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A systematic review of programmed learning approach in science education

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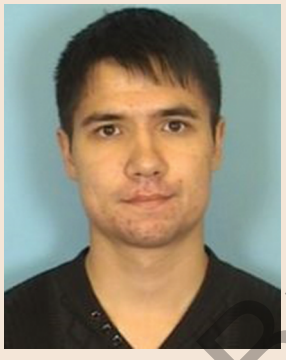
Additional information is available at the end of the article

Abstract: Natural science subjects have always been the most challenging for students in schools and universities. While the pandemic brought about a lot of new challenges, it also gave academics the chance to test out evaluation methodologies they had previously thought about but hadn't used in a relatively low-risk setting. The programmed learning approach is a teaching and learning pedagogy that creates better learning experiences. Therefore, this systematic literature review focuses on the impact of programmed instruction on the learning process. The analysis was made based on the PRISMA review methodology. Five databases were searched to find 33 articles about the benefits of programmed instruction in science education published between 1970 and 2022. In terms of research participants, the majority of the studies (14 studies) focused on undergraduate students, college students (5 studies), lecturers/teachers (3 studies), mixed (2 studies), and adults (1



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Timur Sadykovis a PhD, assistant professor at the Department of Inorganic and Technical Chemistry, Chemistry Faculty, Buketov Karaganda University (Kazakhstan). He is a member of the laboratory of methods for teaching chemistry. Timur has been actively studying modern interactive methods and technologies, programmed learning, educational websites, and mobile applications for teaching chemistry.
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PUBLIC INTEREST STATEMENT

A direct consequence of scientific and technological progress is innovation. Their use is a characteristic feature of a modern and developing society. Programmed instruction is learning according to a pre-developed program, which provides for the actions of both students and teacher (or a learning machine that replaces his actions).Two factors led to the development of programmed learning. The first factor, teachers noticed that in practice, when using the traditional form of education, there is no clear guidance on the actions of students with educational material from the teacher, as a result of which students have gaps in knowledge. The second factor, scientific and technological progress, was the appearance of the first learning machines, which forced to reconsider approaches to learning. Learning machines are technical learning tools that automate certain stages of the learning process based on interaction with each student individually. This interaction is carried out because learning machines can exchange information with students: the machine receives information from the student that characterises the progress of learning the educational material and automatically reacts to this information.

study). Our systematic review found the following benefits of programmed learning: effective and fun teaching approaches, proven favourable impacts on behaviour change, increased scores for college and secondary school students, and raised students' interest.

Subjects: Education & Development; ICT; Theories of Learning; Education Studies; Research

Keywords: programmed instruction; programmed learning approach; teaching machine; systematic literature review; education

1. Introduction

Rapid enrolment in online courses has been observed in the 21st century and biological determinates, such as various stamps of COVID-19 that challenge how schools and universities respond to education. Faced with an unusual learning environment, students are often pressed to unlearn longstanding learning habits and engage in new ways of learning. However, this "programmed instruction" has empirical support from the past, which we trace back to Herbert's element association doctrine or even earlier.

The conceptual basis of programmed learning is the theory of interactionist orientation (symbolic interactionism, role theories, and theories of the reference group), which was developed in the 1930s of the 20th century. The concept of programmed instruction originated in the United States of America. The first teaching machine was invented by (Pressey, 1927) and was a roll of paper in a box with an opening to read a text and write answers. It was not until the 1950s that practical methods of programming were developed. In 1954, B. F. Skinner of Harvard University developed linear programming. Skinner's research was supported in part by the National Defense Education Act and different foundations in the 1950s (Kurbanoglu et al., 2006).

Skinner defended traditional American psychology based on the behaviour approach as well as organism behaviour control. According to him, the learner's behaviour is shaped by the program and he follows the S-R-R (stimulus-response-reinforcement) model (Hošková-Mayerová & Rosická, 2012). Criticizing Skinner's program (Crowder, 1959), created his branching program. Moreover, Skinner received grants from the U.S. Office of Education and the Carnegie Corporation in the 1960s.

The concept of humanistic psychology and psychotherapy (the 60s of the XX century), as well as socio-perceptual cognitivism (1960s) had a great influence on programmed learning. The AutoTutor teaching machine, which was introduced in 1962, employed optically coded 35 mm film for both text and machine instructions, as well as buttons A through E for student responses. According to a science editorial from the end of 1962, there would be 250 programmed courses in elementary, secondary, and college mathematics, 60 in science, 25 in electronics and engineering, 25 in foreign languages, and 120 in social studies. In 1969, the Forera 501 had four tracks: pictures, text, sound, and more branching possibilities (Rutkaus, 1987).

The USSR fully accepted that idea as an optimum learning control method in the 1960s. It was developed, improved and enhanced resulting from extensive knowledge, particularly in pedagogy, psychology cybernetics, the theory of information, and mathematical logic. In 1962, there were roughly sixty companies designing programs and companies manufacturing teaching machines across the United States. The state of California led the country in the manufacture of the machines, while New York designed most of the programs. The brainchild of Skinner and others had indeed become an industry.

The early success of programmed instruction seemed to indicate that machine technology and behaviourist principles worked well together. In the following years, truly titanic work was done in

the field of information exchange concerning certain concepts of programmed learning, as well as the results of experiments conducted. Although programmed instruction eventually faded as a substantive movement in American education, it laid the groundwork for much of today's modern educational technology. When it comes to programming theory, the United Kingdom and Germany are well-known centres. This discipline began to develop a few years later in other European countries and former Czechoslovakia, however, this fact benefited from advanced cybernetics and various logic-mathematical disciplines that could be more effectively utilized. Germany gained respect in this field as a result of strong vital international information and knowledge exchange. It used highly advanced mathematical-cybernetic methods, a well-developed programmed learning model concept, and a relatively short practical further utilization (Tomić & Osmić, 2006).

In the 1970s, IBM and Apple began manufacturing computers. The software of these computers' operating systems was gradually refined as well. Initially, it was a DOS system, later graphical user interfaces such as Windows, Apple, and Linux (the most typical operating systems) were developed. In 1972, the PLATO IV system introduced touch displays into the classroom for the first time as a computer-aided instruction (CAI) system. There was concern that a CAI system might isolate children and restrict their social development, according to a PLATO IV system usability study conducted with primary school students (Zelený & Mannova, 2006).

