ZDM
https://doi.org/10.1007/s11858-019-01120-1

ORIGINAL ARTICLE

Mathematical help-seeking: observing how undergraduate students use the Internet to cope with a mathematical task

Mario Sánchez Aguilar[1] · **Danelly Susana Esparza Puga**[2]

Accepted: 20 December 2019

Abstract
We report on a study focused on identifying how undergraduate students make use of the Internet as a source of help to solve their mathematical queries. In particular, with the help of monitoring software, we observe how a group of engineering students use the Internet to solve a mathematical task related to the concept of definite integral, and we produce a characterization of their help-seeking behaviors. We observed that students manifest instrumental help-seeking behaviors mostly associated with the procedural items of the task (such as solving a definite integral), although there were executive help-seeking manifestations associated with the declarative questions (such as providing definitions). There was a general pattern of behavior manifested by the students who participated in the study; this pattern was dominated by the use of search engines and keywords to identify sources of mathematical help.

Keywords Mathematical help-seeking · Internet-based help-seeking · Undergraduate students · YouTube

1 Introduction

Help-seeking is a fundamental element in the study of school mathematics. It is difficult to imagine a mathematics student who during their school years has not encountered doubts or questions related to the contents of their mathematics lessons or their mathematical assignments. The emergence of these doubts or questions, and the search for help to try to clarify them, is an inherent component of the process of studying mathematics in school and beyond.

Technologies such as the Internet and mobile devices have modified the ways in which students seek mathematical help. These technologies have made it possible to expand and diversify the sources of mathematical information available to students. In addition, such technologies allow quick access to these information sources. Nowadays many students prefer to watch a YouTube video at home rather than to turn to a library in order to clarify a mathematical interrogation (Puga 2013).

The most recent educational studies on help-seeking have focused on investigating the ways in which technologies such as the Internet impact students' help-seeking practices (see for example Qayyum 2018). Although our practical experience shows that students frequently use this type of digital resource for their mathematics lessons, little is known from the mathematics education research perspective about the factors that influence and shape the help-seeking behaviors of mathematics students in this digital era.

In this paper we report on an investigation aimed at advancing our understanding of the Internet-based help-seeking behaviors of undergraduate mathematics students, particularly engineering students. Through the use of a conceptual framework constructed with notions coming from help-seeking research, we characterize the help-seeking behaviors that students display when facing a mathematical task with whose mathematical underpinnings they are not completely familiar.

To develop the research study, we used a method that has the potential to overcome some of the limitations inherent in the empirical methods that have been usually deployed in research on mathematics help-seeking. Several studies that have aimed to investigate the help-seeking behaviors of mathematics students are based on students' self-reports (see

✉ Mario Sánchez Aguilar
mosanchez@ipn.mx

Danelly Susana Esparza Puga
danelly.esparza@uacj.mx

[1] Instituto Politécnico Nacional, CICATA Legaria, Programa de Matemática Educativa, Mexico City, Mexico

[2] Universidad Autónoma de Ciudad Juárez, Instituto de Ingeniería y Tecnología, Ciudad Juárez, Mexico

Published online: 07 January 2020

for example Ryan and Pintrich 1997; Skaalvik and Skaalvik 2005); however, it has been claimed that self-report measures are considerably inaccurate when compared to actual behaviors (Junco 2013). In our study we make use of self-reports but we complement them with the analysis of students' solving of mathematics tasks, supported by the use of monitoring software.

To situate our own work in the research landscape, in the following section we present an overview of educational research on help-seeking, placing special emphasis on studies related to help-seeking in mathematics.

2 An overview of help-seeking research

Help-seeking is a phenomenon that has been studied for several years by sociologists, psychologists and other scholars. Generally speaking, help-seeking studies aim to identify and explain what demographic, sociocultural and psychological factors encourage people to seek—or to avoid—the help of others. Traditionally these studies have been developed in medical, work-related, welfare and social security contexts (e.g., Wistrand 2017).

In the earliest research studies, help-seeking behavior was conceptualized with a negative connotation. It was interpreted as a manifestation of dependence or as an indicator of a deficient development in the individual (Beller 1955); it was associated with deterioration in self-esteem, self-perception, and individuals' sense of competitiveness (e.g., Shapiro 1978). In sum, help-seeking was conceptualized as a behavior that should be avoided.

The work by Nelson-Le Gall (1981, 1985) contributed to developing a more positive conceptualization of help-seeking behavior, particularly in the field of educational research. She claimed that "researchers have tended to consider only the costs of seeking help for the individual's sense of competence rather than the costs of not seeking help for the acquisition and mastery of skills" (1985, p. 63). The main contribution of Nelson-Le Gall was to propose a reconceptualization that moved away from the stigmatized vision of help-seeking, and where this behavior was understood as a skill or competence useful for learners in addressing problems that otherwise would be difficult to overcome. Now help-seeking could be seen as a useful skill for students' self-learning. Nowadays the conceptualization and the theoretical notions developed by Nelson-Le Gall are widely acknowledged and applied, and help-seeking behavior is perceived as an important strategy for attaining success in school.

2.1 Research on help-seeking in mathematics education

There is a tradition of studying help-seeking in mathematics from a psychological perspective. The first studies that were developed within this perspective sought to understand basic issues about mathematics students' help-seeking behavior. For example, Newman and Schwager (1993) investigated which people students (aged 9–13) preferred to ask for mathematical help when needed. They found that students generally preferred their teachers to classmates as helpers because they were thought to be more likely to facilitate learning and less likely to think they were 'dumb' for asking questions.

Some researchers began to notice that help-seeking behaviors could be different when mathematics students worked in teams; furthermore, helping behaviors were viewed as an important indicator of the overall quality of the groups' social interactions (Kempler and Linnenbrink 2006). Subsequently, studies focused on analyzing the nature of help-seeking behavior in small peer groups were conducted. For example, Webb and Mastergeorge (2003) tried to identify the helping behaviors, within peer-directed small groups, that may be most effective for student learning in collaborative mathematics classrooms. Their findings show that effective help-seekers ask precise questions, persist in seeking help, and apply the explanations received. In contrast, effective help givers provide detailed explanations of the material as well as opportunities for help recipients to apply the help received, and they also monitor student understanding.

Another group of studies tried to identify the personal traits and contextual factors that influence the help-seeking and help avoidance behaviors among mathematics students. For instance, there are studies that have developed student profiles according to the help-seeking tendencies that they exhibit (Ryan et al. 2005; DeFeo et al. 2017). A study that illustrates the influence of contextual factors on help-seeking behaviors is that of Turner et al. (2002), in which they explain how mathematics classrooms can be structured in different ways and therefore privilege some students' achievement behaviors. In other words, the students tend to perceive these different classroom climates and adjust accordingly their own help-seeking behaviors.

There are studies suggesting that help-seeking positively influences mathematics achievement, as reflected in students' grades in mathematics. An example is the study by Schenke et al. (2015), in which the relation between self-reported help-seeking tendencies and standardized mathematics achievement was examined. The results of their study show that student reports of seeking help from the teacher and seeking instrumental help (a kind of help-seeking behavior that is focused on understanding, and that we explain later in more detail) were both associated with significant gains in mathematics achievement.

Most of the research studies that have been developed on mathematical help-seeking have students as subjects of study. An exception is the work by Marais et al. (2013), which is concerned with teacher knowledge of learners' help-seeking behavior. The participating teacher was asked to estimate the expected help-seeking behaviors of learners when they were solving mathematical word problems, and then these estimations were compared with the actual help-seeking behavior of the learners. The analysis showed that, in many instances, the teacher's knowledge of the source of help was congruent with learners' actual help-seeking. Such congruency was taken to indicate how accurate knowledge on the part of the teacher can aid interaction and learning support. Based on our literature review we can affirm that mathematics teachers' practices and knowledge about help-seeking is still an underexplored area in our field.

