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Systematic Review

Promoting Personalized Learning in Flipped Classrooms: A Systematic Review Study

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Abstract: Flipped classroom (FC) is a widely accepted, innovative pedagogy designated to enhance students' learning by changing the paradigm of instruction. It has the potential to adapt learning to the students' needs, interests, and mutual expectations by using the advantages of both online and face-to-face learning, which strengthens the quality of the instruction. The potential of FC to foster personalized learning (PL) has become vital in education, as individuals face different possibilities and difficulties in the learning process. To date, no systematic review study has focused on the ways in which PL occurs in FCs and the role of personalized FCs in education. The present study aims to close this gap by exploring the value of flipping instruction and strategies to support PL. We searched the literature, focusing on peer-reviewed research studies published in English that focus on PL in FCs. The key results include (a) the study characteristics, (b) the approaches developed and used in FCs to enhance PL, and (c) the role of personalized FCs in teaching and learning. Overall, this systematic review study provides insight into successful FC implementations and strategies to sustain PL.

Keywords: adaptive learning; blended learning; flipped classroom; flipped learning; hybrid learning; inverted classroom; personalized learning; systematic review

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Citation: Cevikbas, M.; Kaiser, G. Promoting Personalized Learning in Flipped Classrooms: A Systematic Review Study. *Sustainability* **2022**, *14*, 11393. https://doi.org/10.3390/su141811393

Academic Editor: Antonio P. Gutierrez de Blume

Received: 17 August 2022
Accepted: 7 September 2022
Published: 10 September 2022

1. Introduction

Innovative digital technologies and emerging pedagogies are rapidly becoming ubiquitous in our lives, and they have the potential to improve education, which is related to their usefulness as a tool for the achievement of particular goals [1,2]. In recent years, one of the most popular emerging pedagogies has been the flipped classroom (FC), which is based on a hybrid mode of instruction [3] that basically integrates school work at home and home work at school [4,5]. In this innovative approach, students are allowed to access various online learning resources and flexibly choose their own learning paths [6]. To a certain extent, FC enables the instructors to understand their learners' expectations, strengths, weaknesses, needs, and current level of knowledge before class hours by means of technological tools; furthermore, the instructors have more opportunities to maximize class hours for personalized deep learning activities than in conventional classrooms [2,4,7,8].

PL accommodates students' individual differences and allows them to work toward their particular learning goals at their own pace [9]. In the literature, the terms "personalized learning" and "adaptive learning" are frequently used interchangeably [10]. The development of new technologies has made PL increasingly adaptive, and adaptive learning increasingly personalized [11]. Some researchers [10–12] have discussed using the term "personalized adaptive learning" (instead of PL or adaptive learning), which combines PL and adaptive learning. However, there are distinct differences from each. PL entails a student-centered approach that is optimized to meet the learners' individual needs with the aim of fostering personal growth, while adaptive learning entails technologically enriched learning scenarios in which the individuals' learning progress is monitored, and the teaching content is dynamically modified to promote the students' engagement and learning performance [12].

PL is most commonly considered to be an approach that gives the students control of their own learning, diversifies and adapts instruction for each student, and provides personalized feedback with real-time assessment [10]. PL systems can improve the students' learning performance, engagement, motivation, and metacognitive skills [10,13,14], as well as reduce student dropout rates [15]. However, the practical implementation of PL is still a big challenge, especially in conventional educational systems [10,16,17]. For example, initiatives to incorporate personalization into traditional instructional models might be challenging, as personalized instruction may consume the majority of class hours [2]. Personalizing flipped instruction might be also challenging; without technology, it is time-consuming to provide students with immediate personalized feedback and conduct real-time personalized assessments [18]. Although a personalized flipped classroom (PFC) is possible without digital technologies, technology-poor applications of FCs have been the subject of concern and criticism [19]. Personalization in FCs requires learners to exhibit continuous learning interest, motivation, engagement, and self-control, in which technology supports learners to undertake an active role [20].