In 1986, significant changes occurred in schools when they gradually began to use local computer networks to exchange files, applications and technical devices. After the creation of the global World Wide Web (1991) and the appearance of the first web browser, learning became truly "interactive" (1994). The internet is a communication medium that also serves as a virtual learning environment. Internet application services make possible access to educational content from anywhere in the world. These technologies have enabled a significant advancement in the development of the use of information technologies in the educational sphere. In the United Kingdom, software named "JumpStart" was introduced for primary school students in 1994. This program made it possible to teach mathematics, reading and natural sciences at a level appropriate for the child's age, and it was also perfectly combined with pre-programmed tasks and games. During the first years of school, a number of educational programs were made available here (Dryden & Vos, 2001).

Cisco Systems established "network academies" in 83 countries in 2002, offering students a four-semester course. They learn not only how to design, create and maintain computer networks, but also how to conduct practical classes over the Internet. Simultaneously, Clever Software released a "computer tutor" program to assist students in preparing for exams in China. Pepperdine University in California has been offering educational courses for undergraduates and doctoral students since 2002, with some of the courses being presented as programmed tasks in science education. As is customary, physical presence (offline) at these courses is required only three times per year (Sadykov & Ctrnactova, 2019; Sadykov et al., 2021).

Online evaluations, according to (McLoughlin & Luca, 2002) can lead to collaborative learning by enabling analysis, communication, and higher-order thinking. In the early days of online assessment, learners were given surface-assessment activities, which led to a focus on objectivist knowledge. To evaluate a variety of learning outcomes, a balanced approach is required (Warschauer, 2003). Advocates for technological advancements in Africa, particularly computer-mediated communication, which encourages involvement and strengthens social presence.

(de Freitas & Oliver, 2005) proposes three broad theoretical perspectives for online and blended learning: (1) the associationist/empiricist perspective (learning as activity); (2) the constructivist perspective (learning as achieving understanding through individual or social approaches); and (3) the situative perspective (learning as social practice). The rise of online learning, as observed by (Petrova & Rowena, 2005) as the implementation of eLearning utilising web-based technology, undoubtedly allows us to reach audiences who were previously difficult to serve. Since 2005, the

development of interactive technology and other free web-based apps has enabled teachers to provide many sorts of classes.

(Hrastinski, 2006) researched the usage of instant messaging in an online course. He discovered that groups who used the instant messaging system had greater levels of course engagement. Computers have emerged as the most potent instruments in the development of student's abilities to inquire and assist the teaching of science with the development of information technology (Fetaji et al., 2007).

(Zucker & Light, 2009) suggest that laptop programs will be most successful as part of balanced, comprehensive initiatives that address changes in education goals, curriculum, teacher training, and assessment. E-learning was defined by (Fee, 2009) as a technique for creating various learning methods utilising digital technology, which creates chances for learning to spread.

(Duncan-Howell, 2010) emphasises the need of regular engagement between learner and teacher during online classes; these interactions foster learners' feelings of security and self-confidence, as well as their sense of social bonding. According to (Slotta, 2010) mobile technology can be used as an auxiliary technology for thinking tools in supporting programmed learning activities. It has the power to encourage fundamental social interactions for learning and connecting with others. The use of wireless, mobile, portable, and handheld devices is gradually improving interaction in the classroom.

Similarly (Dillenbourg & Evans, 2011), believed that the development of multi-touch interactive surfaces opens up new avenues for computer-assisted collaboration in the classroom. It allows multiple participants to interact directly with the content, rather than using a mouse or keyboard, which reduces reliance on a single input device.

Most significantly (Anthony, 2012), discovered that female students participate in online courses at a greater rate than male students. This research implies that online learning may aid in closing the gender participation gap. One of the most important variables in successfully integrating e-learning is finances (Sarkar, 2012).

(Drijvers, 2013) recognised the most relevant elements influencing the integration of technology in primary and secondary school settings as the pedagogical design of the tools, the role of educators, and the educational context (Andoh, 2013). Stated that to integrate and use a programmed learning approach in the school, teachers need to adapt and improve their existing teaching and learning practices, according to the newest trends in the education system, from a conventional style and teacher-dominated way of teaching to a more interactive method and programmed learning with the help of information and communication technology. According to (Xu & Jaggars, 2013) demographic parameters such as age, gender, geography, and previous academic success influenced learners' adaptation to online learning.

According to (Sari, 2015) online and programmed learning is an alternative that can be used in the rapidly expanding world of technology and communication (Hung & Chou, 2015). Create a measuring scale for analysing the online teacher's role and attitude during online classes and use it to investigate student views of online and blended learning systems. In order to effectively engage students in an online classroom, teachers must also promote student interaction and provide direct learning support (Abdulwahed et al., 2015; Harnegie, 2015). The instructional effort that teachers provide during programmed instruction is referred to as autonomy support. This form of assistance is provided to detect, then endorse and encourage, and finally grow and increase pupils' independent motivation (Reeve, 2016).

According to (Alhabeeb & Rowley, 2017) transferring to online learning gives a significant opportunity to improve student's learning experiences (Yang & Su, 2017). Investigated Massive

Open Online Courses (MOOCs) in order to determine learners' readiness to participate in and respond to I.T. and online teaching approaches. They discovered that attitude is one of the most important influencing elements for learners' behavioural intention to use online platforms.

(Shand & Farrelly, 2018) noted that they were discouraged from running online classes since it took so long to construct their online pedagogy and choose a suitable technology platform for content distribution. Education organisations can develop e-learning centres and give professional training to teachers to increase their digital literacy to enable successful participation with e-learning technologies.

(Alzahrani et al., 2019) claim a good association between content quality variables and user satisfaction in programmed learning at four Malaysian universities. They claimed that perceived online learning quality is also affected by information quality. Format, understandability, readability, relevancy, up-to-dateness, and detail were all major predictors of good information quality. According to (Pérez-Escoda et al., 2019) integrating emerging educational technologies alone will not improve teaching and learning outcomes if they are not complemented by appropriate training (Martin et al., 2019). concluded, that the main components of an efficient web—based learning process are the online course design, online teaching technique, online assessment and evaluation tools, and timely feedback (Brunton et al., 2019). Define flexible users as individuals who engage in part-time or online distant learning throughout the early phases of the study life cycle in their research on the establishment of a Head Start Online MOOC.

