Attention, relevance, confidence, and satisfaction motivation model in mathematics education: a systematic literature review

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Article Info

Article history:

Received Jun 13, 2024
Revised Sep 19, 2024
Accepted Sep 30, 2024

Keywords:

Literature review
Mathematics achievement
Mathematics education
Motivation
The ARCS model

ABSTRACT

With the aims to find out how the attention, relevance, confidence, and satisfaction (ARCS) motivation model was applied into mathematics education; what research methods were used; and what outcomes were reported in these empirical studies, this paper systematically reviewed the empirical studies applied the ARCS motivation model into mathematics education trends on 2013-2023. Among 26 articles identified, the findings of this review indicated that the data from several contexts support the applicability of the ARCS model in diverse environments for mathematics learning, across different stages students, and in various nations. Three dimensions of the role of the ARCS model in mathematics education studies are identified: instructional design; theoretical framework; and measurement tool. Quantitative method was used most, and experimental studies and quasi-experimental studies were the main methods. Three types of outcomes were mainly focused on the past empirical studies: affective outcomes, cognitive outcomes, social outcomes. The findings highlighted the prospective paths that this area of research should pursue.

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1. INTRODUCTION

Motivation plays a crucial role in shaping students’ performance in mathematics [1]. Extensive studies have highlighted the significance of motivation in influencing mathematical achievements [2]–[4]. When learners are motivated, they exhibit greater concentration and excel in mathematical tasks, demonstrating resilience especially when faced with challenging concepts [5]. It is imperative to ensure and sustain students’ motivation towards learning mathematics [6]. In educational research, attention, relevance, confidence, and satisfaction (ARCS) motivation model from Keller is widely used and practiced [7]. The theoretical foundation of ARCS model is expectancy-value theory [8]. The ARCS model posits that effective student motivation hinges on: i) capturing and maintaining attention; ii) elucidating the relevance of the content; iii) nurturing self-belief in attainable success through effort; and iv) instilling a sense of accomplishment and gratification [8]. This model follows a systematic process of definition, design, development, and evaluation [8]. These four dimensions play a significant role in improving students’ motivation in learning mathematics [9].

The purpose of attention is to capture the students’ attention through kinds of instructional methods and presentations [10]. An effective approach to engage students in mathematics class is to offer diverse and multifaceted methods of delivering mathematics content, such as utilizing computer programs, videos, or group activities to sustain learners’ motivation in learning mathematics [11]. These ways combine the characteristics of mathematics to present mathematics content to students, which will make students find it interesting and pay more attention on mathematics class. For relevance aspect, teachers should establish a connection between mathematics class and their practical relevance in the future [10]. Several effective strategies for teaching mathematics, include: i) making connections between the curriculum and real-world problems; ii) addressing the specific educational needs of learners; iii) linking current content to future applications; iv) clearly defining objectives; v) promoting collaborative group work; and vi) providing individualized attention to learners [12]. Demonstrating the relevance of mathematics enhances motivation as students may perceive the connections between mathematics and other subjects, fostering a deeper comprehension of the necessity of mathematics learning for their own benefit. For confident aspect, when students possess the necessary confidence to initiate and perhaps finish a mathematics assignment, so assuming personal accountability, their self-efficacy is being addressed [13]. Emphasizing students' learning abilities to improve their confidence is essential. Enabling students to present what kind of work they have finished provides them with the opportunity to experience a sense of accomplishment [12]. Satisfaction focuses on the emotional response of students towards the mathematics activities they have successfully completed. Personal satisfaction is the sense of pride that a student experiences when successfully completing a mathematics task [10], [14]. Learners should be proud and satisfied of what they have achieved throughout the mathematics course. This satisfaction will motivate students to solve more mathematics tasks.

Li and Keller [15] conducted a comprehensive review study that examined the ARCS model using data from 27 articles. The study focused on educational contexts, research methods, and outcomes. However, no literature review focuses on the application of ARCS in mathematics education specifically. The mathematics achievement of students is impacted by numerous factors, with motivation being a significant factor. According to Putwain *et al*. [16], there is a belief that students who are motivated will provide greater focus to learning mathematics, leading to higher marks in the subject. Conversely, students who lack motivation or experience negative emotions, such as worry, will struggle to achieve high levels of performance in mathematics [17]. It can be seen that for mathematics education motivation is very important. ARCS as a crucial motivation model, it's necessary to study the details of its application in mathematics education so that researchers can better play its role in mathematics education. This study aims to address this gap by reviewing the past relevant empirical studies systematically to evaluate the application of the ARCS motivation model in mathematics education to answer the three questions:

i) How was the ARCS model applied to mathematics education?
ii) What research methods were used in previous empirical studies?
iii) What are the reported outcomes following the application of ARCS model in mathematics education?

