# Developing Adaptive Help-Seeking Regulation Mechanisms for Different Help-Seeking Tendencies

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**ABSTRACT:** Help-seeking is an important self-regulated learning strategy and skill for effective learning. Studies have found that some students have poor help-seeking behaviors and that this leads to poor learning performance. Some researchers have developed help-seeking regulation mechanisms to detect and regulate students' poor help-seeking behaviors. Studies have also found that students have different help-seeking tendencies. Thus, adaptive help-seeking regulation mechanisms for different help-seeking tendencies are required. This study applied a help-seeking questionnaire and a K-means clustering approach to identify three help-seeking tendencies in the context of a computer assisted learning system (CALS). Then, adaptive help-seeking detection and regulation mechanisms were developed for these three help-seeking tendencies. The regulation mechanisms also adopted historical student records of problem-solving and help-seeking data for each problem as parameters to account for the difficulty of each problem. Furthermore, an experiment was conducted with a control group and an experimental group. Students in the experimental group used a CALS with adaptive help-seeking regulation mechanisms, whereas students in the control group used a CALS without the regulation mechanisms and could seek help at will. The experimental results showed that students in the experimental group had better learning performance for difficult problems, better help-seeking behaviors (i.e., less executive help-seeking) for easy problems, and a higher ratio of solving problems by themselves without seeking help than students in the control group.

**Keywords:** Help-seeking behaviors, Help-seeking tendencies, Negotiation-based regulation, Individual difference, Intelligent computer assisted learning systems

## 1. Introduction

Help-seeking is an important self-regulated learning strategy and skill for effective learning because some students' poor performance results from their poor help-seeking behaviors, such as unawareness of the need for help, help avoidance and help abuse (Karabenick & Gonida, 2018; Hirt, Karlen, Suter & Merki, 2020; Karabenick & Berger, 2013; Mbato & Cendra, 2019). In particular, students' help-seeking behaviors affect their learning performance in computer assisted learning systems (CALSs) with on-demand help support (Aleven et al., 2003). Many CALSs provide students with worked-out examples and tutored problem-solving exercises to assist them in learning (Clark, Nguyen, & Sweller, 2006; Van Gog, Kester, & Paas, 2011). Worked-out examples demonstrate how to solve specific problems by presenting solution examples and explanations, whereas tutored problem-solving exercises support students in practicing how to successfully solve problems with the help of systems. Many CALSs provide on-demand help support so that students can seek help from systems when they encounter difficulty in solving problems. Researchers have suggested that CALSs offer different types of help to assist students in solving problems, such as verification of solution situations, error-indicating hints, corrective hints, instruction-based hints, and answers as bottom-out hints (i.e., executive help) (Chou, Huang & Lin, 2011; Dempsey, Driscoll & Swindell, 1993; VanLehn, 2006). However, students may have poor help-seeking behaviors, such as not seeking help (i.e., avoidant help-seeking) or abusing help (i.e., executive help-seeking), and these poor help-seeking behaviors are correlated with poor learning performance (Chou et al., 2018; Muldner et al., 2011; Ryan & Shin, 2011; Shim, Rubenstein & Drapeau, 2016; Smalley & Hopkins, 2020). Therefore, researchers have developed intelligent CALSs that detect and regulate students' poor help-seeking behaviors to promote better learning performance (Aleven et al., 2006; Aleven et al., 2016; Chou et al., 2018; Roll et al., 2011).

Researchers have also found that students have different help-seeking tendencies and can be described as strategic help-seekers (SHSs), executive help-seekers (EHSs), avoidant help-seekers (AHSs), and independent help-seekers (IHSs) (Chou et al., 2018; Gall, 1985; Hirt et al., 2020; Karabenick, 2003; Martín-Arbós, Castarlenas & Dueñas, 2021; Ryan, Patrick & Shim, 2005; White & Bembenutty, 2013). SHSs tend to seek help for learning (i.e., strategic help-seeking/instrumental help-seeking). EHSs tend to seek help for completing tasks

without effort. AHSs tend to avoid seeking help because of the threat posed by help-seeking. IHSs tend to solve problems by themselves. Therefore, students with different help-seeking tendencies require different help-seeking regulations. However, there is little literature available regarding the CALS providing adaptive help-seeking regulation mechanisms for different help-seeking tendencies. This study proposed an approach for identifying students' different help-seeking tendencies in the context of a CALS and developing adaptive help-seeking regulation mechanisms for different help-seeking tendencies to account for students' individual differences. Furthermore, the effect of adaptive help-seeking regulation mechanisms on students' help-seeking behaviors and learning performance was evaluated.