According to (Nambiar, 2020) satisfaction with online classes is dependent on various elements, including quality and timely contact between learners and educators, technological assistance, targeted online class modules, and the adjustment of practical classes for the online platform (Martin et al., 2020). Research focused on evaluating the larger aspect of research topics in online learning and found that online learner characteristics may be generally classified into demographic, academic, cognitive, social, self-regulation, and motivational characteristics. Additionally (Bao, 2020), points out a connection between studying alone at home, an unsuitable learning environment, and a lack of self-discipline. Although programmed learning can be facilitated by online resources, it can be difficult for teachers to maintain student interest while also limiting distraction and technology abuse. Educators will need to design content for digital platforms not only to fulfil the aim of information distribution but also to foster their creative thinking and implementation abilities (Modan, 2020).

According to (Camacho & Legare, 2021) using online education programmes requires a more flexible approach than a more classic one. (Eli-Chukwu et al., 2022)agree that most educational institutions adopted e-learning reactively and add that one of the problems of e-learning is the lack of research that guides the technological implementation of e-learning.

2. What is programmed learning?

Programmed instruction can be defined as instruction that is carried on by the use of a programmed text, or teaching machine, using material that is basically similar to that used in conventional instruction (Connor, 1967). (Lee, 2004) defined the programmed learning approach as an instructional strategy, in which the learner is presented in a logical sequence with many small learning frames or pieces of information. According to (I. Chen, 2006) programmed instruction is desirable in many instructional settings because it provides instant knowledge and feedback, as well as enhanced individualized learning in mathematics instruction.

The main requirement is to break down study material into small steps and to provide immediate feedback and confirmation of each step, which includes information presentation, questions and student responses (Hošková-Mayerová & Rosická, 2012). The main principles of programmed learning are shown in Figure 1.

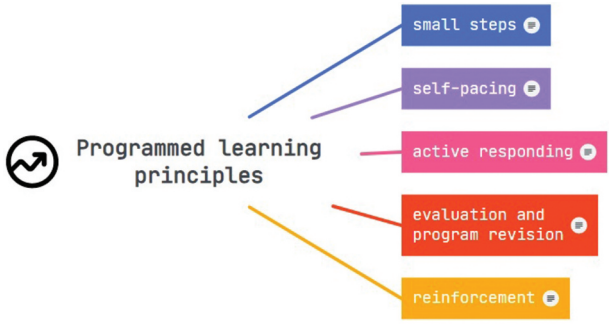

Figure 1. Principles of programed learning. (Source: Author).

There are two basic methods of programmed learning:

(A) Skinner linear programs enable students to progress through the instructional process in a specific order as they provide correct answers. Learners are given specific information in a series of frames and asked to recall this information during frequent comprehension tests (Oginni & Owolab, 2012). Each frame contains a small amount of information as well as a statement with a blank that the students must fill out (Anderson & Fretzin, 2004). If a learner answers correctly, he or she advances to the next frame (Lockee et al., 2001).

(B) Crowder-branched programs present learners with information, then present a situation requiring a multiple-choice or response, and instruct students to proceed to the next frame, where he or she learns whether or not the choice was correct. A student who responds incorrectly will be either returned to the original frame or routed through a sub-program designed to correct the deficiency indicated by the incorrect choice. A learner who responds correctly moves on to the next frame in the program. This process is repeated at each step of the program, and depending on the errors made, a student may be exposed to different materials (McDonald et al., 2005).

As can be seen from these methods the main features of programmed instruction are:

(1) *Step-by-step*. Each step is a question or problem, to which a student must respond actively before proceeding. Because each step builds on previous knowledge, a student is never required to answer a question about a subject until he has learned the answer.

(2) *Active response*. Learners do not simply receive information, rather, they exercise and practice their knowledge and skills.

(3) *Progressing satisfactorily*. Once a student has responded to an item, he can locate a correct answer, which is usually displayed alongside with a question (Williams, 1961).

Despite the boom of programmed instruction designed for education in the past, there is a lack of studies conducted on programmed learning advantages in science education. The majority of the studies focused on students' perception and feedback as a whole without focusing on specific educational skills. Therefore, this systematic literature review aims to synthesize the findings of studies related to the benefits of the programmed learning approach.

This systematic literature review was conducted to answer the following research question: What are the advantages of the programmed learning approach in science education?

3. COVID-19 as a driving force for programmed learning

COVID-19 has struck our educational system to its core like a lightning bolt. Since the current COVID-19 epidemic, teachers have had to prepare and give classes from their homes, which presents its own set of logistical and technological issues. COVID-19 is predicted to have

influenced 1.5 billion students worldwide (Teräs et al., 2020), with much face-to-face instruction increasingly shifting to the online environment. While the pandemic added many extra challenges, it also gave a chance for academics to test evaluation methodologies they had previously explored but not applied in a relatively low-risk context. The quality assurance methods for modifications to modules and assessments had to be accelerated, and institutional environments were exposed to major and quick changes in this respect.

(Kapasia et al., 2020) surveyed university students in Bengal, India, during the epidemic. The findings revealed that pupils endure huge hurdles as well as psychological and behavioural issues as a result of internet weakness (Saputra et al., 2021). Examined students' perceptions of online and programmed learning during COVID-19 in Indonesia and discovered that students perceive online learning as ineffective learning activities, unpleasant learning activities, limiting self-actualization in education, and assisting in becoming independent learners (Treve, 2021). Discovered that the most significant hurdles to online research during the outbreak of the Coronavirus epidemic were a lack of technological resources such as PCs and high-quality mobile networks (Duraku & Hoxha, 2021). Investigated the modes of programmed lesson delivery, such as the learning platforms used by teachers to teach students during school closures, as well as the difficulties students encountered when using information and communication technologies (ICT).

(Watermeyer et al., 2021) present the findings of a survey of 1148 academics, which emphasise the many problems that academics faced during the emergency online migration of their profession (e.g., increased workload, decreased working conditions, and disturbance of confidence and trust). Children from low-income families confront additional hurdles when it comes to programmed learning since they lack necessary resources such as a proper workplace, dependable internet, and digital equipment (Lancker & Parolin, 2020). According to (Darmody et al., 2021) pupils from high-income homes are more likely to have parents working from home during COVID-19 constraints, as well as more access to high-speed internet and other tools that aid with programmed learning.