Instruction must be attractive to students, feasible to teachers, and robust in use [3,21,22]. Modern digital technologies can make PL in FCs attractive and practical by organizing content, enhancing differentiation, diversifying paths of learning, and confirming mastery [23]. Although PL can be achieved via miscellaneous methods in FCs, innovative approaches can strongly facilitate the learners' PL experiences [10,23,24]. The effectiveness of FC for personalized instruction can be reinforced by emerging technologies, such as augmented and virtual reality (VR), cloud technology, artificial intelligence, mobile technology, machine learning, learning analytics (LA), and gamification [19,22]. Although researchers have situated PL within various theoretical frameworks and practical contexts, there is currently no consensus on how to operationalize the innovations [25]. This suggests that there is a need for the careful integration of innovative emerging technologies into the designs and practical implementations of FCs to enhance the students' PL experiences [19].

FC offers plenty of advantages for the learners and positively affects the individuals' academic, emotional, and social development [3], and PL is an efficient approach that can increase the learners' motivation, satisfaction, engagement, and understanding [10]. Despite the potential benefits of both approaches for the learners and educators, studies on the combination of PL and FC remains limited [16,26]. In particular, research on the PFC and its implementation in the digital era is still in its infancy [10,14,26]. To the best of our knowledge, hardly any systematic review study has focused on the combination of PL and FC and the impact of the PFC on educational outcomes. To close this gap, the current innovative systematic review study aims to explore strategies used for PL in FCs, and the impact of PFC on teaching and learning, providing insights for future research.

1.1. Flipped Classroom and the Most Recent Developments in the Field

FC is a relatively new, but continuously developing, field. Various conceptualizations of FC have been presented to date [3,27]. Although initial attempts at FCs were built on technology-poor instruction, such as reading texts [3,27–29], these approaches contributed to shaping the contemporary FC models [7]. Researchers have applied different terms to refer to the instructional approach we now recognize as FC. The *inverted classroom* and the *classroom flip* were proposed in the early 2000s [5,30], but, especially after Bergmann and Sams [4], this approach became known as *flipped classroom*. Early initiatives define FC as an approach in which learning and teaching activities that have traditionally taken place in the classroom setting now take place outside the classroom, and vice versa [5]. Blended/hybrid learning is considered an umbrella term, and FC is placed under the rotation model, which contains both brick-and-mortar and online instruction [31,32]. Later, Bishop and Verleger [33] identified two major aspects of the FC: (a) computer-based individual learning, and (b) interactive group work activities in the classroom. According to this conceptual framework, the pre-class activities must include explanatory videos and the in-class activities must serve interactive learning. Although the prevailing opinion among the researchers is that explanatory videos are a crucial part of FCs, different types of materials, such as reading texts, podcasts, and visual documents, can be used in FCs, or videos might be optional [4]. According to another approach, lecture videos can be included in classroom teaching instead of pre-class teaching [34]. Shortly after the studies of Bergmann and Sams [4] and Bishop and Verleger [33], a consortium of researchers from the Flipped Learning Network (FLN) [6] differentiated between the concepts of *flipped learning* and the *flipped classroom*, presenting the four pillars of F-L-I-P (flexible environment, learning culture, intentional content, and professional educator) and proposed a more generic definition than those proposed by the previous researchers:

Flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides the students as they apply concepts and engage creatively in the subject matter [6].

Later, Chen, et al. [35] adapted the FLN's flipped learning concept to the higher education context. This entailed expanding F-L-I-P to include P-E-D (progressive activities, engaging experiences, and diversified platforms).

Since the COVID-19 pandemic broke out, there have been further developments related to FC. The suspension of face-to-face instruction in schools led researchers and educators to reconsider the design of FC. The most recent studies have moved both synchronous and asynchronous FC learning to online platforms [36]. This new learning mode, referred to as the fully online FC, has been found to be as successful as the traditional FC models for fostering positive learner outcomes [37]. The developments regarding the conceptual framework of FCs over the last two decades confirm that FC is an innovative and flexible pedagogical model.

Several systematic review studies have focused on the efficiency of FC in education, although none have focused on PL. The most recent reviews have yielded mixed—but promising—results, showing that the advantages of FC in education outweigh its disadvantages [3,38,39]. According to the results of these reviews, FC has led to improvements in students' learning performance [7,14,38–42], motivation [3,38], attitudes towards learning [14,39,40,42], satisfaction [3,38,40], engagement [3,7,14,38,41,43,44], social interaction [3,38,39,41,44], collaboration [3,38,39], and communication skills [3,39]. However, the literature has also reported several challenges related to the FC, such as technological glitches [3,7,38,41,45]; time-consuming activities and high workload [3,38,39,41,45]; adaptation problems, resistance to change, and unfamiliarity with the new learning model [3,7,38,39,45]; and stress, anxiety, and frustration [3,7,38].