2. METHOD

A systematic method is utilized in this study to review the literature on the implementation of the ARCS model in the field of mathematics education. This methodology was derived from the standards known as the preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) [18]. The PRISMA-ScR is an evidence-based, minimum set of recommendations designed primarily to encourage transparent and complete reporting of systematic reviews. It is a road map to help authors best describe what was done, what was found, and in the case of a review protocol, what are they are planning to do [19]. Many systematic reviews have employed the PRISMA criteria extensively. The full reports of the review process guarantee the reliability and quality of the research by enabling readers to replicate and validate the research's implementation. Rigorous criteria are used in this study to ensure the high standard of the papers and avoid any potential biases in the selection procedure. The following criteria were utilized during the review process:

- These papers were empirical research that were published in three well-known databases: Education Resources Information Center (ERIC), Scopus, and ScienceDirect.
- The papers reviewed in this study included participants of various educational levels: primary school, secondary school, and higher education. Various learning styles were included, for example, game-based learning or computer-assisted learning.
- The research utilized the ARCS motivation model as instructional design, theoretical framework, or measurement instrument.
- The papers were written in English.

The study examined the related papers in the electronic database included ERIC, Scopus, and ScienceDirect from 2013 to 2023. "ARCS," "ARCS model," "attention, relevance, confidence, satisfaction," "mathematics," and "mathematics education" were the terms searched for the review. Throughout the review procedure, the researchers systematically downloaded these papers that were relevant to the searched terms and proceeded to review them consecutively. A total of 21 articles were found from three databases: 11 from ERIC, 3 from Scopus, and 7 from ScienceDirect. Additional papers were identified using Google Scholar which also following the same rigorous selection criteria. These criteria included evaluating the relevance of the articles to the research topic, ensuring that they were peer-reviewed, and assessing their methodological quality and contribution to the field. After this careful examination, five additional articles from Google Scholar were selected for inclusion. This examination involved a detailed review of the abstracts, methodologies, and findings to ensure they aligned with the research objectives. As a result, a total of 26 articles were included in the final review. Figure 1 illustrates the four primary steps undertaken in this review. The four stages of the process are identification, screening, eligibility, and inclusion.

Each individual article served as the basic unit of analysis. This review employed content analysis as a method and utilized a summative methodology for content analysis, in which all the articles were evaluated and compared according to three research objectives [20]. Four sequential steps of analysis were used to conduct the analysis, as shown in Figure 2. Ultimately, the findings were presented in different sections. First section reported the mathematics educational contexts and the role of the ARCS model in mathematics education studies. Some summary charts were generated containing information about the research contexts and the ARCS strategies implemented in this phase. Second section, the research design, relevant variables, and measurement methods were presented. Research outcomes were analyzed respectively in the third section. The outcomes of the research were classified into three different domains: affective outcomes, cognitive outcomes, social outcomes.

