing the number of books and (2) after excluding the most pronounced outliers (i.e., cases which considerably exceeded other cases above the upper Whisker; e.g., for the number of books for adults, cases with 2,300, 1,200, and 1,100 were considered as outliers, while cases with 250 to 700 books – although being above the upper Whisker – were retained), resulting in $n=325$ (see Supplementary Material). The overall pattern of results corresponds to the results reported here. Discrepancies in the effects of the books-at-home measures are indicated in the following sections.

6.2 Multiple linear regressions for explaining HLE and grades in math and Spanish with the number of books as assessed with open-ended questions

We first investigated whether the number of books at home (as assessed with open-ended questions) explained students' grades in Spanish and math, controlling for child gender, Spanish spoken at home, and parental education (H1_{question}; Table 2). Effects of the number of books for adults and for children were investigated separately (Models 1a – 2b in Table 2) before jointly adding them to the regression model

Table 2 Multiple Linear Regression Models Explaining Students' Grades in Spanish and Math ($N = 332$)

Variable	Model 1a: Effects on the Grade in Spanish			Model 1b: Effects on the Grade in Math			Model 2a: Effects on the Grade in Spanish			Model 2b: Effects on the Grade in Math			Model 3a: Effects on the Grade in Spanish			Model 3b: Effects on the Grade in Math		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
<i>Assessment Method: Open-Ended Questions on the Number of Books at Home</i>																		
Child gender ^a	.24	.05	.000	.12	.05	.025	.25	.05	.000	.13	.05	.015	.24	.05	.000	.13	.05	.016
Spanish spoken at home	.03	.05	.546	.06	.06	.246	.04	.05	.455	.07	.06	.195	.04	.05	.478	.07	.06	.206
Parental education	.21	.05	.000	.17	.05	.002	.21	.05	.000	.16	.05	.004	.20	.05	.000	.15	.06	.006
Number of books for adults	.10	.06	.102	.08	.06	.187							.05	.07	.479	.04	.07	.610
Number of books for children							.15	.06	.012	.14	.06	.018	.13	.07	.057	.13	.07	.059
R^2	.12			.06			.13			.07			.13			.07		
<i>Assessment Method: Photos of the Number of Books at Home</i>																		
Child gender ^a	.24	.06	.000	.11	.06	.051	.24	.05	.000	.12	.06	.031	.25	.06	.000	.12	.06	.039
Spanish spoken at home	.03	.06	.656	.08	.06	.195	.05	.06	.433	.09	.06	.110	.03	.06	.572	.09	.06	.132
Parental education	.25	.06	.000	.17	.06	.008	.22	.06	.000	.13	.06	.029	.23	.07	.000	.14	.07	.038
Number of books for adults	-.05	.13	.731	.06	.12	.613				-.08	.14	.549	-.01	.13	.913			
Number of books for children							.07	.12	.588	.19	.11	.100	.10	.13	.460	.19	.12	.118
R^2	.11			.06			.12			.08			.12			.08		

Note: ^a0 = boy, 1 = girl. Number of books for children is the sum score of (1) the number of books for children who do not read by themselves and (2) the number of books for literate children and youth

(H2_{question}; Models 3a and 3b). In each model, child gender and parental education significantly contributed to explaining variance in grades in Spanish and math, indicating that girls received better grades than boys and that higher parental education came along with increased student achievement. Whereas no incremental effects were observed for the number of books for adults (Models 1a and 1b)⁴, the number of children's books explained significant amounts of variance in students' grades in Spanish and in math (Models 2a and 2b). Yet, the effects of the number of children's books just missed the level of statistical significance when jointly considering them with the number of books for adults (Models 3a and 3b). This effect is probably due to an increase in the number of predictors in the model, resulting in a reduced number of degrees of freedom, a slight increase in the standard errors for most predictor variables and, thus, reduced likelihood for significant coefficients. The regression coefficients of the two indicators of the number of books did not differ significantly (for grade in Spanish: Wald- χ^2 [$df=1$]=1.99, $p=.159$; for grade in math: Wald- χ^2 [$df=1$]=2.18, $p=.140$). The amount of variance explained in school grades in Models 3a and 3b was relatively small, with $R^2 = 0.13$ (Spanish) and $R^2 = 0.07$ (math). These differences in the amount of explained variance seem to be mainly due to differences in the predictive power of child gender, whereas effects of the number of books are largely comparable across domains.