## 2. Literature review

### 2.1. Identification of help-seeking tendencies

Help-seeking is a self-regulated learning process that includes being aware of the need for help and seeking help from available helpers (Gall, 1985; Karabenick & Gonida, 2018). Students may be influenced by cognitive, motivation and social factors and reveal different help-seeking tendencies (Gonida et al., 2019; Karabenick & Gonida, 2018). For example, SHSs have high mastery-approach goals and seek help for mastering their learning tasks. EHSs have high performance-approach goals and may seek help when help is not needed to perform better than others. AHSs have high performance-avoidance goals, regard help-seeking as threats and fails, and avoid seeking help. Researchers have identified SHSs, EHSs, and AHSs through observation by teachers in the context of the classroom (Ryan, Patrick & Shim, 2005). Furthermore, researchers have designed help-seeking questionnaires to assess students' help-seeking profile, such as executive help-seeking and help-seeking threat, applied clustering methods, and identified SHSs, EHSs, IHSs, and AHSs in the context of the classroom (Karabenick, 2003; Finney et al., 2018; White & Bembenutty, 2013). However, most studies have explored students' help-seeking tendencies from teachers or classmate helpers in the context of the classroom, and there is little literature available regarding students' help-seeking tendencies in the context of CALSs. This study applied a help-seeking questionnaire and a machine learning clustering method to identify students' different help-seeking tendencies in the context of a CALS.

### 2.2. Intervention of help-seeking behaviors

Researchers have found that external feedback from teachers or CALSs can help students be aware of and regulate their poor self-regulated learning (Butler & Winne, 1995; Chou & Zou, 2020). Similarly, external feedback from teachers or CALSs can be applied to help students be aware of and regulate their poor help-seeking behaviors. Researchers have developed mechanisms for CALSs to detect poor help-seeking behaviors, such as help avoidance and help abuse, and provide external feedback for intervention (Aleven et al., 2006; Chou et al., 2018; Roll et al., 2011). However, these intervention mechanisms do not consider students' help-seeking tendencies. Students with different help-seeking tendencies tend to have different poor help-seeking behaviors. For example, AHSs tend to avoid help-seeking even if they are aware of the need for help. Therefore, the system should prompt and encourage AHSs to seek help rather than prompt AHSs not to seek much help. EHSs tend to abuse help. Thus, the system should focus on reminding EHSs not to seek too much help. Furthermore, problems have different difficulty levels, and more difficult problems require more solution time and help. Researchers have also confirmed that students seek help more frequently as problem difficulty increases (Hao, Wright, Barnes & Branch, 2016). A one-size-fits-all regulation mechanism does not account for different help-seeking tendencies and problems with different difficulty levels. Therefore, this study developed different adaptive help-seeking regulation mechanisms for students with different help-seeking tendencies and for problems with different difficulty levels.

The effects of help-seeking interventions on help-seeking behaviors and performance are generally evaluated (Karabenick & Gonida, 2018). Since students seek help more frequently as problem difficulty increases (Hao et al., 2016), the effect of help-seeking intervention may differ for easy and difficult problems. Thus, this study evaluated the effect of help-seeking interventions for easy and difficult problems.

## 3. Method

The method includes three steps. Step one applied a help-seeking tendency questionnaire and clustering approach to identify students' different help-seeking tendencies in the context of a CALS. Step two developed adaptive

help-seeking regulation mechanisms for different help-seeking tendencies to account for students' individual differences and for problems with different difficulty levels. Step three divided students into an experimental and a control group to evaluate the effect of the adaptive help-seeking regulation mechanisms on students' help-seeking behaviors and learning performance. The details of the three steps, the help-seeking tendency questionnaire and the CALS adopted are presented below.

### 3.1. The help-seeking tendency questionnaire

This study adopted a help-seeking tendency questionnaire that was modified from a help-seeking tendency questionnaire (Karabenick, 2003) that was designed to assess students' help-seeking tendencies when seeking help from human helpers. The questionnaire was modified to assess students' help-seeking tendencies when seeking help from a CALS. The questionnaire includes seven 7-point Likert scale items and three scales measuring help-seeking willingness, executive help-seeking and help-seeking threat (see Appendix). The help-seeking willingness scale has two items to ask students whether they seek help from the system if they have trouble solving problems. The executive help-seeking scale has two items to ask students whether they seek help from the system because they want to avoid solving the problems on their own. The help-seeking threat scale has three items to ask students whether they consider that seeking help from the system is a failure or an admission that they are not smart enough. In Karabenick's study (2003), the Cronbach's alpha values of the three scales were 0.62, 0.78, and 0.81. The Cronbach's alpha values of the three scales in this study were 0.578, 0.677, and 0.774.

### 3.2. The system support problem-solving and help-seeking

The CALS, named NALS-HS (negotiation-based adaptive learning system for help-seeking), adopted in this study was derived from a CALS developed in a previous study of help-seeking (Chou et al., 2018). The system enabled students to learn from worked-out examples and tutored problem-solving exercises. First, the system provided a worked-out example for a program and explanations of its execution and output. After that, students were asked to solve a program-output-prediction problem by predicting the output of a program. Figure 1 shows the system interface for problem-solving and help-seeking. The right part of the interface is the program for predicting the output. Programs were designed to output five lines, each of which had five output values. Students input their prediction of the output in the left part of the interface value by value and line by line. Five buttons were located at the bottom to allow students to seek help, edit the next line of the output, return to the previous line of the output, review the worked-out example, or finish the prediction.