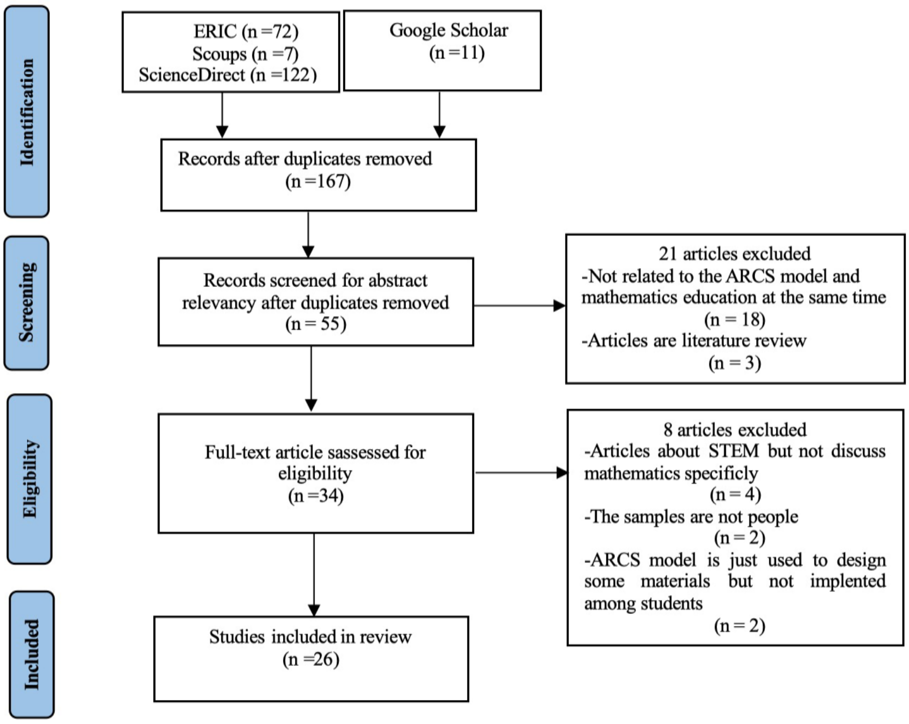

Figure 1. The selection procedure of reviewed studies

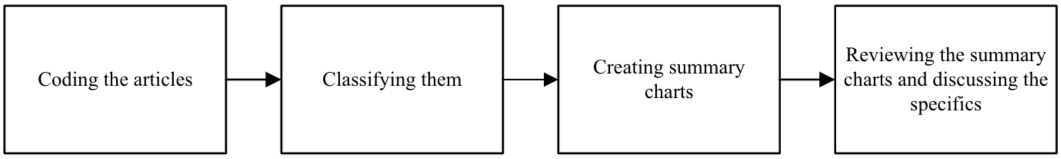

Figure 2. Steps of analysis

3. RESULTS AND DISCUSSION

This section presents the results of the review of the 26 studies and the results were presented to address the three research questions. The discussion of related results was also expanded to make this result more clearly understood. The application of ARCS model in these studies, research methods and outcomes of these studies were discussed.

3.1. How was the ARCS model applied to mathematics education?

The results of this research question were discussed from two aspects: the study context/environment and the role of the ARCS model in mathematics education research. The study context includes the countries of studies, the publication year, participants of studies and course delivery methods. The role of the ARCS model in mathematics education research was divided into three categories: instructional design, theoretical framework, and measurement instrument.

3.1.1. Study context

To comprehend the distinct educational environments, this study context includes three aspects: countries of studies, participants of studies, and course delivery methods. Table 1 shows that the research covers various cultures and countries, including China [21]–[25], Colombia [26], [27], Indonesia [28]–[34], Korea [35], Malaysia [2], [36], South Africa [37], Turkey [1], [38], and United States [11], [13], [39]–[42]. This established a strong foundation for the applicability of any findings that arise from the data. Most studies (7 of 26) were from Indonesia and the next highest studies (6 of 26) were from United States. The number of related studies in China was closely followed by 5 studies.

The analysis of publication year data demonstrated a nonlinear growth in the quantity of articles published in the examined fields from 2013 to 2023, with a notable increase in 2019, as shown in Figure 3. The application of the ARCS model in technology-enhanced learning contexts is gaining increasing interest [7]. In addition, ARCS model has been already commonly employed in web-based, online, and mixed learning contexts [43]. The post-pandemic period has seen the rise of this kind of learning model as a widely accepted approach in education. It has played a significant role in transforming education from traditional face-to-face methods to a combination of face-to-face and online learning modes [44]. Notably, 62% (16 out of 26) of the research were conducted during the past five years. Although the relevant studies were decreased from 2019, ARCS model was still very important in mathematics education [42]. The pandemic caused substantial disruptions across various academic disciplines. Many researchers, especially in fields such as mathematics education, had limited access to necessary resources, resulting in reduced productivity. This is consistent with findings from studies indicating a decline in research productivity during the pandemic across various fields [45]. It was remarkable that experimental studies on the ARCS motivation model are more typical in mathematics education [15].