Overall, FC offers many advantages for education, but there are some challenges related to personalized instruction, especially in FCs without technology. Although FC gives instructors more time to personalize their teaching than traditional classrooms, they often cannot create personalized content for each student and provide personalized immediate feedback and real-time assessment, due to the limited time and huge workload [3,10,25,27]. Therefore, an effort must be made to improve PL in FCs, particularly through the use of digital technologies. Oudbier, et al. [46] highlight that six major factors play an important role in the effectiveness of FCs: the student characteristics, teacher characteristics, implementation, task characteristics, pre-class activities, and in-class activities. When personalizing flipped instruction, these factors can be taken into account. Considering its importance, the present systematic review study focuses on methods for combining FC and PL.

1.2. Personalized Learning

PL has emerged as a principal goal in student-centered educational systems [14]. The students are able to achieve deep learning when they have PL opportunities and personalized support based on their needs [47]. In the literature, there is no consensus on the conceptualization of PL. Researchers have used various terms to refer to the concept, such as "adaptive learning" and "individualized learning." As mentioned earlier, the terms "personalized learning" and "adaptive learning" are mostly used interchangeably in the literature [10,48], but PL is agreed to go beyond "individualized learning" [23,49]. PL is an approach that is differentiated and paced to the learners' needs, and formed by their learning preferences and special interests [50]. The learners have a choice and voice in what, how, when, and where they can learn [23,51]. In the Organisation for Economic Co-operation and Development's report, "Schooling Tomorrow–Personalising Learning," Miliband [52] presents a vision and an agenda for PL that contains five aspects to consider in policy development: (a) an assessment to diagnose each learner's personal needs, (b) the competence development of individuals through teaching and learning strategies based upon the learners' needs, (c) curriculum choices that engage and value each learner, (d) school and/or class organization based upon the individuals' learning progress, and (e) community support of schools to make progress in the classroom. According to Shemshack and Spector [10], personalized learning plans allow learning to be personally relevant, engaging, respectful of individual differences, suitable for the capabilities of the learners, and motivational.

PL has been implemented with the help of various technologies [53] intended to organize the learning processes and access the various information sources [54]. The appropriate use of digital technologies promotes convenient and easy access to learning materials and allows the learners' individual characteristics to be efficiently addressed [55]. Intelligent adaptive tutoring systems, LA, machine learning, and mobile technologies are among the mainstream, innovative research areas intended to recognize learners' personal learning needs, expectations, and skills [17,56,57]. These technologies provide important solutions to existing issues, especially those arising from large classes, by focusing on the analytical data about the students and/or courses, which can allow instructors to understand the students' current learning performance and predict their future achievement [56]. Technology-enhanced PL has been emphasized as advantageous for the learners' educational outcomes from a theoretical point of view. However, the empirical evidence is still limited, and further research on the innovative strategies of PL is needed [10,14,17].

1.3. Research Questions

The purpose of the current systematic review study is to examine the state of empirical research on PL approaches integrated into FCs, and the role of PFC in educational outcomes. Accordingly, the following research questions are addressed:

- RQ1: How PL can be fostered in FC settings? Which strategies, platforms, and tools are used in FC research to enhance PL?
- RQ2: What is the role of PFC in learning and teaching?

In the following section, we have detailed the methodology of our systematic review, focusing on the manuscript selection process and analysis of the included studies. Then, we provide the key results of our review study by discussing the related literature, focusing on the descriptive results, innovative and emerging approaches to personalize instruction in FCs, and the effectiveness of PFC in education. The paper concludes with a discussion of the current and future possibilities to enhance PL in FCs, and the contributions of our review to the field.

2. Materials and Methods

The current systematic review study focuses on the empirical peer-reviewed studies that are strongly related to the strategies for fostering PL in FCs. The renewed Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [58] were used to ensure transparency and quality. Before our literature search, we identified the most frequently used terms in the FC and PL research fields, focusing on the previously conducted studies, including the systematic review studies, presented in the previous section. Our examination revealed that the emphasis is placed on the terms "flipped" and "inverted" for FC and "personalized" and "adapted" for PL. Thus, it was important to use these terms to reach the most related papers from the literature. We utilized a combination of these keywords—*((personalized learning OR adaptive learning) AND ((flip* learning) OR (flip* teaching) OR (flip* instruction) OR (invert* learning) OR (invert* instruction) OR (invert* teaching))*—to search the papers' titles, abstracts, and keywords. Although there is no unified agreement on the conceptualization of PL, "personalized learning" and "adaptive learning" are frequently used interchangeably [10]. Thus, we applied both terms in our literature search.