It is important to note that some of the research studies that we reviewed possess common characteristics. For instance. most of them have mathematics learners as study subjects (e.g., Ryan and Pintrich 1997; Zusho and Barnett 2011); the use of quantitative approaches in order to find correlations between variables is also a common feature among various research studies (e.g., Skaalvik and Skaalvik 2005; Blondeau and Awad 2017). In addition, most of the studies use self-reports on students' help-seeking behaviors as their main source of empirical data (e.g., Turner et al. 2002; Schenke et al. 2015). However, a characteristic that is shared by all the studies that we reviewed is that they consider only human agents (teachers, classmates, family members, faculty staff) as sources of help. In other words, few studies have addressed the way in which digital technologies—such as the Internet—can serve as a source of mathematical help for students, and how such technologies affect mathematics students' help-seeking practices. In the next section we review research studies that have been developed in that direction.

2.2 Research on Internet-based help-seeking in mathematics

Early studies developed in this area focused on characterizing students' help-seeking behaviors in Internet-based mathematics help forums (Puustinen et al. 2009; van de Sande 2011). Puustinen et al. (2009) examined, over a period of 42 months, the content of students' help-seeking messages in a French forum that provides students with free individualized help in mathematics. The researchers were interested in clarifying if there were different forms of help-seeking messages among the students (aged 11–15 years), and whether the form of those messages changed with age. Their results showed that the older students' messages contained context-related information and explicit requests for help more often than the younger students' messages did. This was interpreted to imply that "only the 15-year-olds were capable of producing help-seeking messages that were both fully understandable and socially acceptable" (p. 1045). This result implies that, due to their difficulty in formulating clear help requests, the youngest students were at a high risk of being misunderstood by the tutor in the forum.

The work of van de Sande (2011) confirmed something that was perceived in the study of Puustinen et al. (2009): the fact that mathematics students from different regions of the world used the Internet as a source of mathematical help, particularly online mathematics forums. One of the aims of this study was to characterize student activity in a free and open online mathematics forum called Math Help Forum (see https://mathhelpforum.com). This is a forum with users around the world, where people post their mathematical doubts and questions in order to solve them collaboratively with other forum users. As part of its results, the study of van de Sande offers a characterization of students' behavior in the construction of the solution to the mathematical problems or questions that they post. This characterization identifies students who passively wait until the problem they posted in the forum is solved, while other students get more actively involved in the collaborative construction of the solution.

Our own research has focused on understanding how digital technologies such as the Internet affect undergraduate mathematics students' help-seeking behaviors (Puga and Aguilar 2015; Aguilar and Puga 2015; Puga 2018a). While Puustinen et al. (2009) and van de Sande (2011) showed the popularity of online help forums among mathematics students, we asked ourselves: what other Internet resources do the students use for seeking mathematical help and how do they use them? After all, our own teaching experience and the research literature (e.g., Hrastinski and Aghaee 2012) suggested that the universe of Internet resources on which students relied to support their learning was much broader.

The help-seeking study that we developed initially (see Puga and Aguilar 2015) was based on students' self-reports obtained through focus groups. We focused on identifying the most popular Internet resources used as a source of mathematical help among engineering students. We also explored their frequency of use, and the reasons why students used and trusted those sources of help. We found that all the participating students (engineering students, aged 21–25 years) used the Internet to try to clarify their questions related to their mathematics lessons. Often, they turned to sites such as YouTube, Facebook and Google to find mathematical help; particularly, they resorted to these sites to clarify doubts and review topics covered in class, to find different ways to solve a problem, to verify results, and to see task solutions explained step by step. We also found that several students based the reliability of the Internet sources that they consulted on the authority provided by the academic degree or status of the author, or the prestige of the institution that produced the resource. For instance, there was a student participating in one of the studies who claimed: "YouTube seems reliable to me because university teachers upload the videos" (Puga and Aguilar 2015, p. 2542).

In this paper we report the most recent findings derived from our research on Internet-based mathematical help-seeking among undergraduate students. We implemented a methodological enhancement in our research by complementing students' self-reports with actual observations of their help-seeking behaviors on the Internet when solving a mathematical task. As we show, this has allowed us to develop a more detailed description of their help-seeking behaviors on the Internet.

3 Conceptual clarifications and research aim

In this section we introduce some notions that allow us to formulate with more precision our research interest, and our own theoretical stance on mathematical help-seeking.

3.1 Mathematical help-seeking and types of help-seeking

Inspired by research that conceptualizes help-seeking as a self-regulated learning strategy (e.g., Nelson-LeGall 1985; Karabenick and Gonida 2018), we understand *mathematical help-seeking* as a self-regulated learning strategy in which an individual draws on the people and resources around them (including technological resources such as the Internet and mobile devices) as sources of help to overcome the difficulties and doubts that arise during their mathematics learning process.

When we use the terms *Internet-based mathematical help-seeking* or *Internet-based help-seeking*, we refer to mathematical help-seeking behavior that is solely based on resources from the Internet.

As noted by Nelson-Le Gall (1981, 1985), help-seeking may serve multiple purposes:

> The student's goal in seeking help may be merely task completion, without comprehension or mastery as an objective. Alternatively, the student's purpose in seeking help may be to avoid criticism from an agent of evaluation, or to avoid the task altogether. Help may be sought, however, for a far more constructive purpose, such as enhancing the student's own competence. (Nelson-Le Gall 1985, pp. 66–67)

Thus, Nelson-Le Gall (1985) distinguishes between two types of help-seeking: one that is dependency-oriented (called *executive help-seeking*) and another that is mastery-oriented (called *instrumental help-seeking*). *Executive help-seeking* refers to situations in which student's purpose is to find something or someone to help them to solve a problem, or reach a goal on their behalf. In this kind of help-seeking the student is interested only in solving the problem, but is not interested in learning how to solve it. Instances of executive help-seeking in mathematics are asking a friend to solve a mathematical task on one's behalf or searching on the Internet for ready-made solutions to one's mathematical problems. In the case of *instrumental help-seeking*, the student's search is more focused on promoting a self-understanding of an idea or a problem-solving process. Furthermore, the amount of help requested tends to be limited, so that the student receives only the amount of help needed to solve the problem on his or her own. Receiving hints, indirect help, and explanations, are examples of instrumental help-seeking in mathematics.

It is preferable for individuals to develop instrumental help-seeking skills. Nelson-Le Gall (1985) argued that "continued reliance on others to provide more than is needed would be detrimental to the development of independent mastery and might even induce dependency" (p. 67). Put another way, it is not desirable to have learners' conduct dominated by executive help-seeking behavior. On the contrary, the researcher cited studies from that time (e.g., Ames 1983) to argue that instrumental help-seeking should be considered an achievement behavior that is associated with the development of self-regulatory skills.

3.2 The blurry frontier between help-seeking and information-seeking

A domain related to help-seeking is the one termed *information-seeking* or *information search* (see for example Sapa et al. 2014). As we pointed out in the previous section, help-seeking research has traditionally considered only human agents (teachers, classmates, family members, faculty staff) as a source of help. In contrast, information-seeking behavior is traditionally associated with "learner-initiated efforts to obtain further task-related information from books or other *non-human sources* when undertaking an assignment" (Puustinen and Rouet 2009, p. 1014, our emphasis). However, digital technologies blur this dichotomy between human and non-human sources.

Consider as an example a student who did not fully understand a mathematical procedure that was explained in class, and later from home he turns to a YouTube video that shows a teacher explaining step by step the way to carry out the procedure that he did not understand. Is the student consulting a human or non-human source to try to understand the procedure? A possible answer to the previous question is that the student is consulting a non-human source of information, which embodies a human source of help. Suppose now that the same student uses the comments section of the video he has just watched to raise a specific query about the procedure. Then in the following hours he receives a personalized response from the author of the video. What would now be the answer to the previous question?