We next explored the relations between the number of books (for adults [H3_{question}] and for children [H4_{question}]) and the HLE while controlling for child gender, Spanish spoken at home, and parental education (Model 4 in Table 3). Both parental education and the number of books for children were significantly and positively related to the HLE, whereas the effect of the number of books for adults was nonsignificant⁵. The effects of the number of books for adults and the number of books for children differed significantly from each other (Wald- χ^2 [$df=1$]=4.96, $p=.026$), further substantiating the above finding. The predictors jointly explained 15% of the variance in the HLE.

In a final step, we investigated the relation between the HLE and students' grades in Spanish and math by adding it as a further predictor beyond child and family background characteristics and the two variants of the open-ended books-at-home question (H5_{question}). The HLE was unrelated to students' grades in both domains and did not increase the amount of explained variance (Models 4a and 4b in Table 3).

6.3 Multiple linear regressions for explaining HLE and grades in math and Spanish with the number of books as assessed with photographs

We first investigated whether photographs of the number of books for adults (H1_{photos}) and for children (H2_{photos}) contributed to explaining student achievement in Spanish and math when controlling for important background variables (Models 1a through 3b

⁴ The number of adults' books emerged as a significant predictor of grade in math (but not in Spanish) when collapsing continuous answers into categories (Table S4) and as a significant predictor of grade in Spanish (but not in math) when excluding outliers (Table S6).

⁵ When collapsing continuous data into five answer categories, adults' books – but not children's books – were significantly associated with the HLE (Table S5). However, excluding outliers yielded the same result pattern as the one reported here (Table S7).

Table 3 Multiple Linear Regression Models Explaining the Home Literacy Environment and Students' Grades in Spanish and Math ($N=332$)

Variable	Model 4: Effects on the Home Literacy Environment			Model 4a: Effects on the Grade in Spanish			Model 4b: Effects on the Grade in Math		
	β	<i>SE</i>	<i>p</i>	β	<i>SE</i>	<i>p</i>	β	<i>SE</i>	<i>p</i>
<i>Assessment Method: Open-Ended Questions on the Number of Books at Home</i>									
Child gender ^a	.09	.06	.126	.24	.05	.000	.12	.05	.021
Spanish spoken at home	.00	.06	.961	.04	.05	.470	.07	.06	.190
Parental education	.20	.06	.001	.20	.05	.000	.14	.06	.014
Number of books for adults	.09	.08	.237	.05	.07	.519	.03	.07	.700
Number of books for children	.22	.07	.002	.12	.07	.074	.11	.07	.120
Home literacy environment				-.01	.06	.937	.06	.07	.346
R^2	.15			.13			.07		
<i>Assessment Method: Photos of the Number of Books at Home</i>									
Child gender ^a	.06	.07	.378	.25	.06	.000	.12	.06	.047
Spanish spoken at home	.04	.07	.552	.04	.06	.564	.09	.06	.125
Parental education	.19	.08	.015	.22	.07	.001	.12	.07	.066
Number of books for adults	.10	.14	.475	-.09	.14	.542	-.02	.13	.869
Number of books for children	.17	.13	.203	.10	.14	.465	.19	.13	.132
Home literacy environment				.03	.07	.674	.06	.07	.383
R^2	.12			.12			.09		

Note. Number of books for children is the sum score of (1) the number of books for children who do not read by themselves and (2) the number of books for literate children and youth. Model 4 when using open-ended questions on the number of books at home: $\chi^2=70.822$ ($df=42$, $p=.004$), CFI = 0.966, RMSEA = 0.045, SRMR = 0.039

Model 4ab when using open-ended questions on the number of books at home: $\chi^2=99.397$ ($df=54$, $p=.000$), CFI = 0.958, RMSEA = 0.050, SRMR = 0.042. Model 4 when using photos of the number of books: $\chi^2=60.038$ ($df=42$, $p=.035$), CFI = 0.978, RMSEA = 0.036, SRMR = 0.044. Model 4ab when using photos of the number of books: $\chi^2=88.877$ ($df=54$, $p=.002$), CFI = 0.967, RMSEA = 0.044, SRMR = 0.045. ^a0 = boy, 1 = girl

in Table 2). As before, child gender and parental education significantly contributed to explaining grades in Spanish, with girls outperforming boys and students whose parents had higher formal education outperforming those whose parents had lower formal education. As an exception, in one model (Models 1b), the effect of gender on students' grades in math was nonsignificant. Again, the number of books for adults was not predictive of grades in Spanish and math. However, in contrast to the results for the open-ended books-at-home question, there were no incremental effects of the number of children's books, neither when investigating them separately (Models 1a through 2b) nor jointly (Models 3a and 3b)⁶. When the number of books for adults