We conducted a literature search on 26 March 2022, within three reputable electronic databases: Web of Science, SCOPUS, and ERIC. We did not restrict the search with the publication years and scientific disciplines. Rather, we identified four inclusion criteria to select the eligible papers: (a) the papers must be written in English; (b) they must be peer-reviewed journal articles, conference proceedings, or book chapters; (c) they must be indexed in WoS, SCOPUS, or ERIC; and (d) they must be strongly related to PL in FCs and describe PL methods in detail.

Figure 1 presents a flow diagram of the manuscript selection process. The process included three important steps: (a) identification, (b) screening, and (c) inclusion. In the first step, we identified 932 records in the electronic databases. We eliminated 24, based on the language and document-type criteria, and we electronically deleted 46 duplicate records. MS Excel and EndNote X9 software were used to record and manage the identified references. In the second step, we screened the titles, abstracts, and keywords of the records and excluded 706 irrelevant papers. Then, we screened the full-text versions of the remaining 156 papers, employing our inclusion criteria. Ultimately, we included 41 studies in our systematic review, with the consensus of the authors. The included 41 studies are highlighted with asterisks in the reference list.

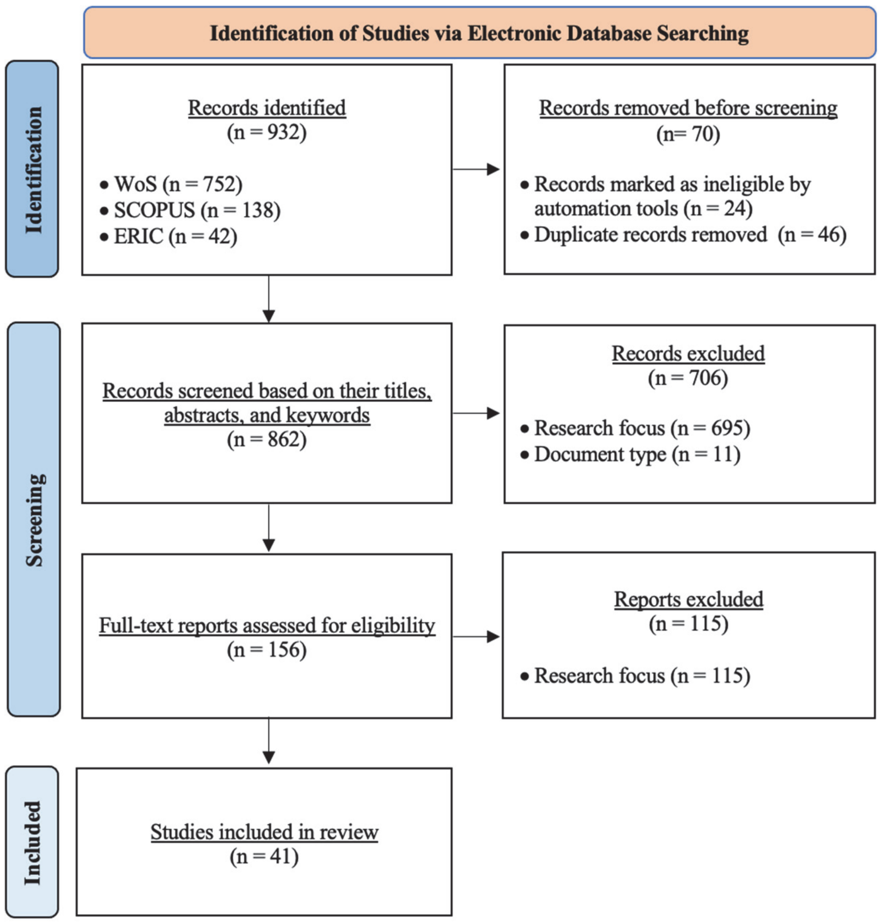

Figure 1. Flow diagram of the paper selection process.