On the other hand (Naciri et al., 2020), suggest that m-learning and programmed instruction are unavoidable alternatives for higher education. (Verawardina et al., 2020) underline the need for preparing instructors and students for the COVID-19 pandemic by explicitly defining their roles. Such prospects include innovative ideas and tools for online learning as well as programmed learning (Mseleku, 2020). Most institutions, such as New York University Shanghai, Duke Kunshan University and Zhejiang University, Peking University and Tsinghua University, and Shanghai Jiao Tong University, have introduced or developed their online learning platforms as an alternative to class-based teaching and learning with programmed instruction. For successful online teaching (Rapanta et al., 2020), emphasise the significance of the effective design of online learning activities, which increases teacher presence, and an assessment and feedback mechanism. They also gathered the opinions of online education experts on the global online transition during the pandemic.

(Asio et al., 2021) investigated the electronic devices used by students for programmed education and discovered that students primarily used smartphones when schools were closed. According to (Abunamous et al., 2022) there are no statistically significant differences between E-learning and classical learning in terms of students' accomplishment-based demographic characteristics (university years and scientific speciality), as well as student satisfaction (teaching staff style, educational programmes provided, and quality).

We believe the COVID-19 outbreak had a substantial influence on learners and their learning experiences. Most research, however, focuses on learners transferring from face-to-face teaching modules, and there is still a need to better understand the views of students who are already comfortable with programmed learning, working from home, and frequently balancing a complicated work-life-study balance.

4. Methodology

A systematic literature review was carried out following with the Preferred Reporting Items for Systematic Review (PRISMA) (Santhanasamy & Yunus, 2022). The systematic literature review selects, identifies and evaluates research to answer a specific research question. As the purpose of this paper is to investigate the benefits of programmed instruction in science education, the originality of this approach in comparison to traditional learning methods is determined. We have searched the Scopus, Google Scholar, ERIC, Web of Science, and Taylor databases for articles relating to the programmed learning approach. The identification phase, screening phase, eligibility phase, and inclusion phase are all involved.

Phase 1: Identification Phase. To begin, the databases used for this systematic literature review included Scopus, Google Scholar, ERIC, Web of Science, and Taylor. The articles were published between 1970 and 2022. The Web of Science and Scopus databases combine a diverse range of scientific literature from a variety of disciplines. The Google Scholar and Taylor databases are searchable and contain the majority of the peer-reviewed literature on a variety of disciplines, whereas the Education Resources Information Center (ERIC) is a searchable database of education research and information. The articles were found using related keywords from three search engines required for the review, as shown in Table 1.

Phase 2: Screening Phase. The titles and abstracts of the articles were screened in all five databases, namely Scopus, Google Scholar, Web of Science, Taylor, and ERIC. The titles were screened based on how closely they matched the keyword. The abstracts of each article were then skimmed and scanned.

Table 1. Keywords used to find articles

Databases	Keywords
Scopus	Programmed learning AND science education, programmed instruction AND science education, teaching machine AND science education, programmed instruction AND benefit, programmed instruction AND education, programmed learning AND online learning
Google Scholar	Programmed learning AND science education, programmed instruction AND science education, teaching machine AND science education, programmed instruction AND benefit, programmed instruction AND education, programmed learning AND online learning
ERIC	Programmed learning AND science education, programmed instruction AND science education, teaching machine AND science education, programmed instruction AND benefit, programmed instruction AND education, programmed learning AND online learning
Web of Science	Programmed learning AND science education, programmed instruction AND science education, teaching machine AND science education, programmed instruction AND benefit, programmed instruction AND education, programmed learning AND online learning
Taylor	Programmed learning AND science education, programmed instruction AND science education, teaching machine AND science education, programmed instruction AND benefit, programmed instruction AND education, programmed learning AND online learning

Phase 3: Eligibility Phase. The articles were reviewed and determined to be eligible. The downloaded full text was eligible, and restricted articles were excluded. In other words, the articles chosen should be geared toward answering the research questions.

Phase 4: Exclusion Phase. The research question articles were excluded from this paper after they were checked for eligibility during the eligibility phase. Articles, book chapters, proceedings, reviews, and meta-analysis papers that were not published in English were excluded. This is an important process because it is the final step in refining the search for relevant articles on the advantages of the programmed learning approach in science education. The details were summarized from the searching process using the PRISMA flow chart in Figure 2.

The criteria for programmed learning to improve educational skills were used to select 33 articles. The article was divided into three research methods. There were 19 quantitative studies, 2 qualitative studies, and 12 mixed-method studies. An in-depth investigation leads to a better understanding of the scope of the research and provides reliable reporting quality.

5. Results

From 1970 to 2022, a total of 216 articles were discovered in five databases and additional records, namely Scopus ($n = 62$), Google Scholar ($n = 55$), Eric ($n = 25$), Web of Science ($n = 32$), and Taylor ($n = 42$). During the screening process, 28 duplicate articles were removed, leaving 188 articles. After screening the title and abstract, 70 articles were excluded from the results. Then, 85 articles were removed because they did not have access to the full text and were comprised of review papers, meta-analyses, and bibliometric studies. Finally, 33 articles were chosen from among those that met the inclusion and exclusion criteria to be included in this review. Table 2 provides an overview of the research studies, country, research methods, and research participant level.

Table 3 presents the findings of the top 10 countries in terms of research productivity in the area of programmed instruction. The top countries' contributions are as follows: the USA, 71 research