If students sought help, the system provided adaptive help in the middle part of the interface (Figure 1). The system detected students' solutions and provided adaptive help to assist them in solving problems (Table 1) (Chou et al., 2018). Students' solutions were correct, incomplete, or incorrect solutions. If students correctly solved the problem, the system verified that they had submitted the correct solution. If students' solutions were unfinished solutions without errors, the system provided three levels of hints in sequence to help students complete their solutions: informing students that their solutions were unfinished solutions without errors (i.e., verification); prompting the output of the next line (i.e., an instruction-based hint); and informing students of the output of the next line (i.e., a bottom-out hint of the answer). If students' solutions had errors, the system provided four levels of help: informing students that their solutions had errors to prompt students to check their solutions; indicating the location of the first error to guide students to find their errors and fix them; instruction-based hints for the located line of the first error to prompt students to fix their errors; and bottom-out hints. Bottom-out hints are classified as executive help, whereas the other hints are classified as instrumental help (Gall, 1985).

*Table 1.* Adaptive help for different solution situations (Chou et al., 2018)

| | Correct solution | Incomplete solution | Incorrect solution |
|---|---|---|---|
| Level 1 help | Verification (correct) | Verification (incomplete) | Verification (incorrect) |
| Level 2 help | - | Instruction-based hint | Error-indicating hint |
| Level 3 help | - | Answer (bottom-out hint) | Instruction-based hint |
| Level 4 help | - | - | Answer (bottom-out hint) |


*Figure 1*. System interface for problem-solving and help-seeking in program-output-prediction problems

### 3.3. Step 1: Identifying students' different help-seeking tendencies

A help-seeking tendency questionnaire and a machine learning clustering method, K-means, were applied to identify students' different help-seeking tendencies. An experiment was conducted in an introductory computer programming course for undergraduate students at a university. Among 60 enrolled students, 52 students, including 37 male and 15 female students, completed the questionnaire and participated in the experiment; there were 29 freshmen, 8 sophomores, 10 juniors, and 5 seniors. The students were majoring in computer science. In a computer classroom, the students were asked to use NALS-HS to solve two problems without help-seeking regulation mechanisms. After that, the students were asked to fill out the help-seeking tendency questionnaire.

*Table 2*. Clustering results for help-seeking questionnaire data (Mean/Standard Derivation)

| | Cluster 1: AHSs ($N$ = 5, 10%) | Cluster 2: EHSs/SHSs ($N$ = 31, 60%) | Cluster 3: IHSs ($N$ = 16, 30%) | |
|---|---|---|---|---|
| Help-seeking willingness | 2.1/1.12 | 4.69/0.93 | 2.75/0.68 | EHSs > AHSs, IHSs |
| Executive help-seeking | 2.5/1.12 | 3.19/1.04 | 2.09/0.84 | EHSs > IHSs |
| Help-seeking threat | 4.2/1.07 | 3.12/0.87 | 2.17/0.63 | AHSs > EHSs > IHSs |

*Note.* AHSs: avoidant help-seekers; EHSs: executive help-seekers; SHSs: strategic help-seekers; IHSs: independent help-seekers

K-means clustering was conducted to divide students into clusters based on their results for the three scales. K-means is an unsupervised machine learning method used to divide data into assigned K clusters (Xu, 2005). Different K values were tested to examine whether the clustering results were meaningful. The results showed that there was at least one cluster in which the number in the cluster was fewer than 5 when the K value was 4 or larger; thus, the K value was set to 3 to avoid clusters with too few students and to avoid too few clusters. In addition, a three-cluster solution was highly interpretable. Table 2 lists the clustering results for the help-seeking questionnaire data. A Kruskal-Wallis H test showed that there were statistically significant differences in help-seeking willingness ($\chi^2$ (2) = 36.220, $p$ < .001), executive help seeking ($\chi^2$(2) = 11.868, $p$ < .01), and help-seeking threat ($\chi^2$ (2) = 17.527, $p$ < .001) among the three clusters. The results of Dunn's multiple comparison tests showed that cluster 2 had higher willingness to seek help than clusters 1 and 3; cluster 2 had higher executive help-seeking than cluster 3; cluster 1 had higher help-seeking threat than cluster 2; and cluster 2 had higher help-seeking threat than cluster 3. Accordingly, cluster 1 had higher help-seeking threat and lower help-seeking willingness, characteristic of AHSs. Cluster 2 had higher willingness to seek help and executive help-

seeking, but its executive help-seeking value was medium, characteristic of EHSs or SHSs. Cluster 3 had lower willingness to seek help, executive help-seeking, and help-seeking threats, which are characteristic of IHSs.