After identifying the eligible papers, the full texts were screened three times and a qualitative content analysis was conducted [59]. The identified codes were structured around three themes: (a) the general characteristics of the reviewed studies (i.e., publication year, document type, author affiliation, research methodology, sample, sample size, and scientific discipline), (b) the approaches developed or applied to personalize the learning/instruction in FCs, and (c) the role of the personalized FC in teaching and learning. For the sake of reliability, five included papers were randomly selected and cross-checked by an external intercoder with experience in qualitative content analysis and familiarity with the FC research area. A satisfactory coding reliability rate (0.93) [60] was determined, based on the formula proposed by Miles and Huberman [59]: "reliability rate = number of agreements/(number of agreements and disagreements)." The authors and intercoder spent time discussing the discrepancies between their codes and reached full agreement before reporting the results.

Although we followed the most recent PRISMA guidelines to strengthen the quality and transparency of the review [58], some interesting research studies may have been excluded due to the study selection criteria about the language, document-type, and selected electronic databases. Another restriction may be related to the automated selection of the papers through data engines, called jingle-jangle fallacy [61]. For example, we used the terms "personalized learning" and "adaptive learning" in our literature search to capture the most relevant studies. We did not use the terms "individualized learning" or "customized learning" for PL, as these concepts do not capture the meaning of PL precisely [23,49]. However, these terms may have already been used by authors of respective papers, but our search has not included them.

3. Results of the Systematic Review

For this review study, we have organized our synthesis of the results and discussion into three main sections: (a) an overview of the studies, (b) ways of developing PL in the context of FC, and (c) the role of PFC in the learning and teaching process.

3.1. Overview of the Reviewed Publications

In this systematic review, we analyzed 41 research studies—28 journal articles and 13 conference proceedings—on PL in FCs. These studies were published between 2005 and 2022. Figure 2 shows that the publication trend has not been marked by steady progress. Although there was a remarkable increase in the number of publications in 2020, the total number of published papers on PL in FCs is far from satisfactory.

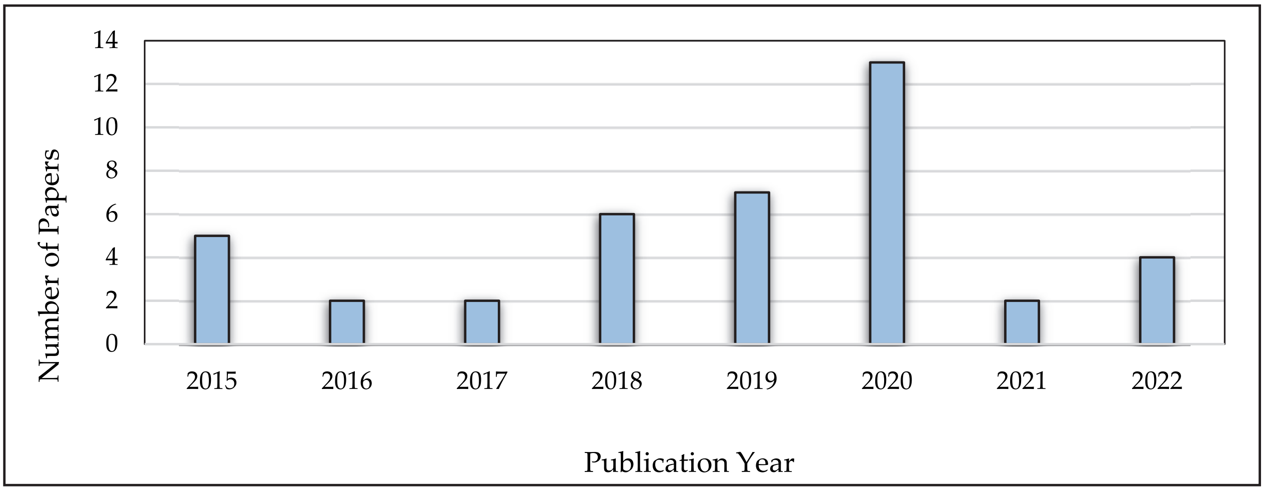

Figure 2. Number of papers on PL in FCs published by year.