What we want to illustrate with the previous example is how digital technologies such as the Internet, tend to blur the dichotomy between "the human" and "the non-human", which usually supports the distinction between information-seeking and help-seeking. Thus, in this research, we adopt the position of Puustinen and Rouet (2009), in which help-seeking is "regarded as a more comprehensive construct than information searching that includes traditional human support, but also those situations in which the student/expert interaction is 'mediated' by an information system" (p. 1018). In this way, we found relevant for our own research, studies such as that of Sapa et al. (2014) which investigated the way in which mathematics students and professional mathematicians use the Internet to search for academic information—even if such studies are labeled as "information-seeking".

3.3 Aim of the study

We now present, in a more precise way, the aim of the research study on which we report in this paper.

Our general interest is focused on characterizing the Internet-based mathematical help-seeking behaviors of undergraduate students. However, we want to move one step ahead of students' self-reports, and use a procedure that is closer to the observation of students' actual behaviors. Thus, based on the use of monitoring software, the main aim of our research is as follows:

- Research aim. *To characterize the mathematical help-seeking behavior of undergraduate students when they turn to the Internet to try to solve a mathematical task.*

To develop the characterization, we use the concepts of executive help-seeking and instrumental help-seeking presented in Nelson-Le Gall (1985). Additionally, through the analysis of the interviews, the videos produced by the monitoring software, and the procedures registered by the students in the worksheets, we provide an account of Internet resources that the students use, and how they use them.

In the next section we explain the empirical method that we implemented in order to achieve the research aim.

4 Method

As we illustrated in the literature review, most of the studies on help-seeking use self-reports on students' help-seeking behaviors as their main source of empirical data. However, self-reported measures of behavior are problematic.

Junco (2014) made the argument for considering self-report measures inaccurate when compared to actual behaviors. He mentioned several research studies from different areas of knowledge that show significant differences between self-reported and actual behaviors. In a previous study (Junco 2013), the same researcher reported discrepancies between college students' self-reports on social networks use and their actual behavior. According to Junco (2013, 2014), a possible alternative to try to relate self-report measures to current behaviors in computer-based activity, is to use monitoring software.

In this study we adopted the use of monitoring software with the aim of getting a little closer to students' actual help-seeking behaviors. The use of monitoring software allows us to contrast students' self-reports, but also assists us in producing a detailed description of their help-seeking behaviors on the Internet. The students who participated in this study were monitored while they were solving a mathematical task specially designed for the research. In what follows we describe (1) the characteristics of the students who participated in the study, and the research activities in which they participated, (2) the design and implementation of the mathematical task tackled by the students, and (3) the analysis of the data generated during the implementation.

4.1 Characteristics and activities of the research participants

Thirty Mexican engineering students from the Institute of Engineering and Technology at the Autonomous University of Ciudad Juárez in Mexico (UACJ) participated in the study. This institute is a public institution of higher education and is located in the city of Ciudad Juárez on Mexico's northern border, south of the city of El Paso, Texas, in the United States. The Institute has an approximate population of 4500 students from this area and with socio-economic backgrounds ranging from medium to low.

Twenty-one participants were male students and nine were female students. The students volunteered to participate in the study, and they were aware that their activity would be recorded and analyzed for research purposes. At the time they participated in the study, the undergraduates were studying a branch of engineering (such as civil engineering, mechanical engineering or biomedical engineering). The age range of the participants was 18–36 years, because they were enrolled in different semesters. During their first semester, students take mandatory courses such as advanced algebra, differential calculus, integral calculus, and introduction to probability and statistics. The second author of this paper was the mathematics teacher for the participating students in at least one course, which facilitated their cooperation and participation in the study.

The students participated in two research activities during the study. First, ten students volunteered to be interviewed (in focus groups of five members) about their own help-seeking behaviors. The interviews took place in a classroom at the UACJ, during the semesters August–December 2016 and January–August 2017. The same interview guide reported on by Puga and Aguilar (2015, p. 2540) was followed, and all the interviews were audio recorded. The main purpose of this interview was to identify the Internet sites most frequently used by the students; however, they were also interviewed about the frequency of use of those sites, how they used them, the perceived advantages and disadvantages of using them, and the reasons to trust them. Secondly, all the students solved a mathematical task, assisted by the use of a computer with Internet access. According to their mathematical background, some students solved a task related to the notion of rate of change, while other students—most of them—solved a task related to the notion of definite integral. In this paper we report on the group of twenty-four students who participated in the mathematical activity on definite integral. We also report on the main findings of the interviews. Details of the investigation that are not reported in this paper can be consulted in the dissertation of Puga (2018b).

4.2 Design and implementation of the task

We designed a seven-item task related to the concept of definite integral. The task includes a couple of declarative questions (linked to definitions), and the rest are procedural questions (related to calculations and estimations). We included different types of questions to examine whether they affect the kind of help-seeking behavior that the students manifest. Next, the seven items included in the task are presented (Figs. 1, 2):

1. How would you define the definite integral?
2. What is the difference between the definite integral and the indefinite integral?
3. Consider the graph of the function $f(x) = -x^2 + 4x$. How would you calculate the area under the curve from $x = 0$ to $x = 4$?

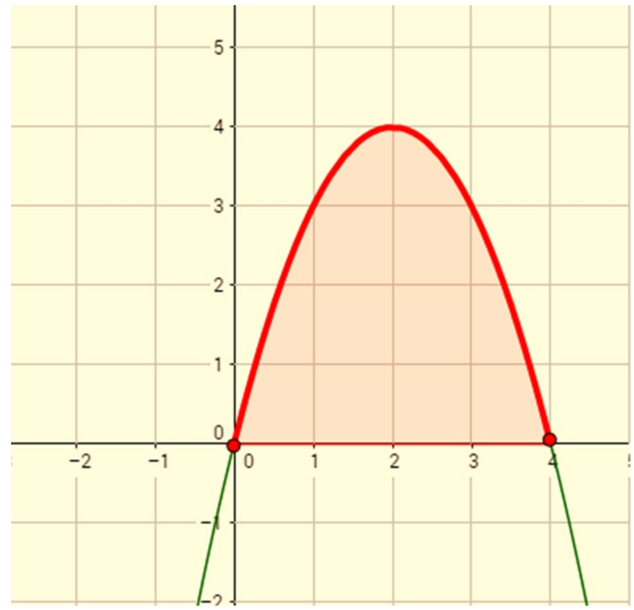


Fig. 1 Graph of the function $f(x) = -x^2 + 4x$

4. Taking into consideration 5 rectangles, estimate the area under the curve defined by $f(x) = -x^2 + 4x$
5. What happens when you estimate the area under the curve of the function $f(x) = -x^2 + 4x$ by considering 8 rectangles?
6. Calculate $\int_0^4 (-x^2 + 4x)dx$
7. Is there any relationship between the area that you calculated in the exercises 4 and 5 with the result that you obtained in exercise 6?

The task was designed for students who had knowledge of differential calculus and elementary knowledge of integral calculus. At the time of applying the task the students had covered the topic of indefinite integral, but not yet the topic of definite integral. A prerequisite was that the participating students did not know the topic of definite integral, but that they had the necessary mathematical background to be able to tackle the proposed task. In a sense, we were trying to design a *problem* for the students—in the sense of Schoenfeld (1985)—as opposed to an *exercise*; all this to try to generate an authentic need for mathematical help-seeking.

The task was implemented during downtime between lessons in a classroom at the UACJ, which was equipped with personal computers and Internet access. At the time of the implementation, on all computers we had installed an open source monitoring software called *iSpy* (see https://www.ispyconnect.com). The activity was implemented in four sessions (six students participated in each session), with a duration that ranged from 60 to 90 min. The sessions were held during the semester January–August 2017.