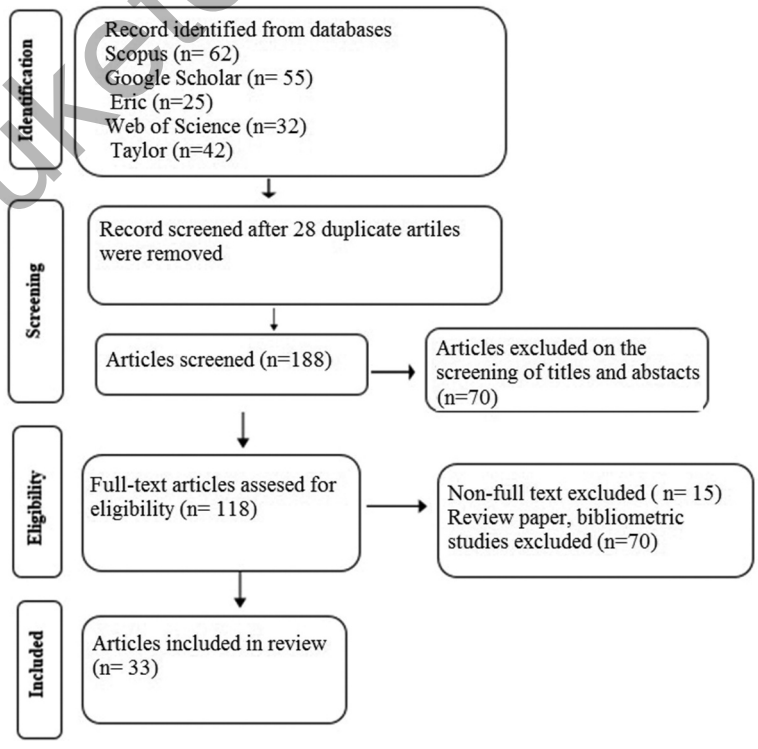

Figure 2. Procedure of the Systematic Review Process. (Source: Author).

Table 2. Characteristics of research studies

No.	Author(s)	Affiliation	Research Method	Research participants
1	(Cooper & Mertens, 1970)	Ball State University (USA)	Quantitative	Undergraduate students
2	(Hinchliffe, 1982)	Sheffield City Polytechnic (England)	Mixed-method	Undergraduate students
3	(Kromrey & Purdom, 1995)	University of South Florida (USA)	Quantitative	95 undergraduate students
4	(Guła-Kubiszewska & Wieczorek, 2004)	University School of Physical Education (Poland)	Qualitative	183 adults
5	(Ingvarsson & Hanley, 2006)	University of Kansas (USA)	Mixed-method	undergraduate student teachers, parents
6	(Kurbanoglu et al., 2006)	Sakarya University (Turkey)	Quantitative	40 chemistry teachers
7	(Florence, 2008)	University of North Carolina (USA)	Quantitative	240 undergraduate students
8	(Bebell & O'dwyer, 2010)	Boston College's Technology (USA)	Mixed-method	lower-secondary students, college students
9	(Fienup & Critchfield, 2011)	Illinois State University (USA)	Mixed-method	80 college students
10	(Olympiou & Zacharia, 2011)	University of Cyprus (Cyprus)	Quantitative	72 undergraduate students
11	(Ziden et al., 2011)	University of Science (Malaysia)	Quantitative	4th grade (primary school)
12	(Oginni & Owolab, 2012)	Ekiti State University (Nigeria)	Mixed-method	700 lower-secondary students and 50 teachers
13	(Wu et al., 2012)	National Cheng Kung University (Taiwan)	Quantitative	48 nursing students
14	(Avinash & Shailja, 2013)	Gorakhpur University (India)	Quantitative	lower-secondary students
15	(Mukadam et al., 2014)	AMC MET Medical College (India)	Qualitative	98 college students
16	(Yan et al., 2014)	University of Aizu (Japan)	Mixed-method	90 undergraduate students
17	(Lopes & Soares, 2016)	Polytechnic Institute of Porto (Portugal)	Quantitative	72 undergraduate students
18	(Milošević et al., 2016)	University of Novi Sad (Serbia)	Mixed-method	50 secondary school students
19	(Wahyuni, 2016)	Universitas Jember (Indonesia)	Mixed-method	seventh grade (lower-secondary students)
20	(Yang & Su, 2017).	Henan University (China)	Mixed-method	undergraduate students, teachers

(*Continued*)

No.	Author(s)	Affiliation	Research Method	Research participants
21	(Stoffová, 2018)	Palacký University Olomouc (Czech Republic)	Mixed-method	55 secondary school students
22	(Zendler & Reile, 2018)	University of Education Ludwigsburg	Quantitative	44 undergraduate students
23	(Ikram & Asim, 2019)	Institute of Business Management (Pakistan)	Quantitative	150 secondary school teachers
24	(Biswas et al., 2020)	Noakhali Science and Technology University (Bangladesh)	Quantitative	416 students of different ages
25	(Gopal et al., 2021)	Chitkara University (India)	Quantitative	544 undergraduate students
26	(Kokibasova et al., 2021)	Buketov Karaganda University	Quantitative	50 secondary school students
27	(Ospanova et al., 2021)	Buketov Karaganda University	Quantitative	28 secondary school students
28	(Root & Rehfeldt, 2021)	Southeast Missouri State University (Usa)	Qualitative	24 undergraduate students
29	(Shamir & Levin, 2021)	Tel Aviv University (Israel)	Mixed-method	18 lower-secondary students
30	(Zalazar-Jaime et al., 2021)	National University of Córdoba (Spain)	Quantitative	5686 students of different ages
31	(Ayanbode et al., 2022)	Babcock University (Nigeria)	Quantitative	245 undergraduate students
32	(Chandrasiri & Weerakoon, 2022)	University of Peradeniya, Sri Lanka	Mixed-method	48 nursing students
33	(Saleh & Jalambo, 2022)	University College of Applied Sciences (Palestine)	Quantitative	156 second-level diploma female students

publications (32,87%); India, 27 (12,5%); and Indonesia, 20 (9,26%). Moreover, the USA demonstrates a superior academic impact to the rest of the world, with the highest number of citations (123). The UK is ranked fifth in research publications and second in citations (49). Lastly, developing, emerging, and technologically advanced economies such as India, Indonesia, and China have significantly contributed to this field, with these countries contributing 27, 20, and 18 research publications, respectively.

In terms of research participants, the majority of the studies (14 studies) focused on undergraduate students, followed by secondary school students (8 studies), college students (5 studies), lecturers/teachers (3 studies), mixed (2 studies), and adults (1 study). As illustrated in Figure 3, it is clear that programmed instruction is widely used among university students when compared to other levels of education.