To reveal the international researchers' interest in PL in FCs without domain restrictions, the country affiliations of all authors (n = 130) were analyzed. The analysis revealed that the researchers came from 19 different countries. The greatest number of researchers were from China (20%, n = 26), followed by the US (15%, n = 23), the UK (11%, n = 14), Australia (10%, n = 13), Morocco (7%, n = 9), Taiwan (7%, n = 9), Turkey (5%, n = 6), Norway (4%, n = 5), Brazil (4%, n = 5), Ukraine (3%, n = 4), Russia (2%, n = 3), the Netherlands (2%, n = 3), Thailand (2%, n = 2), Serbia (2%, n = 2), Sweden (2%, n = 2), Canada (1%, n = 1), Estonia (1%, n = 1), Finland (1%, n = 1), and Qatar (1%, n = 1). The distribution of the continental origin indicated that most researchers in this field are from Asia (32%, n = 41), followed by Europe (29%, n = 38), North America (18%, n = 24), Australia (10%, n = 13), Africa (7%, n = 9), and South America (4%, n = 5).

The researchers most frequently used quantitative research methods (54%, n = 22), followed by mixed method (32%, n = 13), and qualitative research methods (15%, n = 6). Inconsistent with this result, most studies recruited small sample sizes; more than half (56%, n = 23) had fewer than 100 participants, while only 3 had more than 1000 participants. Interestingly, no studies focused on primary school students. The overwhelming majority of the studies (76%, n = 31) focused on undergraduates, and a few focused on secondary school students (12%, n = 5) and in-service teachers and educators (12%, n = 5).

An analysis of the scientific discipline of the reviewed studies indicated that more than half of the studies were related to the engineering sciences (e.g., chemical engineering, computer sciences, mechanical engineering, and civil engineering) (54%, n = 22), followed by the humanities and social sciences (e.g., educational sciences, English foreign language, governance and sustainable development, and economics) (24%, n = 10); natural sciences (e.g., geosciences, mathematics, and physics) (20%, n = 8); and life sciences (e.g., biology) (2%, n = 1) (see Figure 3). These results revealed that the STEM subjects were the most popular subjects.

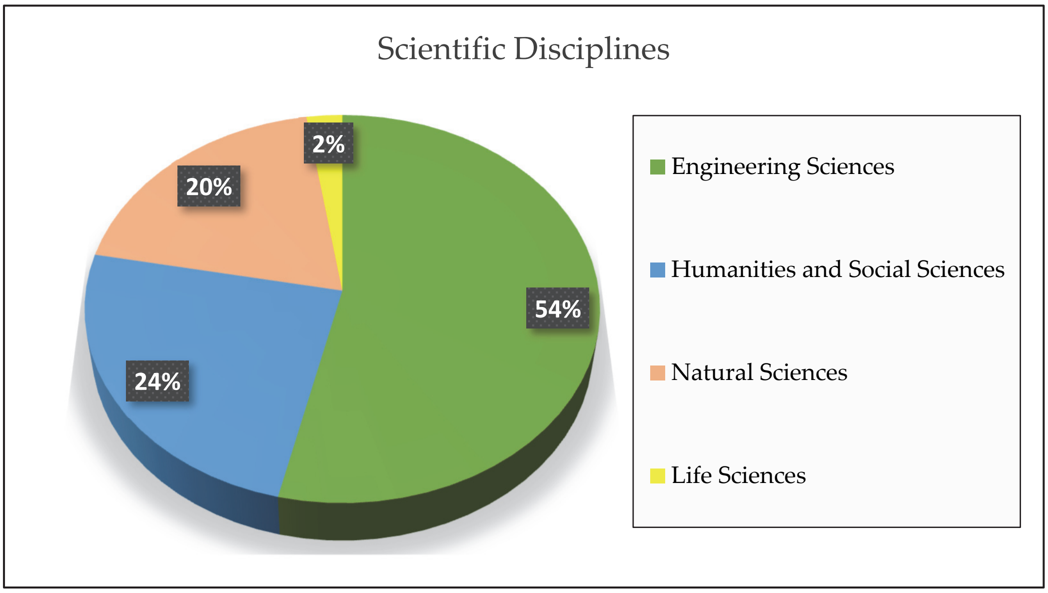

Figure 3. Scientific disciplines of the reviewed studies.

3.2. Ways of Developing PL in the Context of FC (Research Question 1)

Successful applications of PL have been achieved through various methods enabled by the rapid development of innovative educational technologies [24]. To support PL in FCs, researchers have developed and/or used several digital tools and platforms, and they have designed or redesigned adaptive personalized courses. To improve PL in FCs, educators have used emerging approaches such as machine learning, LA, mobile learning, VR and cloud technology, big data, and gamification (see Table 1).