⁶ A slightly different result pattern emerged when collapsing continuous data into categories and when excluding outliers. In both cases, the number of children's books contributed to explaining grades in math

and those for children were considered simultaneously, the regression coefficients of the two indicators of the number of books did not differ significantly (for grade in Spanish: Wald- χ^2 [$df=1$]=0.66, $p=.416$; for grade in math: Wald- χ^2 [$df=1$]=1.45, $p=.229$). Remarkably, both indicators of the number of books had comparably high standard errors. The amount of variance explained in school grades in Spanish and math was very similar to the models that included open-ended questions for assessing the number of books at home, suggesting child gender and parental education to be the main predictors of school grades. As before, parental education significantly predicted the HLE (Model 4 in Table 6). However, neither the number of books for adults (H3_{photos}) nor the number of children's books (H4_{photos}) were significant predictors of the HLE. The effects of the number of books for adults and for children on the HLE did not differ (Wald- χ^2 [$df=1$]=0.40, $p=.527$). Investigating the role of the HLE as a predictor of student achievement in Spanish and math corroborated the above findings (H5_{photos}). In the final models, that included background variables, both indicators of the number of books at home (as assessed by photographs), and the HLE, only child gender and parental education emerged as significant predictors of students' grades in Spanish, whereas students' grades in math were not significantly predicted by any variable.

7 Discussion

While many studies use the books-at-home index in empirical educational and social research, only few have investigated this measure's quality and mechanisms that may help explain its importance for student achievement. The present study, hence, set out to examine the role of the HLE as a potential mediator in the relation between the number of books and student achievement in Spanish and math. By considering different variants of the books-at-home index (i.e., number of books for adults and for children), we aimed at gaining further insights into the underlying processes, whereas the use of different assessment methods (i.e., open-ended questions vs. photographs of the books in the respondents' homes), helped to assess the validity and reliability of typically used questionnaire items.

7.1 Explaining student achievement in Spanish and math as well as the HLE

Using open-ended questions for assessing the number of books at home, we found that the number of children's books but not the number of books for adults contributed to explaining students' grades in Spanish and in math, thus only partly supporting our hypotheses (H1_{question} and H2_{question}). While student gender and parental education predicted student achievement in both domains, this was not the case for the language use at home. Considering important control variables, the number of children's books – but not the number of books for adults – emerged as a significant predictor of the HLE. Again, this finding only partly corroborated our hypotheses,

(but not in Spanish; Tables S4 and S6). Using categories resulted in a significant effect of the number of children's books when considering the number of adults' books (Table S4).

as we had expected positive relations for both the number of parents' and children's books ($H3_{\text{question}}$) with larger effects for the children's books ($H4_{\text{question}}$). The HLE, however, did not contribute to explaining student achievement in either domain and, thus, did not act as a mediator in the relation between the number of books at home and student achievement. Hypotheses 5_{question} and 6_{question} were, thus, not confirmed either.

A different pattern of results emerged when drawing on photographs as an indicator of the number of books at home. Including it as a continuous variable and with outliers, neither the number of books for adults nor the number of children's books were significantly related to grades in Spanish and math (contradicting $H1_{\text{photos}}$ and $H2_{\text{photos}}$) as well as the HLE (contradicting $H3_{\text{photos}}$). Again, student gender and parental education were significant predictors of students' grades in both domains, whereas the HLE was unrelated to student achievement (contradicting $H5_{\text{photos}}$ and, consequently, also $H6_{\text{photos}}$).

Robustness checks based on (1) collapsing continuous data into commonly used categories and (2) excluding extreme outliers yielded largely convergent result patterns (see Tables S3–S7 in the Supplementary Material). However, we observed some significant effects for the number of parents' books for student achievement and the HLE, which is more in line with our hypotheses ($H1_{\text{question}}$ and $H3_{\text{question}}$). As for photos, the number of children's books emerged as a significant predictor of student achievement in some cases when using these alternative analytical procedures (supporting $H2_{\text{photos}}$). Overall, results suggest that the number of children's books is a more important predictor of student achievement than the number of books for adults and that using questions on the number of books at home seems to be a more viable approach than having participants send in photos. There is, however, no clear indication that the use of continuous data as obtained via open-ended questions is superior to transforming this information into commonly used categories.