Table 3. Top 10 countries in terms of research publications on programmed learning

No.	Country	Publications	%	Citations	Average citations per article
1	USA	71	34,6	123	2,011
2	India	27	12,37	65	2,401
3	Indonesia	20	8,9	60	2,088
4	China	18	8,41	74	2,233
5	UK	14	5,94	49	1,578
6	Taiwan	11	4,95	57	1,987
7	Malaysia	9	4,45	22	1,788
8	Japan	8	3,96	15	1,011
9	Turkey	4	1,98	5	0,333
10	Poland	4	1,48	9	0,122

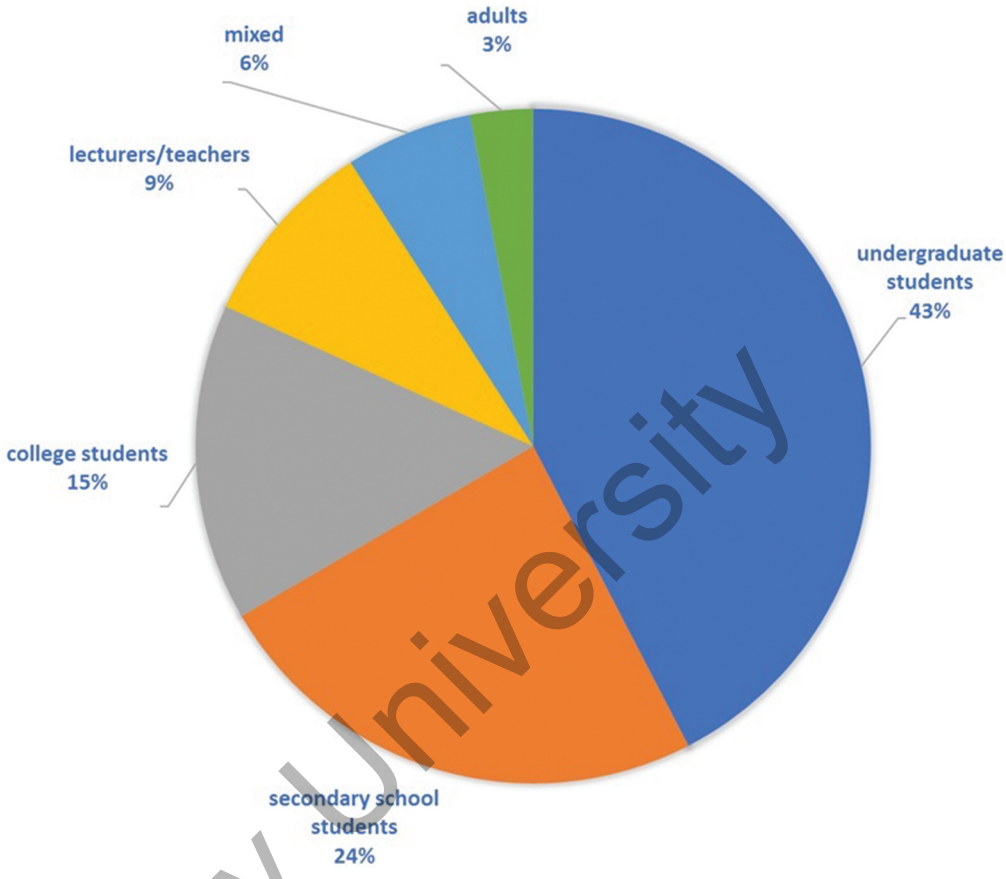

Figure 3. The level of participants in programmed learning studies. (Source: Author).

As a result, programmed instruction is more commonly used in university education. Regarding the research questions, 33 articles on the benefits of programmed learning were identified.

(Cooper & Mertens, 1970) tested the programmed learning approach at least twice before concluding that it was ready for widespread use among undergraduate students. However, after having had this experience, a scientist, who takes the time and makes the effort to do it, is more aware of the students' learning problems and better able to cope with them.

(Hinchliffe, 1982) conducted research, in which students learned chemical equilibrium material through programming and instruction learning. The objective results suggested that substantially self-paced programmed learning was a better technique than conventional lecture in new areas of learning provided that the topic area covered was relatively small.

(Kromrey & Purdom, 1995) conducted a study to compare three methods of instruction for college students. Their analysis of achievement test performance revealed that all three instructional methods resulted in a significant increase in scores.

(Guła-Kubiszewska & Wieczorek, 2004) defined motor effects as the process of learning new motor activities using two types of programmed learning, namely linear and branched programs. They discovered that this method was extremely effective in the learning and teaching of motor activity. In various groups, an average level of mastery of a new motor activity prevailed, which could be interpreted as a very fair outcome for more than half of the learners who achieved the desired result.

The study conducted by (Ingvarsson & Hanley, 2006) evaluated the effects of computer-based programmed instruction on performance outside of the computer context and demonstrated how behaviour analysis on teacher—parent relationships and behaviour change from indirect behavioural processes work (response induction, stimulus generalization).

(Kurbanoglu et al., 2006) compared the effectiveness of programmed instruction versus the traditional teaching approach in teaching stereochemistry, as well as whether gender had any effect on student success. Their stereochemistry test (SAT) and programmed stages (frames) revealed a statistically significant difference in the success level of students' stereochemistry learning between programmed instruction and conventional teaching approaches. Furthermore, it was discovered that female students outperformed their male students in the experimental group. Their findings indicate that programmed learning outperforms traditional lecturing in the teaching of stereochemistry.

(Florence, 2008) conducted a study to investigate the effect of practice with feedback and navigation type on achievement, attitude and time when students used a web-based instructional program. He discovered a statistically significant difference in the main effect of practice and attitude items. It was once again confirmed that practice was effective in assisting students' achievement and attitude. This research emphasises the value of practice and has implications for the design and development of web-based, multimedia instruction.

(Bebell & O'dwyer, 2010) summarized evidence that participation in the 1:1 computer programme was associated with increased student and teacher technology use, increased student engagement and interest levels, and modest increases in student achievement. Teaching materials supported by technology such as the Internet and multimedia increase students' interactivity and motivation and decrease the cognitive load of the learning task.

(Fienup & Critchfield, 2011) conducted a study with students enrolled in a sophomore-level college research methods course. College students reported that the lessons assisted them in mastering information about inferential statistics and hypothesis decision-making. They found the instruction to be as beneficial and enjoyable as traditional teaching methods.

(Olympiou & Zacharia, 2011) documented positive effects and showed that a combination of lab experiments and virtual programs enhanced students' conceptual understanding of light and colour more than the use of lab experiments or virtual tools alone.