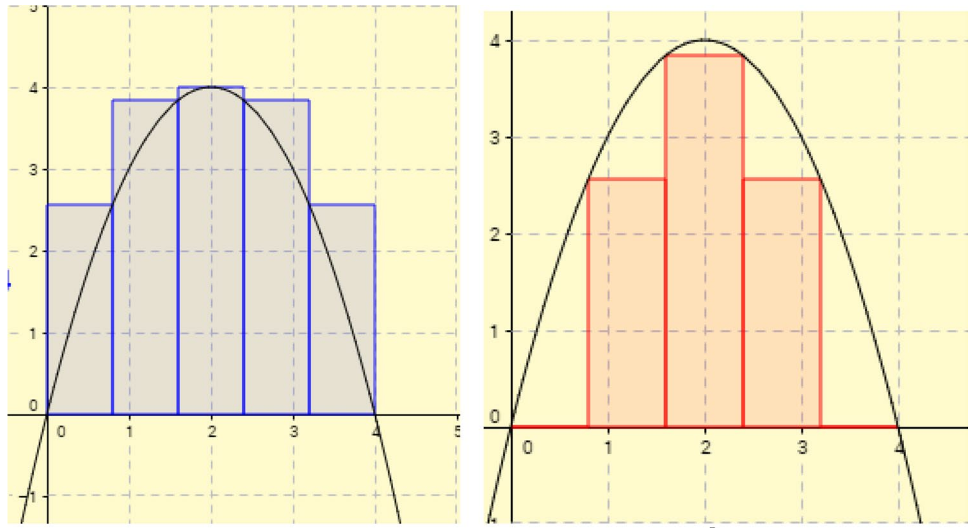


Fig. 2 **a** Upper area. **b** Lower area

The activity was distributed among the students in print. For their solution process the students could use the computer (which recorded all the students' activity), but they could also make calculations by hand or annotations on blank sheets of paper, which were collected as part of the empirical data.

4.3 Analysis of the data generated during the implementation

Three sources of empirical data were generated in this research study: (1) the audio recordings of the group interviews, (2) the video recordings of students' computer-based activity, and (3) the worksheets produced by the students during the solving process of the mathematical task.

All data sources were subjected to an *investigator triangulation* (Rothbauer 2008). That is, the data were analyzed independently by the two authors of the study and, subsequently, such analyses were subjected to a comparison. In this way, the reported findings are the product of collective analysis and discussion, as well as a result of the consensus among the analysts about the interpretation of the data.

In the case of the audio recordings from the group interviews, we focused on identifying specific answers to each of the questions contained in the interview guide. For this we implemented a *tape-based analysis* (Onwuegbuzie et al. 2009) in which we first became familiar with the data—by listening to the interviews repeatedly—in order to identify the answers, and then we transcribed only the parts of the interviews that were useful to illustrate the answers identified.

To analyze the videos of the students' computer-based activity, we applied a method inspired by 'Grounded Theory' to analyze observational data obtained by video recordings (see Griffiths 2013). For this purpose, we began by making detailed transcriptions of the micro-behaviors manifested by each of the students during their Internet search. Table 1 shows an extract of one of those transcripts.

Once these transcripts were produced, a coding process of the micro-behaviors was developed. Examples of the codes produced when categorizing the micro-behaviors are 'copy & paste keywords', 'creative keywords', 'search engine as starting point', 'superfluous source exploration' and 'detailed source exploration'. Then, through comparisons and code groupings, as well as collective discussions,

Table 1 Excerpt from a transcription of a video recording that contains the computer-based activity of a participating student

Minute	Micro-behaviors
1:09	Switch from Bing to Google search engine
1:12	Introduces "definite integral" as keyword in the Google search engine
1:17	Clicks on the first option that appears on the search results page (Basque Government Learning Portal), but the page does not open
1:37	Clicks on the second option from the results page (Vitutor)
1:44	Finds a definition, and he seems to spend a few seconds reading it
2:23	Returns to the Google search results page
…	…

certain categories of behavior emerged. These categories are presented in the results section.

Finally, the worksheets produced by the students were used to compare and validate our interpretations of the behaviors identified through the analysis of the videos. In other words, they served as a data source that allowed us to triangulate and provide reliability to our interpretations of the video recordings.

5 Results

Now we present the results obtained through the analysis of the empirical data. The presentation of results is divided into two sections: (1) main outcomes of the interviews, and (2) analysis of instrumental help-seeking vs. executive help-seeking. All the excerpts from the interviews that are used to illustrate the results, were translated from Spanish to English.

5.1 Main outcomes of the interviews

Analyzing students' self-reports about their help-seeking behaviors is an initial step in achieving our research aim. The results obtained from the analysis of the group interviews were very similar to the results obtained in previous interviews where the same guide was used (e.g., Puga 2013, 2018a). For instance, all interviewees reported using the Internet as a source of help for their mathematics lessons, some of them on a daily basis. YouTube, Google and Facebook were among the most frequently used sites by the students as a source of mathematical help, as illustrated in the following transcripts:

> *Student 2, Focus Group 1*
> "I turn to the Internet every time we see a new topic […] I always google the topics to complement what was seen in class."
> *Student 1, Focus Group 2*
> "I usually watch video tutorials from YouTube, but I also consult Yahoo! Answers and WolframAlpha to confirm my results."

According to the group interviews, a very popular source of mathematical help among students is the YouTube channel called "julioprofe" (probably an abbreviation of the expression "Professor Julio" see https://www.youtube.com/user/julioprofe). This channel is administered by a Colombian mathematics teacher, where he shares step-by-step explanations and illustrations of various mathematical algorithms and procedures. The channel currently has more than three million subscribers. The interviewed students stated that the explanations provided by this teacher are quite clear:

> *Student 3, Focus Group 2*
> "When I'm looking for something I go directly to YouTube and consult julioprofe because he explains very well."
> *Student 4, Focus Group 2*
> "I understand julioprofe better because he makes everything easier."

Finally, the students declared that they used these Internet-based sources of help for the following purposes: (1) to clarify doubts and reinforce topics seen in class, (2) to find different ways to solve a specific problem, (3) to verify results, and (4) to see problem solutions developed step by step. The following transcripts illustrate these uses:

> *Student 3, Focus Group 1*
> "Sometimes teachers assume that we understand or we should know some things, so when they solve exercises they skip steps. For example, when they are going to solve an integral they write the function and the next step is the result of the integral of the function. So, sometimes it is unclear and it is better to search on the Internet for examples to know where these results come from."
> *Student 5, Focus Group 2*
> "I go to the Internet to look for exercises, I like to practice and review. I look for videos of exercises already solved, and I pause them to solve them and then verify my result with that of the video."

5.2 Instrumental help-seeking vs executive help-seeking

As part of the characterization of students' Internet-based help-seeking behaviors—our research aim—we tried to determine if the searches for help to solve the mathematical task were dominated by instrumental help-seeking behaviors, by executive help-seeking behaviors, or by a combination of both. Our analysis shows the existence of a general pattern of help-seeking behavior manifested by the students who participated in the study; such a pattern is dominated by the use of search engines and keywords to identify sources of mathematical help. Furthermore, our results suggest that the help-seeking attempts of all students were dominated by instrumental help-seeking behaviors mostly associated with the procedural items of the task, although there were executive help-seeking manifestations, mainly associated with the declarative questions. Below we illustrate the situations in which students manifested such help-seeking behaviors.

5.2.1 Instances of executive help-seeking

Particularly in the case of the first item where a definition is requested (How would you define definite integral?), it triggered executive help-seeking behaviors in which students would search and copy any definition they could find on the Internet. As shown in Fig. 3, students manifested a strong tendency to use the Google search engine to locate the requested definition, and then to copy it.