The findings that the number of children's books plays a more important role in explaining student achievement than the number of books for adults and that this indicator is also more closely associated with the HLE are generally in line with our assumptions ($H1_{\text{question}}/H1_{\text{photos}}$ to $H4_{\text{question}}/H4_{\text{photos}}$). Thus, when it comes to explaining the relation between the number of books and student outcomes, it can be assumed that this association is mainly due to the learning potential and subsequent stimulating interactions surrounding the books in the home. Conducive interactions such as joint reading and conversations about reading experiences are much more likely to occur with books that are appropriate for school-aged children than for books aimed at adults (de Bondt et al., 2020; Heppt et al., 2022).

However, building on prior research, most of which relied on the number of books for adults (e.g., Eriksson et al., 2021) or used combined measures of the number of parents' books and children's books (Claes et al., 2024; Gustafsson et al., 2011), we had expected that the number of books for adults would also emerge as a significant predictor of student achievement in Spanish and math. As parents with larger home libraries are likely to be frequent readers (cf. Claes et al., 2024) and, hence, to act as role models, to share their reading experiences, and to foster literacy activities, the number of books for adults was also assumed to contribute to the HLE ($H4_{\text{question}}/H4_{\text{photos}}$). An explanation for this unexpected finding may lie in a possibly more

accurate assessment of the number of children's books than of the number of parents' books. As a striking finding when comparing the respective data from the two assessment methods, we found that participants indicated to have fewer children's books than parents' books (based on open-ended questions), which is in line with prior research (Heppt et al., 2022; Lehl, 2018), and that the numbers obtained via open-ended questions vs. captured in photos were quite similar for the number of children's books. For adults' books, however, the numbers indicated when answering the open-ended question exceeded the numbers identified in the photographs by far. It seems likely that the assessment gets increasingly inaccurate at the upper part of the distribution for people who have many books. Thus, ranges of up to 450 books, which was the maximum for children's books in our sample, may be estimated with sufficient accuracy when also presenting visual aids. Yet, differentiating in a range of up to 2,300 books, which was the maximum of adults' books indicated via the open-ended question, may become extremely difficult (and very cumbersome if all books are to be captured in photos; Iglesias, 2024). Along these lines, prior research that used categories for assessing the number of books and that did not differentiate above 200 books, reported much higher correlations for parents' books and children's books (Heppt et al., 2022; Pagel, 2016). Corroborating these assumptions, our robustness checks, involving a categorization of the continuous data and an exclusion of outliers, indeed identified the number of books for adults as a predictor of student achievement (when the number of children's books was not considered).

Contrary to our assumptions ($H5_{\text{question}}/H5_{\text{photos}}$) and to the majority of the pertinent literature (e.g., Niklas & Schneider, 2017; Sammons et al., 2015; Volodina et al., 2024; Wirth et al., 2022), the HLE was unrelated to student achievement in Spanish and math, precluding it as a potential mediator in the relation between the number of (children's) books and student achievement ($H6_{\text{question}}/H6_{\text{photos}}$). Although the bulk of studies on the HLE has focused on literacy activities experienced by children during preschool age (e.g., Claes et al., 2024; Niklas & Schneider, 2017; néchal & LeFevre, 2002), the emerging literature on later HLE suggests that literacy-related activities in the household experienced as children progress through school still have an impact on their academic achievement (McElvany et al., 2009; Sammons et al., 2015). Nevertheless, providing a language-rich environment and engaging in joint reading activities may possibly be even more relevant at an early age when children develop general basic knowledge and narrating skills. During elementary school when students deal with increasingly complex subject matter, language input and conversations might have to be more closely aligned with the lesson content to produce measurable effects.

Regarding the comparison of the two assessment methods, photographs of the number of books emerged as less predictive of students' academic achievement and the HLE than open-ended questions on the number of books. This finding might be largely attributable to the substantial amount of missing values for the photos. This missingness results in a relatively high degree of uncertainty in the estimates, as reflected in the relatively large standard errors (Little et al., 2022; Woods et al., 2024). This large amount of missingness in the photos is due to, among others, participants' preference for answering open-ended questions compared to uploading pic-

tures (Iglesias, 2024), resulting in lower response rates for the latter (further reasons for missing data are described in the Method section).

7.2 Limitations and future directions

This study has several limitations. First, data are based on an opt-in online panel, thus limiting its representativeness. It should be highlighted that quota of different sociodemographic characteristics (e.g., age, educational background) were used to ensure that the sample closely resembled the Spanish population of parents with children aged six to twelve (Iglesias et al., 2023). Yet, based on prior research on survey participation, it can be expected that certain groups (e.g., people with an immigrant background and with very high or very low SES; Feskens et al., 2006; Goyder et al., 2002) were underrepresented in the sample.