(Ziden et al., 2011) carried out an experimental study and concluded that ICT programs have a positive effect on the academic accomplishment of students in science subjects. The study found that male students showed better performance as compared to female students.

(Oginni & Owolab, 2012) investigated programmed instruction (PI) in mathematics. The study used descriptive research with a survey design. Their descriptive study found that using programmed instruction increased students' interest in mathematics and resulted in greater retention and mastery of the subject matter. Based on the findings, curriculum experts were advised to create a variety of curricula using the programmed instruction approach.

(Wu et al., 2012) developed a context-aware mobile learning system that was used as a sensing device for nursing training courses. This system guided the individual students to perform each operation of the physical assessment procedure on dummy patients and provided instant feedback and supplementary materials to them if the operations or the operating sequence were incorrect. After that, students' learning outcomes were notably improved by utilizing the mobile learning system for nursing training.

(Avinash & Shailja, 2013) found that the ICT program is more compelling and effective than the conventional teaching approach in terms of students' achievement scores in chemistry.

(Mukadam et al., 2014) compared the effectiveness of Skinner's programmed learning method to the conventional routing teaching method. They discovered a statistically significant positive correlation between attending Skinner's method topics and exam results. This method fosters creativity and interest in students, which aids in their learning and the overall improvement of the students and institute.

(Yan et al., 2014) presented a program of visualization-based support systems for C programming learning and instruction (PROVIT). It offers useful functions for students and instructors to use during lectures, exercises, or at home. PROVIT has been used in a special lecture for teaching high school students and has proven to be extremely beneficial to the students.

(Lopes & Soares, 2016) found that the opportunity to do online program exercises and have access to the solutions (explained step by step) is crucial for students. The integration of program video tasks into the educational process leads to an increase in students' motivation and interest in studying financial mathematics.

The research of (Milošević et al., 2016) investigated the feasibility of using programmed instruction in the teaching of geography to sixth-grade students in the second cycle of education. Based on the findings, the authors concluded that this type of teaching was more effective than a traditional class. Furthermore, the teacher was more active in providing project conditions and materials, as well as in resolving problems that were beyond the students' abilities.

According to the findings of Wahyuni research (2016), it can be concluded that teaching material developed based on CAI is worthy of use in junior high school instruction because it receives scores of 3.90, 3.71, and 3.70 from experts.

(Yang & Chang, 2017) experimented with junior high school students to assess the smartphone programs to study Geography in Taiwan. The results showed that the students who learned with the proposed system, in the experimental group, achieved better results by learning with ubiquitous Geography learning system assistance.

(Stoffová, 2018) stated that educational computer programs and games contribute to the development of users' algorithmic, logical, combinational and prognostic thinking to drive the development of their winning strategy, which is often the same as the optimal algorithm for solving the problem.

(Zendler & Reile, 2018) conducted an empirical study of learning outcomes using two instructional methods, namely programmed instruction and reciprocal teaching. They include pre-programmed instructions on how to use the Unix operating system, recursive programming, Internet safety and other topics. Their empirical findings indicate that learning with programmed instruction outperforms reciprocal teaching.

(Ikram & Asim, 2019) investigated the relationship between programmed learning and metacognition in Karachi secondary schools. Participants included male and female secondary school instructors teaching a variety of subjects. In this study, a positive and moderate-high correlation ($r = 0.693$) was discovered between programmed learning and metacognition.

(Biswas et al., 2020) evaluated university students' perceptions of using mobile learning programmes during the COVID-19 epidemic in Bangladesh. According to the study's findings, most students viewed m-learning as a useful tool to overcome the education gap during the COVID-19 pandemic.

(Gopal et al., 2021) investigate the factors that influence students' satisfaction and performance in online classes with application educational programs during the COVID-19 pandemic term, as well as the relationship between these characteristics, namely, instructor quality, course design, prompt feedback, and student expectations, all of which have a positive impact on student satisfaction, which in turn has a positive impact on academic performance.

The article by (Kokibasova et al., 2021) presents the results of using mathematical methods to determine the impact of programmed learning on the quality of students' knowledge in chemistry. The results of the analysis showed that the developed application "Nentwig can be used in the study of chemistry at school.

(Ospanova et al., 2021) created the programmed lessons in inorganic chemistry on the topic: "Energy in Chemistry" for 10th grade students. The final cross-section showed that the academic performance of the control group students remained almost unchanged, increased by 2%, and test group increased significantly, improved by 9%.

(Root & Rehfeldt, 2021) assessed the validity of programmed instruction in online courses using quiz performance, the frequency of discussion posts, the instructor's time commitment, generalisations, and student perceptions of the online modalities used. The experiment demonstrated the utility of online programmed lectures in simulating traditional on-campus lectures.

Based on a qualitative and quantitative evaluation of the students' achievements (Shamir & Levin, 2021), concluded that they had demonstrated computational thinking competencies at various levels. The results demonstrated that students were able to successfully design and train a computerized PL system to classify input datasets. They demonstrated an understanding of how data should be selected and filtered for the system to learn with a high probability of making a correct prediction.

Preliminary data from (Zalazar-Jaime et al., 2021) support the social-cognitive paradigm of academic satisfaction in online learning settings for higher education. As a unique finding of this study, it can be highlighted that a bigger contribution of socioemotional support was demonstrated in an e-learning and programme context.

(Ayanbode et al., 2022) investigated the impact of student interactions on satisfaction and perceived success in an online and programmed learning environment. They discovered that students' interactions (student-student, student-teacher, and student-content) had a positive effect on their satisfaction and perceived progress in an online class, and that satisfaction played a significant mediating role in the relationship between interactions and perceived progress.

According to (Chandrasiri & Weerakoon, 2022) the majority of pupils view online (programmed) learning positively. When students have equitable access to online resources, e-learning looks to be an effective learning approach.

The study (Saleh & Jalambo, 2022) indicated that the use of mobile programmed learning improved female students' skills, enhanced their academic achievement, made the learning experience more enjoyable, and improved their use of mobile devices.

6. Discussion and conclusion

The reasons for the choice of science subjects in this review are probably threefold:

(1) The subject matter is suitable for structural treatment according to its character.

(2) Because of the fundamental structure of the science topics, the information would not date significantly, could be easily revised, and would apply to many other areas of science and engineering, allowing greater student access.