However, we have evidence suggesting that students can copy the definition that they locate on the Internet, but without the intention of understanding it. Let's consider as an example the case of student A, who visited a website that contains a definition of definite integral (see Fig. 4). Apparently, he copied only some sentences from the definition, namely, "es el proceso inverso de la diferenciación" (it is the inverse process of differentiation) and "no tiene límites" (it has no limits), and copied them down in a definition that is not adequate, but apparently student A did not realize this (see Fig. 5).

Another example is item 2 (What is the difference between the definite integral and the indefinite integral?). Not all students tried to formulate an answer to this question by considering the information obtained by answering item 1 (How would you define definite integral?) and trying to connect it with the basic knowledge that they were supposed to have about indefinite integrals. Several students simply copied the question and searched for the answer on the internet, obtaining potential answers from forums such as Yahoo! Answers (Fig. 6).

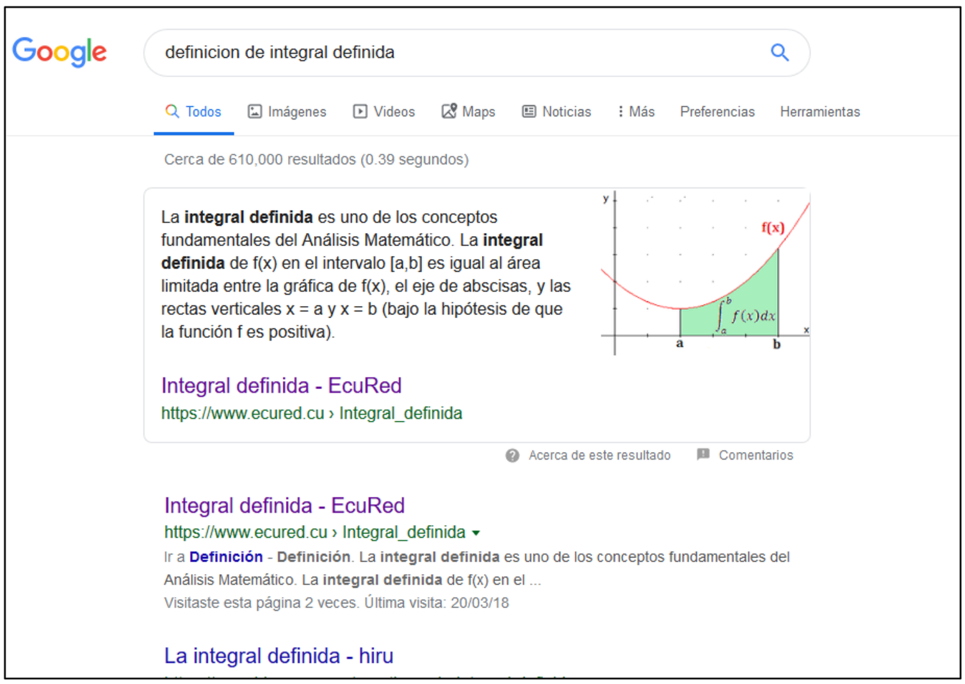
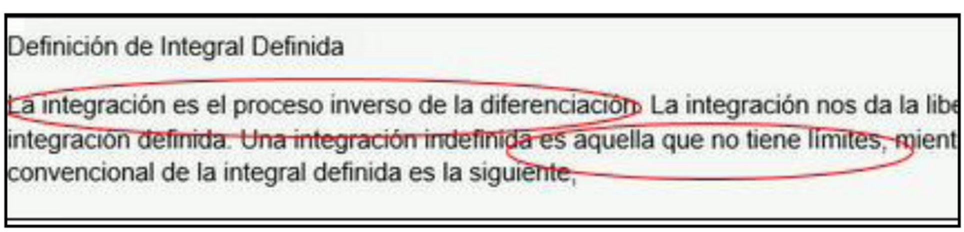


Fig. 3 Screenshot that shows how a student used the Google search engine to write the keyword "definicion de integral definida" (definite integral definition), and thus locate the requested definition


Definición de Integral Definida

La integración es el proceso inverso de la diferenciación. La integración nos da la libe
integración definida. Una integración indefinida es aquella que no tiene límites, mient
convencional de la integral definida es la siguiente,

Fig. 4 Excerpt from the website visited by student A. Enclosed in red ovals are the phrases that the student apparently copied

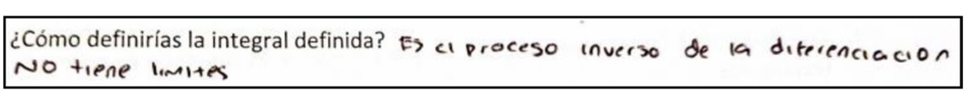


Fig. 5 Definition provided by the student A after visiting the website shown in Fig. 3. The phrase reads: "It is the reverse process of differentiation. It has no limits", but a definite integral does have limits (of integration)

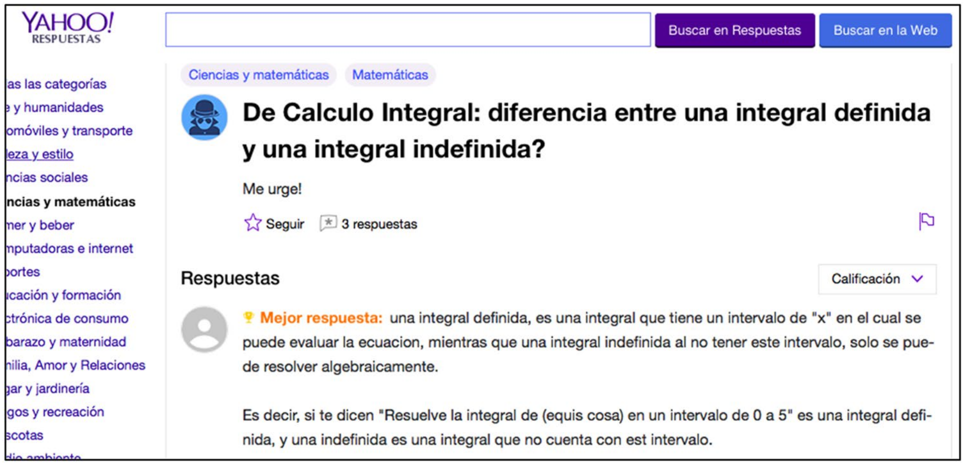


Fig. 6 Screenshot from the Spanish version of the Yahoo! Answers site. In this site a student found a forum in which exactly the same question included in item 2 (What is the difference between the definite integral and the indefinite integral?) had been answered

5.2.2 Instances of instrumental help-seeking

Instrumental help-seeking was more frequent when students approached the procedural items, such as calculating $\int_0^4 (-x^2 + 4x)dx$ (item 6). An example of this behavior was manifested by student B, who initiated the solution of the task by inserting the keywords "definite integral solved exercises" and "calculate area under a curve" in the Google search engine. Although one might think that the student was looking for executive help because he was looking for a site with solved exercises, the student consulted this and other kinds of websites, which nevertheless did not seem to satisfy him and he finally discarded them. Then he went back to the Google search engine and refined his search by using more specific keywords, namely "area under a curve quadratic equation" and "area under a curve with inscribed rectangles". Note how these new keywords are associated with the particularities of the task at stake (Fig. 7).