Table 1. Countries of studies

Studies	Countries	Frequency
[21]–[25]	China	5
[26], [27]	Colombia	2
[28]–[34]	Indonesia	7
[35]	Korea	1
[2], [36]	Malaysia	2
[37]	South Africa	1
[1], [38]	Turkey	2
[11], [13], [39]–[42]	United States	6

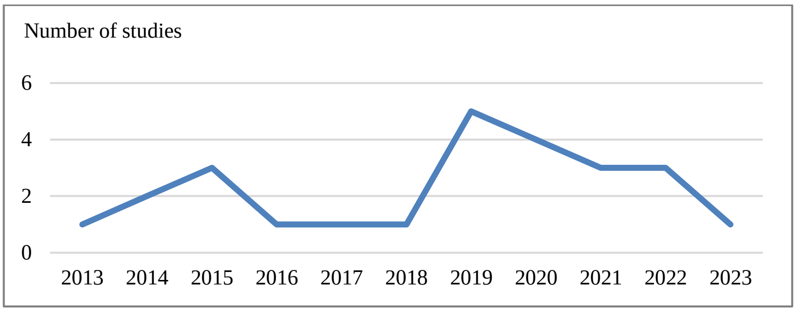

Figure 3. Distribution of publications by year

The diverse range of participants spanning from primary students to graduate students enhanced the generalizability of the results, as presented in Table 2. Most of these studies focused on secondary education (11 of 26) and higher education (10 of 26), which can be more intuitively compared from Figure 4. One study had a sample of graduate students and the rest being undergraduates in higher education. There were only five studies in primary education. Some studies have shown that based on the "attention" dimension of ARCS, technology-based instructional design often incorporates the ARCS model to capture students' attention and interest [2], [11], [13], [15], [21]. Empirical evaluation has showed the positive influence of technology-based learning on students' conceptual comprehension at the secondary school level [46]. Therefore, the technology-based instructional design can be implanted among secondary students and college students easier.

Table 2. Participants of studies

Studies	Participants	Frequency
[1], [22], [23], [30], [39]	Primary school students	5
[2], [31]–[34], [36]	Junior school students	6
[21], [24], [37], [40], [42]	High school students	5
[13], [25]–[29], [35], [38], [41]	College students	9
[11]	Graduate students	1

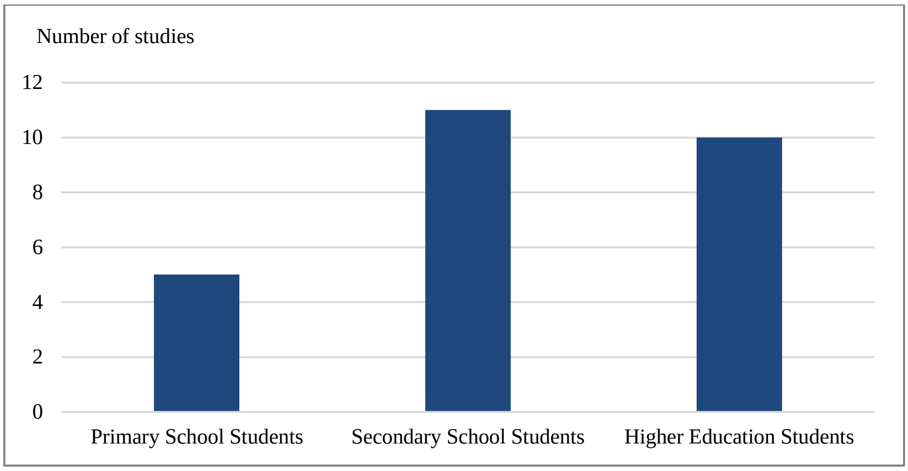

Figure 4. Participants of studies

The ARCS motivation model was implemented to various mathematics courses or instructional sessions, depending on the technologies used in the educational setting, as shown in Table 3. Within these educational settings, the majority of research has combined the ARCS model with technology-based forms of learning such as online learning, digital game-based learning, virtual reality learning, web-based learning, and mobile learning. The approach was implemented e-learning contexts and in flipped classroom in various research. All these technology-based course delivery methods have applied student-centered environments, which can match with ARCS model properly. At the same time, there are also studies (9 of 26) that do not focus on the design of demonstrating classroom instruction, and so use no computer or internet supported instruction.