### 3.4. Step 2: Developing adaptive help-seeking negotiation-based regulation mechanisms

Adaptive help-seeking negotiation-based regulation mechanisms were designed for different help-seeking tendencies (Table 3). With help-seeking negotiation-based regulation mechanisms, the system negotiates with students to co-regulate help-seeking (Chou et al., 2015; Chou et al., 2018; Hadwin, Järvelä & Miller, 2011). This co-regulation scaffolds students' help-seeking to prompt students to be aware of and regulate their poor help-seeking behaviors. Problems have different difficulty levels, and thus, for each problem, the appropriate problem-solving attempts (PSAs, computed as the number of attempts made to complete the solution step), help-seeking amount (HSA, computed as the highest level of hint that students sought for help) and solving time (ST) differ for each step. Students need more PSAs, HSA and ST for each step when solving more difficult problems. Thus, this study adopted the historical records of students' PSAs, HSA and ST for each problem as parameters for the heuristic rules to detect students' situations and to regulate their poor help-seeking behaviors. Rule #1 reminds students not to seek too much help when they have sought too much help (i.e., a poor help-seeking behavior of executive help-seeking). The rule is checked when students seek help. For AHSs and IHSs, the rule detects the situation of seeking too much help when a student has few PSAs (i.e., below or equal to the first quartile of the historical PSA record), a short ST (i.e., below or equal to the first quartile of the historical ST record), and high HSA (i.e., larger than or equal to the third quartile of the historical HSA record). EHSs tend to seek too much help. Thus, for them, the HSA threshold is reduced to the second quartile of the historical HSA record so that the system reminds these students not to seek too much help in advance. If the rule is activated, the system rejects students' help requests, encourages students to solve problems by themselves, and disables the "Help" button for 40 seconds. If students continue to seek help after 40 seconds, the system will provide help. Rule #2 prompts students to seek help when they have difficulty and need help. The rule is periodically checked as students solve problems. For EHSs and IHSs, rule #2 detects the situation of needing help when a student has a long ST (i.e., longer than or equal to the third quartile of the historical ST record) and low HSA (i.e., below or equal to the first quartile of the historical HSA record). AHSs tend to avoid seeking help. Thus, the HSA threshold is increased to the second quartile of the historical HSA record so that the system prompts AHSs to seek help more frequently. If the rule is activated, the system proposes providing help by asking students "*Do you need help?*" with two buttons, "*Yes*" and "*No*." If students choose "*Yes*," the system provides help based on the solution situation. If students reject help, the system detects the situation again after 40 seconds. Rule #3 forces providing hints to students when students are stuck, definitely need help, and reject help. The rule detects a stuck situation when students reject the system's help proposal two consecutive times (i.e., a poor help-seeking behavior of avoidant help-seeking). When the rule is activated, the system forces providing hints to students. Rule #4 respects and does not regulate students' help-seeking behaviors when students neither seek too much help nor have difficulty. When rules #1, #2, and #3 are not activated, rule #4 is activated.

*Table 3*. Adaptive help-seeking negotiation-based regulation mechanisms for different help-seeking tendencies

| Rule | Brief | Situation | Detection rule | Negotiation-based regulation |
|---|---|---|---|---|
| #1 | Remind not to seek too much help | Students have sought for too much help | AHSs, IHSs: (PSAs <= $Q_1$) and (ST <= $Q_1$) and (HSA >= $Q_3$)<br>EHSs: (PSAs <= $Q_1$) and (ST <= $Q_1$) and (HSA >= $Q_2$) | Reject students' help request and disable "Help" button for 40 seconds. If students still seek help after 40 seconds, the system will provide help. |
| #2 | Prompt to seek help | Students have difficulty and need help but do not seek help | AHSs: (ST >= $Q_3$) and (HSA <= $Q_2$) and<br>EHSs, IHSs: (ST >= $Q_3$) and (HSA <= $Q_1$) | Propose to provide hints and accept students' choices. If students reject help, the system detects the situation again after 40 seconds. |
| #3 | Force help | Students are stuck and definitely need help but do not seek help | Students reject the system's help proposal two consecutive times | Force providing hints to students |
| #4 | Respect students' help-seeking | Students neither seek too much help nor have difficulty | Out of rules #1, #2, or #3 | No regulation |

*Note.* $Q_1$: the first (lower) quartile; $Q_2$: the second quartile (i.e., median); $Q_3$: the third (upper) quartile; problem-solving attempts (PSAs), help-seeking amount (HSA), and solving time (ST).

### 3.5. Step 3: Conducting an experiment with an experimental and a control group

Students were divided into an experimental group and a control group to explore whether adaptive help-seeking regulation mechanisms facilitate better help-seeking behaviors and learning performance. Students in each cluster were randomly assigned to the control and experimental groups (Table 4). Because there was an odd number of students in the AHS and EHS clusters, the decision was made to assign one more student to the experimental group than to the control group. When students logged in to the system, those in the experimental group were assigned to use the NALS-HS system with adaptive negotiation-based regulation mechanisms, whereas the students in the control group were assigned to use the NALS-HS system in which the regulation mechanisms were disabled so that they could seek help at will.

*Table 4.* Distributions of students in the control and experimental groups

| | Total | AHSs | EHSs/SHSs | IHSs |
|---|---|---|---|---|
| Control | 25 | 2 | 15 | 8 |
| Experimental | 27 | 3 | 16 | 8 |

Students used the system in classes for six weeks. Each week, students read worked-out examples and conducted exercises in which they sought to solve two related program-output-prediction problems through the assigned system with or without regulation mechanisms in 20 minutes. These two problems were similar to the worked-out examples. Historical PSA, HSA and PT records from 63 students who used the system to solve these problems were used as the parameters of the adaptive help-seeking regulation mechanisms. After that, students were asked to complete a post-test with two program-output-prediction problems similar to the two problems in the exercises in 15 minutes in a pencil-and-paper format. Students were assigned to learn and solve easy problems from weeks 1 to 3 and difficult problems from weeks 4 to 6. In the 7th week, a delay test with six problems that were similar to the problems from the first six weeks was conducted to assess students' delay performance. Students' post-test and delay test scores for easy problems during weeks 1 to 3 and difficult problems during weeks 4 to 6 were computed to assess their learning performance.