Table 1. Approaches used to foster PL in FCs.

Category	Related Studies	n [1]	%
Tools/platforms	[18,19,62–82]	23	56
Learning analytics	[18,22,56,66,67,70,73,77,81,83–88]	15	37
Personalized adaptive courses, including "massive open online courses" (MOOCs)	[18,22,26,65,67,68,70,73,88–93]	14	34
Machine learning	[57,85,90,94]	4	10
Mobile learning	[16,81,95]	3	7
Big data	[81,90]	2	5
VR and cloud technology	[81]	1	2
Gamification	[22]	1	2

[1] n represents the number of studies.

3.2.1. Adapted Courses and Digital Tools/Platforms Used for PL in FCs

Our systematic review revealed that the researchers most frequently (56%, n = 23) used a certain tool or platform (i.e., Bring Your Own Device [BYOD], a multimedia platform designed in Storyline by Articulate, an e-schoolbag platform, Cogbooks, a micro-adaptive learning platform provider, PeerWise, an ICT tool, an online chat and Q&A platform, FCTool, Smart Sparrow, P2P platform, Goconqr, Realize IT, Smart English, and Learn Smart) to promote PL in FC settings. Basically, these online platforms allow the instructors to notice the students' needs, expectations, and difficulties and monitor the students' learning progress in FCs, which has been strongly emphasized as important for PL in the literature [10,96]. The platforms generated reports which instructors can use to personalize instruction and provide diverse content for each learner according to their level of understanding. Moreover, these online platforms make it possible to provide real-time feedback and conduct personalized assessments. In more than one-third of the reviewed studies (34%, n = 14), the educators developed various personalized adaptive courses (frequently online courses, including MOOCs) with the help of the aforementioned online platforms. Considering the importance of these platforms' key features and their use in the studies, below we present the detailed technical results of the educators' efforts to personalize flipped instruction and the students' tasks and learning activities in FC settings.

Kong and Song [71] and Attard and Holmes [63] used a personalized learning hub (BYOD) to foster PL in FC implementations in the higher education context. BYOD encourages the learners to bring their personal digital devices (e.g., laptop and tablet PC) to the learning environment and fosters social interaction between their peers and teachers through electronic resources. When families cannot afford to purchase a digital device, the school lends the learner a device. The learners have opportunities to access various learning materials and to engage in discussions, quizzes, and presentations. They can communicate with their teachers or invited experts and receive immediate online and face-to-face feedback. Depending on their understanding of the subjects, the learners can follow different learning pathways. Learning management systems (e.g., Echo, Khan Academy, and Canvas), content-related tools (e.g., Geogebra and Desmos), innovative technologies (e.g., MS Hololens), and other frequently used educational technologies (e.g., MS OneNote and Excel) are used for the learning.

In four studies [66,67,70,73], the Smart Sparrow interactive learning platform was used to promote PL by developing adapted flipped lessons for each learner. Smart Sparrow provides the learners with multiple representations and resources, such as explanatory videos, reading texts, quizzes, and simulations. After the students choose a personalized path for the preparation of lessons and completion of tasks, their learning activities are automatically evaluated in real time by adaptive online courseware. The students answer a set of questions after the lesson and, if they fail, the Smart Sparrow platform uses adaptive intelligent tutoring technology to direct them to alternative learning materials and e-learning modules. Then, the content-related questions are asked again. If the learners fail again, the platform directs them to the prerequisite module. The metrics provided by the platform help the teachers to provide personalized feedback on the students' learning progress.

The studies used various adaptive learning platforms to personalize learning in FCs. For example, Kakosimos [18] presented a multimedia platform designed in Storyline by Articulate for micro-adaptive instruction that focuses on gathering information about the learning activities and learners' feedback before class hours. The information and feedback are available online for the instructor to personalize the instruction, based on the students' needs and expectations. Micro-adaptive instruction employs specific assessment strategies, such as the "muddies point" and "minute paper," before class hours to structure in-class activities. In Kakosimos's study, eCampus, which is based on Microsoft Learn, was used as an e-learning management system (eLMS). The online platform allowed the learners to interact with animated characters (called Meleti), making instruction dynamic.