The student delved into two of the resources that are found through this second search: a YouTube video and a GeoGebra applet; both resources showed how to approximate areas under a curve using inscribed and circumscribed rectangles, but after a brief inspection, the student discarded them. Nevertheless, there was a video from the YouTube channel "julioprofe" that caught his attention. In this video the integral $\int_1^4 (2x^2 + 3x - 1)dx$ is solved step by step (see https://youtu.be/V7WnsXYJZaM). Although the video lasts a little over six minutes, the student spent

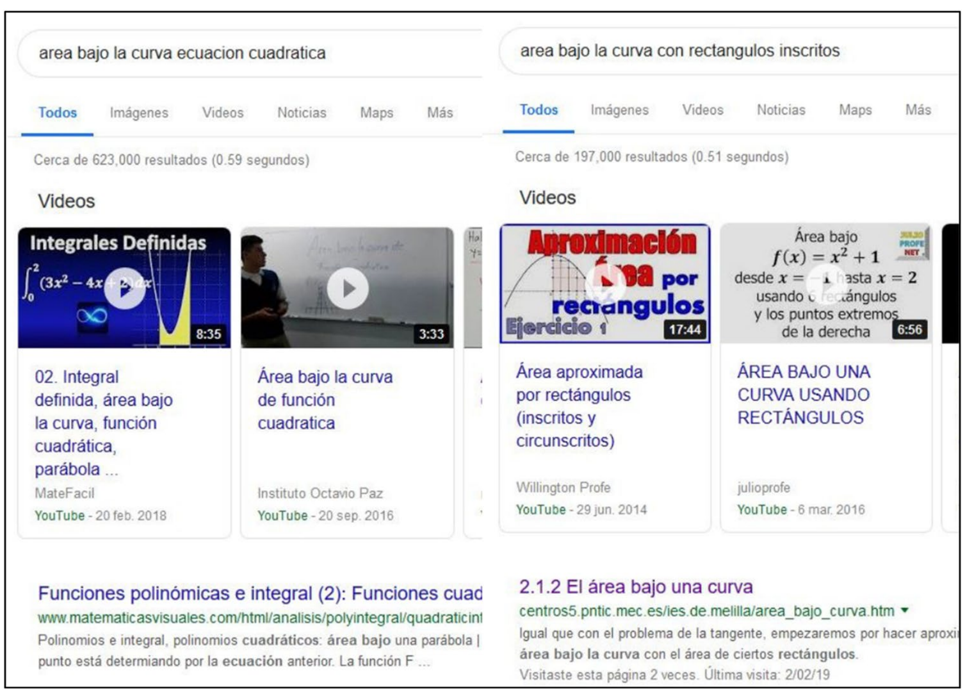


Fig. 7 Results of two Internet searches using the keywords "area under a curve quadratic equation" and "area under a curve with inscribed rectangles"

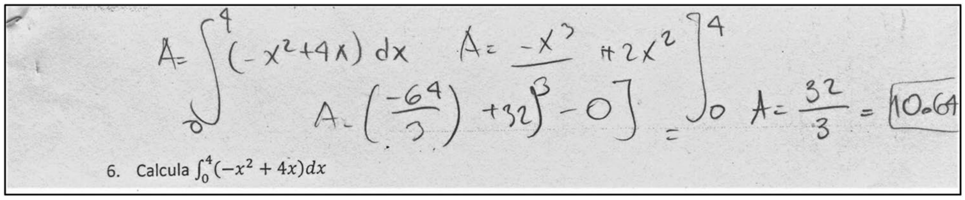


Fig. 8 Student B's worksheet showing his solution to item 6, after apparently learning how to solve it through a YouTube video

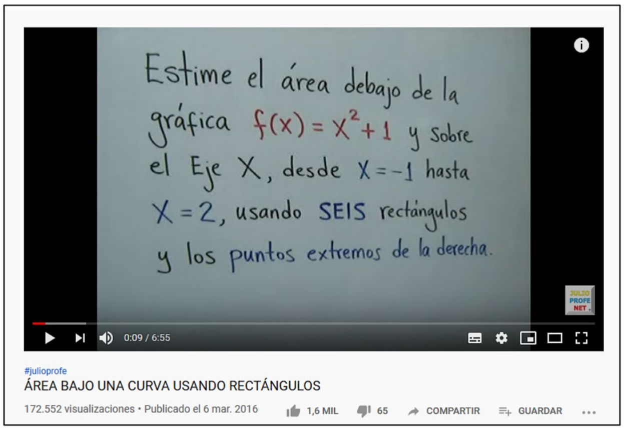


Fig. 9 Screenshot showing that student C stopped the video in a section where the instructor wrote down the exercise to be solved

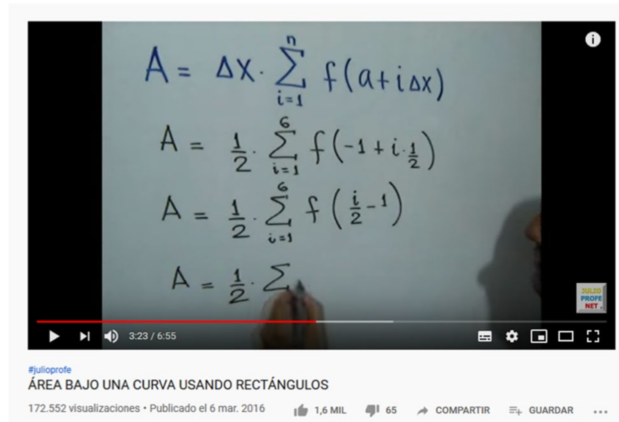


Fig. 10 Screenshot showing that student C paused the video in a section where the teacher illustrates step-by-step the use of the formula to approximate the area under a curve between two points

approximately twelve minutes watching it and replaying some fragments. We interpret this behavior as evidence that there was an effort to understand the algorithm and then apply it to solve $\int_0^4(-x^2+4x)dx$ (item 6). In fact, his worksheets show that the student was able to successfully apply the learned method to solve the sixth item of the task (see Fig. 8).

A similar manifestation of instrumental help-seeking was expressed by student C who addressed the fifth item of the task, where she was asked what happens when the area under the curve of the function $f(x) = -x^2 + 4x$ is approximated by considering 8 rectangles (in comparison with what happens when 5 rectangles are used, as in item 4). To solve this item, she uses a video from the "julioprofe" channel in which he illustrates how to estimate the area under the graph of the function $f(x) = x^2 + 1$ from $x = -1$ to $x = 2$ using six rectangles (Fig. 9).

The video length is 6 min and 55 s (see https://youtu.be/zLbZZZxqc30), but the student took approximately 12 min to watch it. During this period of time she paused and rewinded the video (see Fig. 10).

When analyzing the worksheets of this student, we noticed that she was able to approximate the area under the curve by using the formula $A \approx \Delta x \cdot \sum_{i=1}^{n} f(a + i\Delta x)$ and obtaining $\frac{21}{2}$ as a result. She also wrote "el área es más exacta" (the area is more exact) probably in response to the question posed in item 5 (see Fig. 11).

Notice how in her algorithmic procedure student C used exactly the same notation utilized by "julioprofe" in his video. We interpret this as evidence that the algorithmic knowledge that she applied in item 5 and that led to the conclusion that the approximation of the area is more accurate when using 8 rectangles, was obtained through the independent study of a YouTube video.

6 Concluding discussion

In this study we aimed to characterize the mathematical help-seeking behavior of undergraduate students when they turn to the Internet to try to solve a mathematical task. We observed that the students manifested instrumental help-seeking behaviors mostly associated with the procedural items of the task, although there were executive help-seeking manifestations associated with the declarative questions of the task. This result highlights the need to explore more deeply the relationships between the design of the tasks proposed, and the type of help-seeking behavior that they trigger.