Second, due to its cross-sectional design, it is not possible to draw conclusions about the causal relations between family background (e.g., parental education, number of books at home), the HLE, and students' grades in Spanish and math. Based on theoretical assumptions and prior findings, SES indicators were modeled as predictors of both the HLE and students' grades. Reverse causality can be ruled out for some, but not for all of these relations. While it is quite implausible that children's school grades could have an effect on the number of adults' books in the home or parental education, reverse relationships could be assumed for the number of books and certain aspects of the HLE, for instance. People who score high on reading motivation and consider reading an important activity, are more likely to purchase books and have relatively large home libraries compared to people who enjoy reading less. Longitudinal assessments of the number of books and of various literacy-related attitudes and behaviors would help to gain further insights into their interplay and causal relationships.

Third, this study used school grades as an indicator of student achievement, whereas prior research on the number of books typically relied on achievement test scores (e.g., Eriksson et al., 2021; Evans et al., 2014). School grades show medium to large correlations with achievement on standardized tests (e.g., Bowers, 2011) and are of particular importance for later educational success (e.g., Starr et al., 2024). Yet, they are more prone to bias and, thus, less objective than standardized achievement test scores. Teachers typically do not only consider achievement when grading their students but also – consciously or unconsciously – incorporate aspects such as student SES, personality traits, or motivational characteristics (e.g., Vosylis et al., 2024). As findings based on different performance measures are not directly comparable, future research on different SES indicators and achievement should include both grades and standardized test results.

Fourth, we combined the two items on the number of books for children who do not read by themselves and the number of books for literate children and youth into a single indicator of the number of books for children. Given the sample size and the number of predictors in the models, this seems a viable approach. Additional analyses (Table S8) which included both indicators separately yielded nonsignificant effects for each, likely due to the increased number of predictors and, hence, limited number of degrees of freedom. To gain more nuanced insights into the role of the number of

children's books for student achievement, future research, drawing on larger sample sizes, would benefit from investigating these indicators separately. As families with more children can reasonably be expected to own more children's books, considering the number of children would be an additional asset.

7.3 Implications for the assessment of the number of books and conclusion

The present study identified the number of children's books as a predictor of elementary school students' achievement in Spanish and math when assessed via open-ended questions. By comparing the results of this assessment method with the results obtained from photos of books, the study has important implications for evaluating the reliability and validity of the books-at-home index. Additional analyses based on the transformation of continuous data into commonly used categories and on the exclusion of extreme outliers provide further insights on the use of continuous vs. categorical data when assessing the number of books at home. The high correlations of the number of (adults' and children's) books across assessment methods suggest that the open-ended question can be considered a sufficiently reliable indicator. Yet, open-ended questions suffer from rounding errors (Iglesias, 2026) and it is very difficult to provide accurate estimates of the number of books at home, in particular at the upper end of the distribution. Transforming continuous answers into commonly used answer categories could be a viable approach to tackle skewed data. Moreover, survey participants seem to be much more willing to answer a question on the number of books than to take photos of all the books in their home libraries (cf. Iglesias, 2024). This is reflected in the low response rates for the latter, which hamper the robustness of the analyses. For the time being, researchers aiming to assess the number of books at home are thus well-advised to continue to use questions in their surveys. However, given the rapid development of technological innovations in survey methodology, including the use of artificial intelligence which may soon facilitate the classification of images, the huge potential of an imaged-based assessment has not yet been fully implemented.

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Declarations

Conflict of interest Patricia A. Iglesias and Melanie Revilla are also authors of the tool used in this survey for image collection, called WebdataVisual (Revilla et al., 2022). WebdataVisual is openly available for public use, and the authors do not receive any financial compensation or benefits from third-party utilization of the tool.

Ethical approval The WEB DATA OPP project, of which this study is part, has received ethical approval from the Institutional Committee for Ethical Review of Projects (CIREP) in Universitat Pompeu Fabra (December 17, 2019, CIREP- approval no. 135) and confirmation from the Data Protection Officer of the Universitat Pompeu Fabra (December 20, 2019). Informed consent was obtained from all participants before they could start the web survey.

Open science statement This study, its hypotheses, and the analyses were not preregistered prior to the analyses. However, a study protocol, providing detailed information about the research design, was submitted after data collection but before conducting any data analyses. This study protocol also included the main research question of the present investigation (Iglesias et al., 2023). The present analyses are based on data from the project "WEB DATA OPP: New opportunities to enhance or extend (mobile) web survey data and get better insights". Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0) on the OSF project page. Code files used for data preparation and inferential analyses are also available from the OSF project page: <https://osf.io/54x7s/overview>

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