Table 3. Course delivery methods

Studies	Delivery methods	Frequency
[39], [41]	Blended instruction	2
[1], [2], [11], [13], [21], [24], [36], [38], [40]	Web-based instruction	9
[23], [25]–[27], [34]	Game-based learning	5
[22]	Mobile learning	1
[28]–[33], [35], [37], [42]	No computer or internet supported instruction	9

3.1.2. The role of the ARCS model in mathematics education studies

The role of the ARCS model in educational contexts was divided into three categories in a review study by Fang *et al.* [47]: instructional design, theoretical framework, and measurement instrument. The ARCS model's role in mathematics education, as shown in Table 4, was categorized in this review into the same three areas, namely: i) instructional design: in order to develop new instructions, the ARCS model was integrated into the process and motivational techniques were used [8]; ii) theoretical framework: instructional design or motivation data were analyzed using the ARCS model as a theoretical framework [48]; and iii) measuring tool: the instruction materials motivation survey (IMMS) and course interest survey (CIS) which measures motivation, was used in conjunction with the ARCS model [14].

From Figure 5, we can see that there are many studies used ARCS model as an instructional design (17 of 26) and measurement tool (14 of 26) in mathematics education. Meanwhile, there were some studies in which the ARCS model can be used as both instructional design and measurement tool. The ARCS model was utilized to design and evaluate instructional materials in many education settings, such as game-based learning, digital books, mobile learning, flipped classrooms [38], [49]–[51]. These results showed that it also happens in mathematics education.

The ARCS model, which served as a theoretical framework for the review study by Kivunja [52], was divided into two categories: analysis of instructional design and analysis of students' motivation. It illustrated the functions of the theoretical framework utilized to analyze the research data, as presented in Table 4. Out of the four analyzed papers, only one discussed analyzing students' motivation using the ARCS model as theoretical framework. A case study was conducted to answer the research question: how do students' experiences influence their motivation in the ARCS framework? In the study by Nguyen [41], ARCS model played the theoretical framework role to analyze students' motivation in learning mathematics. The model was applied in three studies to examine instructional design based on the ARCS component concepts. For example, Keller's ARCS model was explored as a theoretical framework for the introductory statistics classes to provide the prospective mathematics teachers with the motivation and stimulation to learn statistics on their own [35].

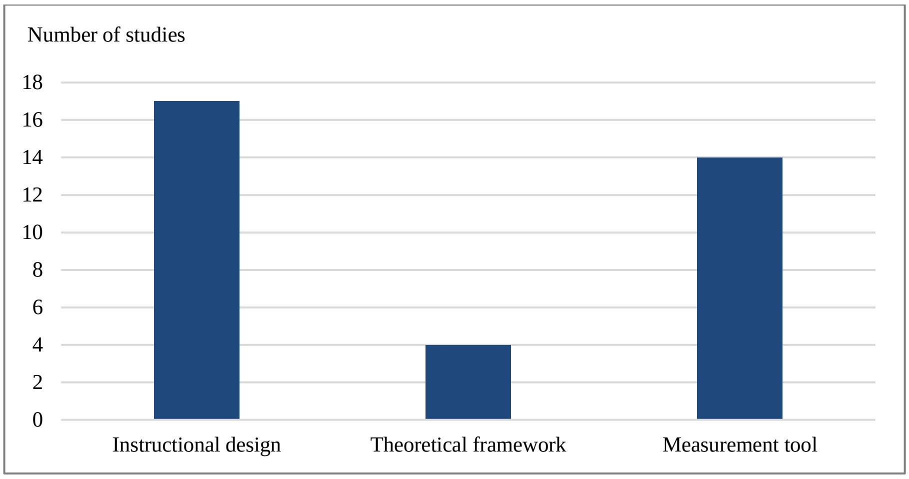

Figure 5. The role of the ARCS model

Table 4. The function of the ARCS theoretical frameworks used in studies

Studies	Functions	Frequency
[41]	Analysis of students' motivation	1
[35], [36], [42]	Analysis of instructional design	3