For instance, it is not clear how students' behaviors would be affected if they were faced with a task that includes conceptual items, and not just procedural or declarative ones. It could also be expected that students' perception of the "formality" of the task and its consequences affects their

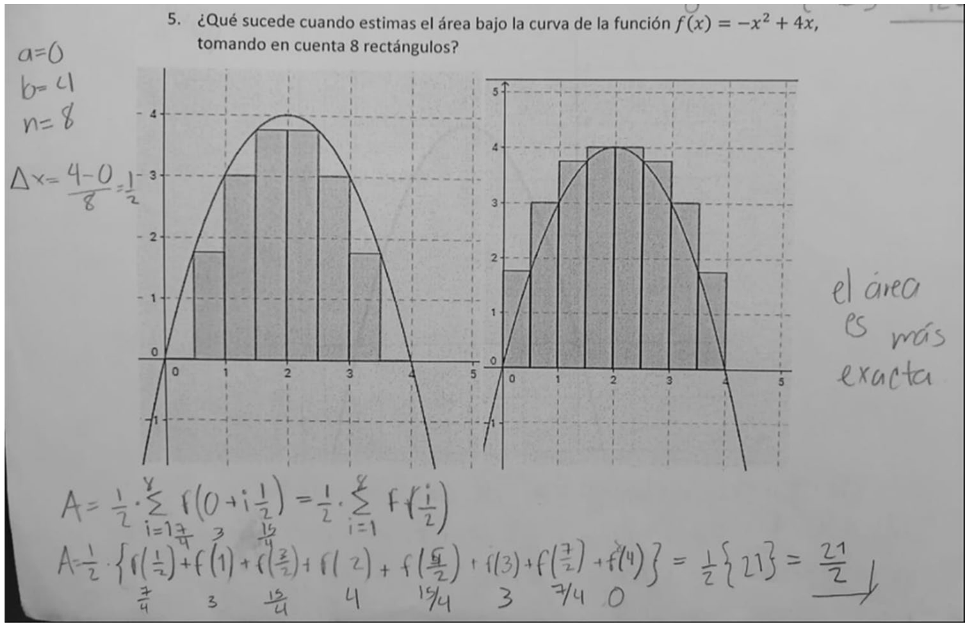


Fig. 11 Student C's worksheet showing her solution for item 5. She used the same formula and notation as the one used in the YouTube video that she watched for approximately 12 min

help-seeking behaviors: studies on students' strategies in Web research tasks have shown that students take a thoughtful approach only when the task has real consequences—such as course evaluation (Rodicio 2015). We also assume that other variables such as the time they have to solve a task can influence the sources of help that students consult and the help-seeking behaviors that they demonstrate. More studies are necessary in order to explore these scenarios.

In the study we observed how the Internet and its resources were fundamental for some students to develop instrumental mathematical help-seeking. As a result of this search for help, students were able to successfully solve a mathematical task on a topic partially unknown to them. This could be interpreted as a positive development of a self-regulated learning strategy. However, our observations suggest that some students do not require solid mathematical knowledge in order to perform the help-seeking process, but only an adequate choice of keywords—which the same search engine may suggest. In this Internet-based mathematical help-seeking scenario, students can find ways to solve mathematical tasks in which there is no need to exert a priori reasoning about the structure of the task or the nature of the mathematical situation at stake, before deciding on specific algorithmic procedures. Moreover, it seems that students do not experience the need to pay attention to the intrinsic mathematical properties (Lithner 2003) of the information obtained on the Internet.

As previously mentioned, our analysis shows the existence of a general pattern of help-seeking behavior dominated by the use of search engines and keywords to identify sources of mathematical help. This kind of behavior coincides with other empirical observations made with study subjects similar to those in our study. Sapa et al. (2014) found that search engines are the most commonly used tools for searching the Internet for information related to scientific and educational activities among mathematics undergraduate students from Poland. Also, within the group of students the most popular way to conduct the exploration in the search engines is typing keywords defining the subject of information needed. These results suggest the existence of similarities in students' Internet-based help-seeking behaviors, but at a general level. We assume that at a more particular level there must be differences, for example, in the sources of help that students from different regions of the world consult. These particular differences could be due to the languages in which the source of help is produced, but probably other cultural and economic disparities that are not so obvious may contribute to these differences.

Although we think that the results presented in this paper are reliable due to the research method applied, we are convinced that our method of inquiry has room for improvement. This type of research would benefit from the incorporation of contemporary devices and methods for recording and collecting information, which turn to the human body for data (de Freitas et al. 2018). For instance, students' Internet-based help-seeking behaviors could be studied in more detail through the use of eye-tracking (Schindler and Lilienthal 2019) and mouse-tracking (Hehman et al. 2015) analytical techniques. These are pending methodological tasks.

Although it would be convenient to incorporate contemporary research methods to further study Internet-based mathematical help-seeking, we think it would be worth investigating other actors involved in this educational phenomenon. In particular, we consider it relevant to study mathematics teachers' practices and perceptions associated with the use of the Internet as a source of mathematical help for students. As previously mentioned, the specialized literature says little about teachers' perceptions, knowledge, and practices related to mathematical help-seeking on the Internet. However, we know from the testimonies of the students who have participated in this and other studies, that there is a myriad of positions among teachers regarding this issue: there are teachers who promote and try to integrate this kind of practice into their lessons, but there are also other teachers who keep such practices banned in their classroom and discourage their adoption among students. What motivations underlie these teachers' behaviors? How could students' help-seeking practices be productively incorporated into formal mathematical instruction?

Answers to questions like the previous ones are necessary elements to close the gap between the way in which young people experience school mathematics—augmented and enhanced by digital technology and social networks—and the way in which the same mathematics is presented to the students in the classroom.

References

Aguilar, M. S., & Puga, D. E. (2015). Mobile help seeking in mathematics: An exploratory study with Mexican engineering students. In H. Crompton & J. Traxler (Eds.), *Mobile learning and mathematics: Foundations, design, and case studies* (pp. 176–186). Florence: Routledge.

Ames, R. (1983). Help-seeking and achievement orientation: Perspectives from attribution theory. In B. M. DePaulo, A. Nadler, & J. D. Fisher (Eds.), *New directions in helping Help-seeking* (Vol. 2, pp. 165–186). New York: Academic Press.

Beller, E. (1955). Dependency and independence in young children. *Journal of Genetic Psychology, 87*(1), 25–35. https://doi.org/10.1080/00221325.1955.10532913.

Blondeau, L., & Awad, G. H. (2017). Sex differences in career guidance of undergraduate math students and the relation to help-seeking behaviors. *Journal of Career Development, 44*(2), 174–187. https://doi.org/10.1177/0894845316642866.

de Freitas, E., Lerman, S., & Parks, A. N. (2018). Qualitative methods. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp. 159–182). Reston: NCTM.

DeFeo, D. J., Bonin, D., & Ossiander-Gobeille, M. (2017). Waiting and help-seeking in math tutoring exchanges. *Journal of Developmental Education, 40*(3), 14–22.

Griffiths, C. (2013). Using grounded theory to analyze qualitative observational data that is obtained by video recording. *Grounded Theory Review*, 1. http://groundedtheoryreview.com/2013/06/22/using-grounded-theory-to-analyze-qualitative-observational-data-that-is-obtained-by-video-recording/.

Hehman, E., Stolier, R. M., & Freeman, J. B. (2015). Advanced mouse-tracking analytic techniques for enhancing psychological science. *Group Processes & Intergroup Relations, 18*(3), 384–401. https://doi.org/10.1177/1368430214538325.

Hrastinski, S., & Aghaee, N. M. (2012). How are campus students using social media to support their studies? An explorative interview study. *Education and Information Technologies, 17*(4), 451–464. https://doi.org/10.1007/s10639-011-9169-5.

Junco, R. (2013). Comparing actual and self-reported measures of facebook use. *Computers in Human Behavior, 29*(3), 626–631. https://doi.org/10.1016/j.chb.2012.11.007.

Junco, R. (2014). iSpy: Seeing what students really do online. *Learning, Media and Technology, 39*(1), 75–89. https://doi.org/10.1080/17439884.2013.771782.