Chou and his colleagues (2018) proposed three help-seeking behavior indicators, namely, the ratio of steps solved with executive help (RSE), the ratio of steps solved with instrumental help (RSI), and the ratio of steps solved by themselves (RST), to evaluate the quality of students' help-seeking behaviors. High RSE is identified as a poor help-seeking behavior (i.e., executive help-seeking), whereas appropriate RSI is identified as a good help-seeking behavior (i.e., strategic/instrumental help-seeking) and RST is identified as an indicator of whether students are able to solve problems by themselves without seeking help. This study adopted RSE, RSI, and RST to evaluate students' help-seeking behaviors.

## 4. Experimental results

Some students missed some activities and their data were excluded from the related analysis. The number of valid samples for each analysis is shown in the following tables.

Table 5 lists students' learning performance for easy and difficult problems. The results of paired *t* tests showed that students' performance on easy problems was significantly higher than that on difficult problems [post-test: $t(39) = 3.661$, $p = .001$; delay test: $t(40) = 9.119$, $p < .001$]. That is, problems during weeks 4 to 6 are more difficult than problems during weeks 1 to 3.

*Table 5.* Learning performance for easy and difficult problems (Mean/Standard Derivation)

| | Week 1~Week 3 (Easy problems) | Week 4~Week 6 (Difficult problems) | Paired *t* test | |
|---|---|---|---|---|
| | | | *t* | *p* |
| Post-test (full mark = 100) ($N = 40$) | 91.59/8.68 | 82.48/14.06 | 3.661 | .001 |
| Delay test (full mark = 75) ($N = 41$) | 71.98/7.47 | 52.29/16.46 | 9.119 | .000 |

Table 6 lists the help-seeking behavior indicators for the students in the control and experimental groups. A Mann-Whitney U test revealed that students in the experimental group had a significantly higher RST on easy and difficult problems than students in the control group (easy problems: $U = 161$, $p = .014$; difficult problems: $U = 134$, $p = .047$). The effect sizes (calculated by Cohen's D) for RST were large (0.92) and medium (0.64) for the easy and difficult problems, respectively. A Mann-Whitney U test also showed that students in the experimental group had a significantly lower RSE on easy problems than students in the control group ($U = 143.5$, $p = .003$). Students in the experimental group also seemed to have a lower RSE on difficult problems than

students in the control group, but the difference did not reach significance. In addition, the effect sizes for RSE were large (0.96) and medium (0.5) for easy and difficult problems, respectively. The results indicated that the adaptive help-seeking regulation mechanisms promoted students better help-seeking behaviors (i.e., less executive help-seeking) for easy problems and a higher ratio of solving problems by themselves without seeking help.

*Table 6.* Help-seeking behavior indicators of the control and experimental groups (Mean/Standard Derivation)

| | Control | Experimental | Mann-Whitney U test | |
|---|---|---|---|---|
| | | | *U* | *p* |
| Week 1~Week 3 (Easy problems) | *N* = 23 | *N* = 24 | | |
| RST | 0.754/0.208 | 0.903/0.100 | 161 | .014* |
| RSI | 0.155/0.153 | 0.075/0.079 | 210.5 | .161 |
| RSE | 0.108/0.113 | 0.022/0.060 | 143.5 | .003** |
| Week 4~Week 6 (Difficult problems) | *N* = 20 | *N* = 21 | | |
| RST | 0.287/0.258 | 0.451/0.256 | 134 | .047* |
| RSI | 0.098/0.089 | 0.068/0.072 | 168.5 | .278 |
| RSE | 0.615/0.284 | 0.481/0.247 | 152 | .130 |

*Note.* $^{*}p < .05$; $^{**}p < .01$.

Table 7 shows the learning performance on the post-tests and delay test for the control and experimental groups. A Mann-Whitney U test revealed that the post-test score for weeks 4 to 6 in the experimental group was significantly higher than that in the control group ($U = 108$, $p = .008$). The effect sizes (calculated by Cohen's D) for the post-test were small (0.19) and large (0.81) for the easy and difficult problems, respectively. In addition, the delay test score for weeks 4 to 6 was approximately significantly higher in the experimental group than in the control group ($U = 143.5$, $p = .086$). The effect sizes for the delay test were small (0.29) and medium (0.53) for the easy and difficult problems, respectively. The results indicated that the adaptive help-seeking regulation mechanisms promoted better learning performance, particularly for difficult problems.

*Table 7.* Learning performance of the control and experimental groups (Mean/Standard Derivation)

| | Control | Experimental | Mann-Whitney U test | |
|---|---|---|---|---|
| | | | *U* | *p* |
| Post-tests (full mark = 100) | | | | |
| Week 1~Week 3 (Easy problems) | 90.3/9.84 (*N* = 21) | 91.9/7.37 (*N* = 25) | 242 | .651 |
| Week 4~Week 6 (Difficult problems) | 76.4/12.97 (*N* = 19) | 87.1/13.29 (*N* = 22) | 108 | .008** |
| Delay test (full mark = 75) | | | | |
| Week 1~Week 3 (Easy problems) | 70.8/9.32 (*N* = 19) | 73/5.44 (*N* = 22) | 193 | .523 |
| Week 4~Week 6 (Difficult problems) | 47.7/18.18 (*N* = 19) | 56.2/14.01 (*N* = 22) | 143.5 | .086+ |

*Note.* $^{+}p < .1$; $^{**}p < .01$.