(3) Some students, particularly those in the technician group, have expressed actual difficulty with some of the fundamental concepts of classical chemistry (e.g., hydrolysis, partial vapour pressures, solving chemical problems, and even oxidation-reduction reactions). Some teachers believed that programmed education may enhance traditional lectures and tutorials in an attempt to address this challenge.

During the 1960s and 1970s, researchers in the United States conducted studies (Blyth et al., 1962; Brown, 1962; Carpenter & Greenhill, 1963; Price, 1962) comparing new technology with traditional teaching practices. Generalized, programmed instruction at the secondary and university levels was no more or less effective than traditional teaching methods (Casas, 2002). Skinner's (1960–1970) solution to these problems was the teaching machine, which provided the scientific foundation for programmed instruction. He described how a mechanical device could use operant conditioning principles to provide immediate reinforcement, keep a student occupied for a set period of time, and lead students to near-perfect performances (McDonald et al., 2005).

According to (Talyzina, 1973) the central problem of education is teaching students to use the rational method in making decisions and to acquire rational methods of performing tasks. Concern only for the final product (the correct answer) frequently leads to negative outcomes; it confirms illogical or incorrect approaches to problem-solving.

The introduction of digital platforms is likely to increase the urgency of this change in the educational system. However, it is difficult to forecast how these changes would influence established institutions that were specifically designed to bring researchers, students, and teachers together. While technical advancements may allow them to progressively transition to programmed instruction, substantial distinctions between face-to-face interactions and online information delivery must be skillfully managed, as illustrated by four main areas of expertise for an online instructor: educational, social, technological, and managerial (Islam et al., 2015). The transition from traditional or hybrid systems to online and programmed instruction will take time. Among these elements, technical assistance has a significant influence on learners' satisfaction with online classes. Though online learning provides ease and flexibility, it also suffers from a lack of proper network connection (Aboagye et al., 2020; Adnan & Anwar, 2020), a lack of technological expertise, experience (Bean et al., 2019; Nambiar, 2020), and a shortage of electricity (Simamora, 2020). The COVID-19 epidemic has created numerous obstacles for higher education institutions around the world. Lockdown and other COVID-19 requirements have caused many academic institutions to transition from face-to-face learning to online learning. With the introduction of COVID-19, the differences between privileged and underprivileged pupils will deepen due to the digital divide and unequal access to e-learning and programmed instruction. The unexpected transition to online learning brought about by the COVID-19 epidemic did not provide regular academics enough time to get used to the new teaching platforms (Chen et al., 2020).

The result of our systematic review showed the following advantages of programmed learning:

- beneficial and enjoyable than traditional teaching methods (Ayanbode et al., 2022; Chandrasiri & Weerakoon, 2022; Fienup & Critchfield, 2011; Hinchliffe, 1982; Milošević et al., 2016; Root & Rehfeldt, 2021);
- demonstrated the positive effects on behavior change from indirect behavioural processes work (response induction, stimulus generalization) (Florence, 2008; Ikram & Asim, 2019; Ingvarsson & Hanley, 2006; Stoffová, 2018; Biswas et al., 2020; Zalazar-Jaime et al., 2021);
- extremely effective in the process of motor activity learning (Guła-Kubiszewska & Wieczorek, 2004); Mukadam et al., 2014; Zendler & Reile, 2018);

- a significant increase in scores for undergraduate and secondary school students (Avinash & Shailja, 2013; Florence, 2008; H. C. Yang & Chang, 2017; Kokibasova et al., 2021; Kromrey & Purdom, 1995; Kurbanoglu et al., 2006; Ospanova et al., 2021; Shamir & Levin, 2021; Ziden et al., 2011);
- increased students' interest (Bebell & O'dwyer, 2010; Lopes & Soares, 2016; Oginni & Owolab, 2012; Saleh & Jalambo, 2022);
- can be used for junior school (Wahyuni, 2016);
- offered useful functions for students and instructors to use during lectures, exercises, or at home (Wu et al., 2012; Yan et al., 2014);
- positive effects and showed that a combination of lab experiments (Olympiou & Zacharia, 2011).

According to the student's opinions in this review, the reasons are materials that were more stimulating and varied for programmed instruction than those for traditional education. While students in programmed teaching worked collaboratively, writing on a worksheet and a computer, students in traditional learning focused primarily on the text and virtually entirely without the use of a computer.

It would be beneficial to conduct research with students from other populations. Furthermore, most instructional design research involves participants being exposed to only a few pieces of instruction over a short period of time. The relationship between performance during instruction and performance on criterion measures must be investigated as well. It is unclear whether performance during instruction can be generalized to criterion test performance (Jaehnig & Miller, 2007).

According to researchers (Ikram & Asim, 2019; Milošević et al., 2016; Root & Rehfeldt, 2021; Shamir & Levin, 2021; Wahyuni, 2016; Yan et al., 2014; Zendler & Reile, 2018) the demise of the teaching machine movement is attributed to three major factors. First, in order to meet the demand for new programs, many programmers ignored the mechanics of programmed instruction and began producing subpar programs. Second, school districts did not believe that the new technology was cost-effective. Third, the educational establishment as a whole rejected these modes of instruction. Although there are various types of programmed learning, they all share the following characteristics.

- The material is broken up into small steps (to minimize the chance of error);
- The immediate confirmation of the response.

The programmed learning material should be written down in full or in outline form. From this preliminary writing, the material can be arranged and rearranged to form the most logical sequence. After the material has been properly sequenced, the construction of frames can begin with questions and answers. Researchers and teachers should try to include variety in the frames they write. Different types of questions are essential for maintaining student interest and active participation. Some frames may be multiple-choice, others may be completion, and still others may involve interpreting data, drawings, or graphs. However, before the actual "frame construction" can begin, a decision must be made regarding the preferred type of programming, namely linear, branching, or adaptive (predictive). At this point, an examination of existing programs by a variety of authors and publishers at varying levels of sophistication will be extremely beneficial. Frame construction should be done in relatively large steps for the first draught. After the program's initial testing, there are more clues for adding frames than for removing them. Even if the frame asks a problem-type question, a blank for the student's answer should be provided whenever possible: the answer space serves as a stimulus for the student to respond to the question. When the framework is complete, summaries or reviews for relevant sections of the program may be added. When all programming is complete, the program should be read for continuity and style, and any necessary changes should be made.

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Correction
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