3.2. What research methods were used in previous empirical studies?

The studies were classified according to their research methods, and the measurements of the main variables were analyzed. The quantitative method was the most commonly utilized research method, appearing in 20 out of the 26 articles. Document A provided a comprehensive overview of the research design employed in each of the articles that were reviewed. Figure 6 shows the proportion of the three research methods. It showed that 54% of relevant studies used quantitative method, 31% studies used mixed method, while only 15% studies used qualitative method. This result indicated that most studies were experimental. Most of the experimental studies conducted motivation intervention based on ARCS motivation model. Intervention studies contribute to the advancement of the field by providing insights into the cause-and-effect links between motivation components and educational outcomes, or between educational settings and motivation outcomes [53]. From a practical standpoint, intervention studies increase our understanding about which interventions are most effective in enhancing educational outcomes in a way that observational research cannot [54].

3.2.1. Research design

Document A demonstrated that the experimental or quasi-experimental design method is extensively employed as a quantitative research method. In experimental design studies, participants were randomized to conditions randomly, but in quasi-experimental design research, randomness was not involved in the assignment of participants to conditions. Experimental and quasi-experimental research often involved one group that taught by learning materials or classroom instructions incorporating ARCS strategies (experimental group), while another group taught by materials or instructions without these strategies (control group). In addition, the researchers employed pre- and post-test experimental design in both the experimental and control groups [22]. This involved comparing the motivation and/or achievement scores of the same individuals before and after the intervention to identify any differences in these variables.

Some studies also designed three or more groups to further determine the impact of different variables on mathematics motivation. Syahputra *et al.* [29] utilized an instructional system that incorporated the ARCS model and the introducing the new concepts, metacognitive questioning, practicing, reviewing and reducing difficulties, obtaining mastery, verification, and enrichment (IMPROVE) method to enhance students' motivation and utilization of self-regulated learning (SRL) strategies while studying trigonometry functions in a web-based learning environment. A total of 236 first-year participants from two Chinese high schools were randomly assigned to the motivational design (MD), SRL intervention (SI), motivational design and SRL intervention (MDSI), or the control groups.

Some studies employed case study, qualitative, or mixed method approaches. The objective of these investigations was to get a more profound comprehension of the motivating challenges that students face when studying mathematics. Additionally, the studies aimed to explore the practical applications of the ARCS model, as well as investigate students' perspectives and attitudes towards mathematics education and learning resources.

The use of case study technique in social sciences research has been a subject of debate due to the differing and sometimes conflicting approaches advocated by various research methodologists. The case study is a commonly employed qualitative research methodology in the field of educational research [55]. To enhance the lesson on recognizing the property of the sample mean in statistical inference of the sampling distribution for aspiring mathematics teachers in an introductory statistics course, a case study was conducted in which an exploratory lesson that integrated Keller's ARCS model was implemented and analyzed [35].

Whether it is quantitative methods, qualitative methods, or mixed methods, all have promoted the research on the ARCS motivation model in mathematics education to a certain extent. The researchers in the experimental and quasi-experimental studies aimed to investigate the causal connection between the utilization of the ARCS model in teaching and the motivation of students in studying mathematics, as well as their mathematics achievement and other related characteristics. These research studies have supplied academics and practitioners with evidence regarding the effectiveness of the ARCS model in enhancing participants' motivation and achievement, as well as other measures, within a particular educational setting. Qualitative, mixed method, and case studies can provide researchers and practitioners with insights into the design process, the rationale behind applying ARCS model in this manner, and the criteria for selecting specific ARCS strategies.

Various research designs are helpful in exploring the impact of the ARCS model in mathematics education. Most researchers attempted to examine the causal relationship between using the ARCS model in teaching and students' motivation in learning mathematics, mathematics achievement, and/or other variables through experimental and quasi-experimental studies. In addition, some researchers further used qualitative methods to explore the reasons and process of the impact of the ARCS model on participants' motivation to learn mathematics.

3.2.2. Measurement methods

The most often measured outcome variables in the evaluated research were motivation in mathematics learning and mathematics achievement. Since motivation cannot be directly observed, it was always measured indirectly. Therefore, in ARCS motivation surveys, questionnaires and interviews were commonly used. The ARCS model application studies utilized the CIS [14] and the IMMS [14] designed specifically for the ARCS model to assess participants' motivation in learning mathematics frequently. The questionnaires used in both surveys are specifically constructed based on the four dimensions of ARCS model. The main difference between CIS and IMMS lies in their respective instructional approaches. CIS is specifically designed for teacher-led classrooms, whereas IMMS is primarily intended for self-directed learning [15]. Out of the 26-research analyzed in this review, six utilized the IMMS or its modified version, while 4 employed the CIS or its modified version to assess students' motivation in relation to the ARCS components.