## 5. Discussion

### 5.1. Identified help-seeking tendencies under different contexts/sources, participants, and identification approaches

This study identified three student help-seeking tendencies in the context of a CALS. Table 8 lists the help-seeking tendencies identified in eight studies. The distributions of the identified help-seeking tendencies vary across studies. SHSs were identified in all studies. EHSs were identified in five studies. AHSs were identified in five studies. IHSs were identified in three studies. In particular, some studies identified some students with mixed help-seeking tendencies; that is, these students did not belong to a single help-seeking tendency but simultaneously presented characteristics of different help-seeking tendencies. For example, White and Bembenutty (2013) identified some students with the properties of both EHSs and AHSs and some students with the properties of both AHSs and SHSs. Some students were identified with both EHSs and SHSs in this study. This reason might be that there is no clear boundary between some help-seeking tendencies or that help-seeking tendencies are not mutually exclusive. However, it may be that students who belong to the same help-seeking tendency have different levels of this tendency or quantitatively ordered profiles. For example, all students were identified as SHSs in the two studies of Finney et al. (2018), but 3 levels or 4 levels of SHSs were identified.

*Table 8*. Help-seeking tendencies identified in different studies

| Study | Context/source | Participants | Identification approach | EHSs | SHSs | IHSs | AHSs |
|---|---|---|---|---|---|---|---|
| Karabenick, 2003 | Classroom | 883 college students (chemistry classes) | Questionnaire & clustering | | 42% | 36% | 23% |
| Ryan, Patrick and Shim, 2005 (study 1) | Classroom | 844 6th-grade students | Observed & reported by teachers | 13% | 65% | | 22% |
| Ryan, Patrick and Shim, 2005 (study 2) | Classroom | 474 5th-grade students (math classes) | Observed & reported by teachers | 7% | 74% | | 19% |
| White and Bembenutty, 2013 | Classroom | 86 college students (elementary teacher candidates) | Questionnaire & clustering | 14%/AHSs | 54% | | 32%/ SHSs |
| Finney et al., 2018 (study 1) | Classroom | 1950 first-year college students | Questionnaire & mixture modeling | | 100% 3 levels | | |
| Finney et al., 2018 (study 2) | Classroom | 2107 college upperclassmen | Questionnaire & mixture modeling | | 100% 4 levels | | |
| Chou et al., 2018 | CALS | 39 college students (programming class) | System records & observed by experts | 38% | 28% | 33% | |
| This study | CALS | 52 college students (programming class) | Questionnaire & clustering | 60%/ SHSs | | 30% | 10% |

The different distributions may be due to differences in the contexts/sources, participants, and identification approaches. First, the contexts/sources may be classrooms in which students seek help from teachers or peers; online chatrooms or discussion boards on which students seek help from teachers, peers, or strangers; or CALSs in which students seek help from the system. Makara and Karabenick (2013) proposed a multidimensional framework for distinguishing help sources: role (formal vs. informal), relationship (personal vs. impersonal), channel (mediated vs. face-to-face), and adaptability (dynamic vs. static). In addition, researchers have argued that seeking help from teachers or peers is a social form of self-regulated learning, whereas seeking help from CALSs is a nonsocial form (Karabenick & Gonida, 2018). Researchers have found that students have different help-seeking tendencies toward teachers (i.e., formal sources) and peers (i.e., informal sources) (Karabenick, 2003; Qayyum, 2018). Some studies explored students' help-seeking tendencies in general, whereas some studies investigated students' help-seeking tendencies in classes on specific subjects, such as chemistry, math, or programming. Students may have different help-seeking tendencies in different classes. For example, a student may be an SHS in a chemistry class but an AHS in a math class. Second, different participants, such as college students and elementary students, may have different help-seeking strategies, skills, and tendencies. Participants in six of the studies were college students, whereas participants in two of the studies were elementary students. It would be interesting to compare the help-seeking tendencies of different types of participants, such as college students and elementary students. Third, there are two main approaches to identifying help-seeking tendencies. One approach employs teachers or experts to identify students' help-seeking tendencies by observing students or investigating system records of students' behaviors. The other approach applies a self-reported help-seeking tendency questionnaire and clustering method to cluster students into several clusters, and experts then identify the help-seeking tendency of each cluster. Help-seeking is a kind of self-regulated learning, and Winne and Perry (2000) proposed that self-regulated learning can be measured as an attitude, which focuses on static and large-grained assessments, through a self-report questionnaire, or measured as an event, which focuses on small-grained dynamic processes, through observation or behavior tracking. Fine-grained evaluations during a long period can reflect more information than a global evaluation from a questionnaire on a specific date (Cantabella et al., 2020). It would be interesting to compare the help-seeking tendency results obtained through questionnaires with those obtained through observation or behavior tracking. In sum, further analytic and

comparative studies of help-seeking identifications are required to investigate students' help-seeking tendencies under different contexts/sources, participants, and identification approaches.