Karabenick, S. A., & Gonida, E. N. (2018). Academic help seeking as a self-regulated learning strategy: Current issues, future directions. In D. H. Schunk & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (pp. 421–433). New York: Routledge.

Kempler, T. M., & Linnenbrink, E. A. (2006). Helping behaviors in collaborative groups in math: A descriptive analysis. In S. Karabenick & R. Newman (Eds.), *Help seeking in academic settings: Goals, groups, and contexts* (pp. 89–115). Mahwah: Lawrence Erlbaum Associates.

Lithner, J. (2003). Students' mathematical reasoning in university textbook exercises. *Educational Studies in Mathematics, 52*(1), 29–55. https://doi.org/10.1023/A:1023683716659.

Marais, C., van der Westhuizen, G., & Tillema, H. (2013). Teacher knowledge of learners' help-seeking in mathematics problem solving. *African Journal of Research in Mathematics, Science and Technology Education, 17*(1–2), 63–73. https://doi.org/10.1080/10288457.2013.826971.

Nelson-LeGall, S. (1981). Help-seeking: An understudied problem-solving skill in children. *Developmental Review, 1*(3), 224–246. https://doi.org/10.1016/0273-2297(81)90019-8.

Nelson-LeGall, S. (1985). Help-seeking behavior in learning. *Review of Research in Education, 12*(1), 55–90. https://doi.org/10.2307/1167146.

Newman, R. S., & Schwager, M. T. (1993). Students' perceptions of the teacher and classmates in relation to reported help seeking in math class. *The Elementary School Journal, 94*(1), 3–17. https://doi.org/10.1086/461747.

Onwuegbuzie, A. J., Dickinson, W. B., Leech, N. L., & Zoran, A. G. (2009). A qualitative framework for collecting and analyzing data in focus group research. *International Journal of Qualitative Methods, 8*(3), 1–21. https://doi.org/10.1177/160940690900800301.

Puga, D.S.E. (2013). Búsqueda de ayuda en Internet: Un estudio exploratorio sobre las prácticas de estudiantes de ingeniería [Help-seeking on the Internet: An exploratory study on engineering students' practices] (Unpublished master's thesis). Instituto Politécnico Nacional Mexico City, Mexico.

Puga, D. S. E. (2018a). Uso autónomo de recursos de Internet entre estudiantes de ingeniería como fuente de ayuda matemática [Autonomous use of Internet resources among engineering students as a source of mathematical help]. *Educación Matemática, 30*(1), 73–91. https://doi.org/10.24844/EM3001.03.

Puga, D. S. E. (2018b). Caracterización de comportamientos de búsqueda de ayuda en Internet ¿Cómo utilizan la web de forma independiente los estudiantes de ingeniería para realizar su actividad matemática? [Characterization of help-seeking behaviors on the Internet. How do engineering students use the web independently to carry out their mathematical activity?] (Unpublished doctoral dissertation). Instituto Politécnico Nacional, Mexico City, Mexico.

Puga, D. E., & Aguilar, M. S. (2015). Looking for help on the Internet: An exploratory study of mathematical help-seeking practices among Mexican engineering students. In K. Krainer & N. Vondrová (Eds.), *Proceedings of the Ninth Congress of the European Society for Research in Mathematics Education* (2538–2544). Prague, Czech Republic: Charles University in Prague, Faculty of Education and ERME.

Puustinen, M., & Rouet, J.-F. (2009). Learning with new technologies: Help seeking and information searching revisited. *Computers &*

Education, 53(4), 1014–1019. https://doi.org/10.1016/j.compedu.2008.07.002.

Puustinen, M., Volckaert-Legrier, O., Coquin, D., & Bernicot, J. (2009). An analysis of students' spontaneous computer-mediated help seeking: A step toward the design of ecologically valid supporting tools. *Computers & Education, 53*(4), 1040–1047. https://doi.org/10.1016/j.compedu.2008.10.003.

Qayyum, A. (2018). Student help-seeking attitudes and behaviors in a digital era. *International Journal of Educational Technology in Higher Education*, *15*, 17. https://doi.org/10.1186/s41239-018-0100-7.

Rodicio, H. G. (2015). Students' evaluation strategies in a Web research task: Are they sensitive to relevance and reliability? *Journal of Computing in Higher Education, 27*(2), 134–157. https://doi.org/10.1007/s12528-015-9098-1.

Rothbauer, P. M. (2008). Triangulation. In L. M. Given (Ed.), *The Sage encyclopedia of qualitative research methods* (Vol. 2, pp. 892–894). Thousand Oaks: Sage.

Ryan, A. M., & Pintrich, P. R. (1997). "Should I ask for help?" The role of motivation and attitudes in adolescents' help seeking in math class. *Journal of Educational Psychology, 89*(2), 329–341. https://doi.org/10.1037/0022-0663.89.2.329.

Ryan, A. M., Patrick, H., & Shim, S.-O. (2005). Differential profiles of students identified by their teacher as having avoidant, appropriate, or dependent help-seeking tendencies in the classroom. *Journal of Educational Psychology, 97*(2), 275–285. https://doi.org/10.1037/0022-0663.97.2.275.

Sapa, R., Krakowska, M., & Janiak, M. (2014). Information seeking behaviour of mathematicians: Scientists and students. *Information Research*, 19, 4.

Schenke, K., Lam, A. C., Conley, A. M., & Karabenick, S. A. (2015). Adolescents' help seeking in mathematics classrooms: Relations between achievement and perceived classroom environmental influences over one school year. *Contemporary Educational Psychology, 41*, 133–146. https://doi.org/10.1016/j.cedpsych.2015.01.003.

Schindler, M., & Lilienthal, A. J. (2019). Domain-specific interpretation of eye tracking data: Towards a refined use of the eye-mind hypothesis for the field of geometry. *Educational Studies in Mathematics, 101*(1), 123–139. https://doi.org/10.1007/s10649-019-9878-z.

Schoenfeld, A. H. (1985). *Mathematical problem solving*. Orlando: Academic Press.

Shapiro, E. G. (1978). Help seeking: Effects of visibility of task performance and seeking help. *Journal of Applied Social Psychology, 8*(2), 163–173. https://doi.org/10.1111/j.1559-1816.1978.tb00774.x.

Skaalvik, S., & Skaalvik, E. M. (2005). Self-concept, motivational orientation, and help-seeking behavior in mathematics: A study of adults returning to high school. *Social Psychology of Education, 8*(3), 285–302. https://doi.org/10.1007/s11218-005-3276-3.

Turner, J. C., Midgley, C., Meyer, D. K., Gheen, M., Anderman, E. M., Kang, Y., et al. (2002). The classroom environment and students' reports of avoidance strategies in mathematics: A multimethod study. *Journal of Educational Psychology, 94*(1), 88–106. https://doi.org/10.1037//0022-0663.94.1.88.

van de Sande, C. (2011). A description and characterization of student activity in an open, online, mathematics help forum. *Educational Studies in Mathematics, 77*(1), 53–78. https://doi.org/10.1007/s10649-011-9300-y.

Webb, N. M., & Mastergeorge, A. (2003). Promoting effective helping behavior in peer-directed groups. *International Journal of Educational Research, 39*(1–2), 73–97. https://doi.org/10.1016/S0883-0355(03)00074-0.

Wistrand, J. (2017). When doctors are patients: A narrative study of help-seeking behaviour among addicted physicians. *Medical Humanities, 43*(1), 19–23. https://doi.org/10.1136/medhum-2016-011002.

Zusho, A., & Barnett, P. A. (2011). Personal and contextual determinants of ethnically diverse female high school students' patterns of academic help seeking and help avoidance in English and mathematics. *Contemporary Educational Psychology, 36*(2), 152–164. https://doi.org/10.1016/j.cedpsych.2011.02.002.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.