Some researchers designed questionnaires based on ARCS motivation model by themselves [24]. In some qualitative studies and mixed studies, researchers used interviews to explore the reasons and process of the impact of the ARCS model on participants' motivation in learning mathematics [26], [39]. Teachers' and researchers' observations was also used to make sure the application of ARCS in the classroom and served as the input to the motivational adaptive instruction for the experimental group [2]. The reviewed articles typically used instructor-designed tests or examinations to evaluate students' mathematics achievement. There were 11 out of 26 studies conducted mathematics achievement test in this review. Some studies used pre- and post-test to examine the achievement increase before and after the motivational intervention [21].

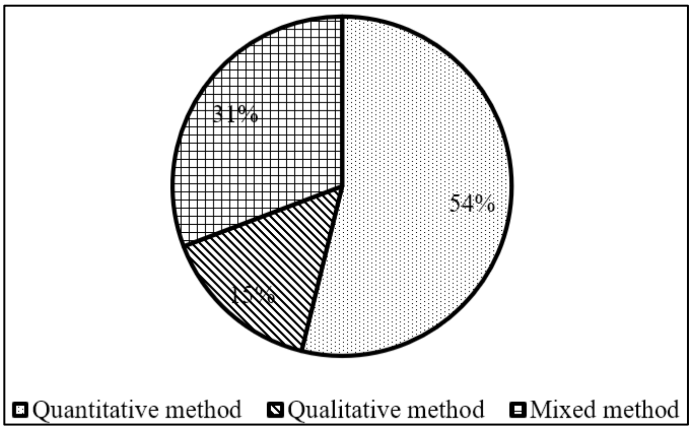

Figure 6. Research method of studies

3.3. What are the reported outcomes following the application of the ARCS model in mathematics education?

Three types of learning outcomes were identified according to the learning outcomes of the reviewed studies, as presented in Figure 7: affective outcomes (25 of 26 studies), cognitive outcomes (14 of 26 studies), social outcomes (1 of 26 studies). Affective outcomes encompass various factors, including students' motivation, emotional responses, subjective attitudes towards the course, and sustained motivation. Affective outcomes were the most significant result that researchers in the ARCS literature have documented. Students' performance in tests and thinking outcomes were the main cognitive outcomes reported in these articles. Communication skills and collaboration abilities are commonly referred to as social outcomes. Collaborative learning facilitates a profound comprehension of subject matter, leading to enhanced academic performance among students in comparison to competitive or individual learning approaches [56].

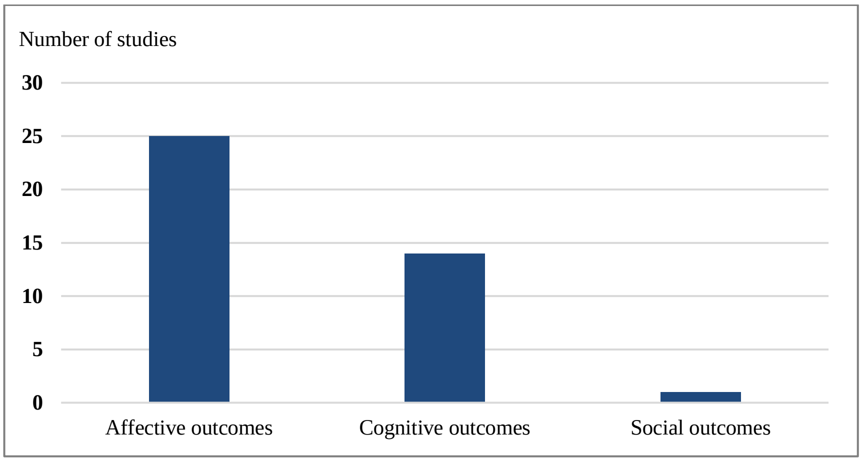

Figure 7. Learning outcomes of studies

3.3.1. Affective outcomes

In this review, the affective outcomes of most studies were positive. The participants' motivation, attitudes and interest in learning mathematics were improved after the ARCS intervention or at least one of the four ARCS components was improved. Or the experimental group showed higher motivation than the control group. For example, the virtual reality has the effect of improving students' learning motivation and learning effectiveness in the digital teaching of mathematics [24]. Using digital game-based learning with the diagnostic mechanism (experimental group) is better than without the diagnostic mechanism (control group) [23]. However, the results of two studies were not positive in this review. The motivation of the participants was not improved, or the motivation was not higher than the control group [2], [31]. They both pointed that motivation and mathematics performance were not strongly correlated for this group of students.