### 5.2. Detection of and intervention mechanisms for poor help-seeking behaviors in CALSs

Table 9 lists the detection and intervention mechanisms for poor help-seeking behaviors in CALSs. Each detection and intervention mechanism was designed based on assumptions about what poor help-seeking behaviors are and how to intervene. Help Tutor is a tutor agent that provides meta-cognitive feedback on help-seeking as students learn with an intelligent tutoring system, Geometry Cognitive Tutor (Aleven et al., 2006; 2016). Help Tutor contains a help-seeking model (comprising approximately 80 production rules) to analyze students' problem-solving and help-seeking behaviors to detect four main categories of student help-seeking bugs (i.e., poor help-seeking behaviors), namely, help abuse, help avoidance, try-step abuse, and miscellaneous bugs. Help abuse indicates that students misuse the help of the CALS. Help avoidance denotes that students could benefit from seeking help but choose to try the step. Try-step abuse means that students try steps too fast. Miscellaneous bugs cover help-seeking bug situations not represented in the other categories, such as students receiving all the hints, including a bottom-out hint of the answer, and still failing to solve the problem. Help Tutor provides students with meta-cognitive feedback as an intervention when help-seeking bugs are detected. For example, Help Tutor intervenes by showing the message "*A hint could be helpful, as this is likely a challenging step to you*" to a student when help avoidance is detected (Aleven et al., 2006).

On the other hand, NALS-HS (version 1) includes six rules to analyze students' problem-solving and help-seeking behaviors and detect three poor help-seeking behaviors, namely, asking for excessive help, having difficulty and needing help but not seeking help, and being stuck and definitely needing help but not seeking help (Chou et al., 2018). NALS-HS adopts a negotiation based regulation mechanism as a help-seeking intervention. A student can actively seek help from the system, and the system may accept the student's help-seeking request or reject the request when the student is detected as having asked for excessive help. The system may also actively prompt a student to seek help when it detects that the student is having difficulty and needs help or force providing hints to the student when he or she is stuck, definitely needs help, and still rejects seeking help. These rules adopt some threshold parameters that can be adjusted. For example, one rule is that a student will be detected as having difficulty and needing help when the student is idle for 40 seconds (i.e., a threshold), and the system will prompt the student to seek help by asking the student "*Do you need help?*" with two buttons, "*Yes*" and "*No*."

*Table 9*. Detection and intervention mechanisms for poor help-seeking behaviors in CALSs

| System | Factors for detection | Poor help-seeking behaviors detected | Intervention |
|---|---|---|---|
| Help Tutor (Aleven et al., 2006; 2016) | Problem solving and help seeking behaviors | Help abuse<br>Help avoidance<br>Try-step abuse<br>General errors | Meta-cognitive feedback |
| NALS-HS (version 1) (Chou et al., 2018) | Problem solving and help seeking behaviors | Asking for excessive help<br>Having difficulty and needing help but not seeking help<br>Being stuck and definitely needing help but not seeking help | Negotiated based regulation |
| NALS-HS (version 2) (This study) | Problem solving and help seeking behaviors<br>Help seeking tendency<br>Problem difficulty levels | Asking for excessive help<br>Having difficulty and needing help but not seeking help<br>Being stuck and definitely needing help but not seeking help | Negotiated based regulation |

This study modified the detection and regulation rules of NALS-HS (version 2) to consider not only problem-solving and help-seeking behaviors but also help-seeking tendency and problem difficulty levels (Table 3). A study has confirmed that students seek help more frequently as problem difficulty increases (Hao et al., 2016). This study adopts historical records of students' problem-solving and help-seeking behaviors for each problem, namely, the lower quartile, the second quartile, and the upper quartile for PSAs, ST, and HSA, as threshold

parameters for the rules for each problem. For students with different help-seeking tendencies, the rules adopt different thresholds to accommodate students' differences. For example, the threshold of detection for seeking too much help for EHSs (HSA >= $Q_2$) is lower than that for AHSs and IHSs (HSA >= $Q_3$) so that the system can remind EHSs not to seek too much help in advance.

In sum, different assumptions regarding poor help-seeking behaviors lead to different detection and intervention mechanisms for poor help-seeking behaviors in CALSs. These assumptions should be validated or modified according to the experimental results. For example, inappropriate attempts (i.e., try-step abuse or making hasty attempts when help would be more beneficial) are generally regarded as poor help-seeking behaviors, but a study found that a high rate of inappropriate attempts on low-skill steps was significantly associated with students' success rate on subsequent relevant attempts (i.e., improved learning), whereas a high rate of inappropriate attempts on medium-skill steps was significantly negatively associated with the subsequent success rate (Roll et al., 2014).

### 5.3. Effects under help-seeking intervention and after help-seeking intervention is faded out

To evaluate the effects of help-seeking detection and intervention, students with help-seeking intervention (experimental group) were compared with students without intervention (control group) in terms of their help-seeking behaviors and performance. Help-seeking intervention is a form of scaffolding; thus, it is necessary to evaluate learning effects under help-seeking intervention and after help-seeking intervention is faded out (Aleven et al., 2016; Chou & Chan, 2016). When a help-seeking intervention is provided, the analysis determines whether the intervention facilitates better student help-seeking behaviors and performance in the learning task, whereas after the help-seeking intervention is faded out, the analysis focuses on whether the intervention helps students to be better help-seekers in future learning tasks. Table 10 lists the effects under help-seeking intervention and after help-seeking intervention has been faded out, which includes the control and experimental groups. Students in the experimental group who used Geometry Cognitive Tutor with Help Tutor had better help-seeking behaviors than students in the control group who used Geometry Cognitive Tutor without Help Tutor (Roll et al., 2006; Roll et al., 2011). Students in the experimental group also had better help-seeking behaviors after the intervention was faded out than students in the control group (Roll et al., 2011). The results indicated that students could be tutored to be better help-seekers. However, there were no significant differences in performance between students in the experiment and control groups.

*Table 10*. Effects under help-seeking intervention and after intervention was faded out

| Study | Effects under help-seeking intervention | Effects after intervention was faded out |
|---|---|---|
| Help Tutor (Roll et al., 2006) | Improved help-seeking behaviors | N/A |
| Help Tutor (Roll et al., 2011) | Improved help-seeking behaviors | Improved help-seeking behaviors |
| NALS-HS (version 1) (Chou et al., 2018) | Improved help-seeking behaviors | N/A |
| NALS-HS (version 2) (This study) | Improved help-seeking behaviors (easy problems)<br>Improved performance (difficult problems) | N/A |

Students in the experimental group who used NALS-HS (version 1) with help-seeking intervention mechanisms had better help-seeking behaviors than students in the control group who used NALS-HS without intervention mechanisms (Chou et al., 2018). However, there were no significant differences in performance between students in the experiment and control groups. In this study, students in the experimental group who used NALS-HS (version 2) with help-seeking intervention mechanisms not only had better help-seeking behaviors for easy problems but also had better performance for difficult problems than students in the control group who used NALS-HS without intervention mechanisms. The results revealed that the help-seeking intervention not only promoted better help-seeking behaviors but also promoted better performance; however, the effect of the help-seeking intervention on behaviors appeared only for easy problems, whereas the effect of the help-seeking intervention on performance appeared only for different problems. The results might indicate that task or problem difficulty is a factor affecting student help-seeking behaviors, performance, and the effects of intervention. Another study found that students' success rate was significantly associated with the rate of inappropriate attempts on low-skill steps but was significantly negatively associated with the rate of inappropriate attempts on medium-skill steps (Roll et al., 2014). In sum, the effects of help-seeking interventions and the influencing factors need further investigation.

## 6. Conclusion

This study proposed an approach for developing adaptive help-seeking regulation mechanisms for different help-seeking tendencies. First, a questionnaire and clustering approach was adopted to identify students' help-seeking tendencies in the context of a CALS. Then, adaptive help-seeking detection and regulation mechanisms were developed for different help-seeking tendencies and for problems with different difficulty levels. The mechanisms take students' individual differences in help-seeking tendency into account to provide them with precise and adaptive help-seeking detection and regulation. The mechanisms also adopt historical student records of problem-solving and help-seeking data for each problem as parameters for the adaptive help-seeking detection and regulation mechanisms to account for the difficulty of each problem. Finally, the results of the experiment showed that adaptive help-seeking regulation mechanisms for different help-seeking tendencies promoted a higher ratio of students solving problems by themselves without seeking help (experimental: 90.3% and 45.1% for easy and difficult problems versus control: 75.4% and 28.7%), better help-seeking behaviors (i.e., less executive help-seeking, experimental: 2.2% versus control: 10.8%) for easy problems, and better learning performance for difficult problems (experimental: 87.1 versus control: 76.4). In sum, the study has shown the feasibility and benefit of the proposed approach of regulating student poor help-seeking. The approach can be applied to develop adaptive help-seeking regulation mechanisms for other CALSs. However, students' help-seeking tendencies may be differently identified for different participants and for different CALSs. Adaptive help-seeking regulation mechanisms should be modified for different identified help-seeking tendencies, and the effects of the modified mechanisms should be explored. Further studies are required to explore how to generally identify help-seeking tendencies and design effective help-seeking regulation mechanisms.

Furthermore, the proposed adaptive regulation mechanisms of collecting data, adopting machine learning methods to identify students with different profiles and designing different regulation mechanisms can be applied in different contexts with different data, different machine learning identification methods, and diverse regulation mechanisms. For example, students' log of participation and solutions in a CALS can be collected for applying machine learning classification methods to identify students with different performances for intervention (Villagrá-Arnedo et al., 2020). Enrolled students' data can be clustered to identify prospective students for the promotion of graduate programs (Croda et al., 2019).

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## Appendix. Help-seeking questionnaire

**Help-seeking willingness**

1. If I were having trouble solving problems I would ask the system to help me how to solve problems.
2. Getting help from the system would be one of the first things I would do if I were having trouble in solving problems.

**Executive help-seeking**

3. The purpose of asking the system for help would be to succeed without having to work as hard.
4. Getting help from the system would be a way of avoiding solving problems on my own.

**Help-seeking threat**

5. I would feel like a failure if I needed help from the system.
6. I would not want anyone to find out that I needed help from the system.
7. Getting help from the system would be an admission that I am just not smart enough to do the work on my own.