3.3.2. Cognitive outcomes

There were also two groups of studies reported either higher/increased achievement or no significant difference in achievement like the affective outcomes. Only one study showed that the mathematics performance was not strongly correlated for this experimental group students [2]. The effectiveness of some ARCS strategies that the researchers selected might be negative under certain conditions. Other studies all got the result that the ARCS experimental group had higher achievement and better mathematics performance in the mathematics tests than the control group or the test experimental group students, or the students' mathematics performance was improved after the intervention. The computer-game activities had a positive effect on the mathematics achievements of the students [1]. Therefore, these authors urged more investigation to carry out in order to study the impacts of the ARCS model in various contexts.

3.3.3. Social outcomes

Only one study in this review got the social outcome which interviewed the participants who were taught by the educational intervention in mathematics teaching that uses games and technology tools [26]. These participants viewed collaborative work was one of the most positive aspects to improve their motivation. It can be seen that teamwork in mathematics learning is also an effective way to promote students' motivation in learning mathematics. Researchers can consider making more use of teamwork based on ARCS model to improve students' motivation in learning mathematics.

The review results of the studies outcomes showed that mathematics motivation and mathematics achievement were the main parts that relevant studies pay attention to. This may be due to the fact that mathematics motivation and mathematics achievement are the two most influential aspects of students learning mathematics. Besides, the results also found that teamwork also had a positive impact on students' learning of mathematics, which encourages scholars to consider this aspect in future research.

Despite the valuable insights this review provides, several limitations should be acknowledged. First, the geographical scope of the reviewed studies remains limited, with a notable underrepresentation of European countries, thus restricting the understanding of how the ARCS model functions across diverse educational contexts. Second, the research timeline reveals a decline in the number of studies published in recent years, which may suggest a reduced focus on the ARCS model in current mathematics education research. This gap highlights the need for renewed attention to the model's application. Third, the existing literature has predominantly utilized quantitative methods, with fewer studies exploring the ARCS model through mixed or qualitative approaches, limiting the breadth of insights into students' motivational experiences in various learning environments. Addressing these limitations will guide future research and contribute to a more comprehensive understanding of the ARCS model in mathematics education.

4. CONCLUSION

This review study highlighted the prospective paths that this area of research should pursue. According to the findings of the role of the ARCS model, the researchers can take use of the ARCS model to study motivation in mathematics education in multiple roles at the same time. This study can provide the researchers evidence to set educational environments, choose suitable methods and design and develop ARSC strategies. The ARCS model seems to offer valuable support to designers and educators, particularly in controlled studies examining its crucial features and areas of efficacy. Researchers are able to design ARCS strategies using those principles and evaluate their impact through experimentation. In general, the students exhibited favorable dispositions towards the ARCS strategies and the mathematics learning materials that incorporated those strategies.

Based on the limitations mentioned in this review study, this paper recommends that researchers take the following factors into account when planning and structuring future relevant studies: i) extend research to additional European countries to promote the application of the ARCS model in mathematics education research within these populations; ii) despite a recent decline in research, due to the significance of motivation in mathematics learning and the advantages of the ARCS model, more scholars are urged to investigate the ARCS motivation model in mathematics education; iii) promote the implementation of the ARCS model in diverse mathematics learning environments, offering students more opportunities to enhance their mathematics learning experience; iv) propose the integration of the ARCS model into various pedagogies, which will bring benefits to the field of teaching and learning in mathematics education; and v) advocate for the integration of the ARCS model with other theoretical frameworks to analyze data or research instructions. Collectively, these recommendations for future investigation will enhance our comprehension of the ARCS model in a broader array of demographics and settings within mathematics education.

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