Wetton and Serafin [80] used a different type of micro-adaptive platform, Cogbooks, for PL in FCs. This platform provides instructors with student data obtained through click-tracking and gives automated feedback on the students' learning progress.

Dai and Liu [19] presented a P2P platform that guides peer interaction in FCs by forming personalized working groups, based on the students' feedback and answers to the prompts. This platform aims to serve large FCs. The learners are divided into small groups, based on their cultural, educational, national, and disciplinary backgrounds, and their level of understanding. The system provides the instructors with analytical reports about the various groups of students to show the diversity of the students and allow the instructors to redesign and modernize the instruction.

In the study of van Leeuwen [77], PeerWise and web lectures were used and the learners' online learning activities were logged. The teachers provided weekly reports to the students on their learning activities and performances. The students also filled in weekly questionnaires at the beginning of each week, and the instructors considered these answers when planning their lectures.

Like van Leeuwen [77], Biggins, Bolat, Crowley, Dogan and Dupac [64] presented an implementation of PeerWise for PL in FCs. In this study, the learners created online multiple-choice questions (MCQs) and used the PeerWise platform as an online repository of the MCQs. Their contributions, comments, and feedback were awarded with trophies on the platform to enhance their engagement. After formulating the questions, the students needed to explain the correct answers for the questions. Then, they received immediate feedback from the teacher.

Shaykina and Minin [76] used an open educational resource, Goconqr, to create and share learning materials in various formats. The students used this tool to memorize new vocabulary in English, and flashcards, quizzes, and mind maps were available online.

Clark, Kaw and Gomes [68] developed adaptive lessons using the Realize IT platform. The students submitted their responses about the challenges and interesting topics in the lessons, with the help of online learning platforms such as Canvas, Blackboard, Panopto, and Proctorio. These platforms contained breakout sessions, mini-lectures, and clicker questions to identify the challenges of students. In this way, the instructors could personalize the instruction.

In the study of Hsieh, Signorini, Chuang and Chen [69], a needs assessment and performance analysis were carried out to explore the students' problems and sources of anxiety. The students answered the pre-formulated questions on the Learn Smart platform, watched videos, and attended live webinars and 24/7 discussion forums. In this way, they obtained information about their own learning pace, learning style, and learning habits. The teachers reviewed the reports of the students' learning progress to identify the most challenging concepts for the students and guide the students' learning process accordingly.

Xiao-Dong and Hong-Hui [81] upgraded an English learning software, Smart English, which provides online personalized learning resources to the learners, based on their location and level of English, via an intelligent and personalized learning system. Digital electronic resources were established for each learner on the platform, and the learners could progress according to their own needs and pace.

Ni, Kwok, Zhen, Xie, Long, Zheng and Li [74] presented an innovative e-schoolbag platform that functions as an e-portfolio and provides opportunities for immediate feedback and monitoring of the students' learning activities. This platform allows the learners to explore problems, generate questions, create problem-solving strategies, and assess their learning progress in mathematics lessons. The platform provides (a) an analysis of learning situations, (b) online exercises with opportunities for immediate feedback, (c) a statistical analysis for each learner or holistic analysis to focus on common errors, (d) individualized learning exercises, and (e) extra learning materials to expand the learners' knowledge.

Louhab, Bahnasse, Bensalah, Khiat, Khiat and Talea [72] combined the FC model with the Moodle platform to provide the learners with adapted content, according to their level of knowledge and skills. They also allowed the instructors to manage the learning mechanism of their own students in FC.

In their effort to create a personalized learning climate, Zhai, Gu, Liu, Liang and Tsai [82] used an online chat and Q&A platform to determine the learners' satisfaction level and offer a space for reflective observations. On this platform, the learners shared their personal solutions for specific problems and learned from their peers' diverse answers and the teacher's personalized feedback.

Araujo, Costa, Viana, Veras, Farias and Ieee [62] developed the FCTool to create personalized study guides (e.g., lists of explanatory videos, scientific papers, and podcasts) based on the learners' needs and expectations, employing Microlabs and problem-based learning. After the students engage in the learning activities and answer quizzes, the FCTool adapts the study guides and lesson content according to the students' learning performance. Google's G Suite was also used to deliver adapted study guides.

Clark and Kaw [65] used an adaptive e-learning platform to enhance the pre-class preparation and make the instruction personalized. The platform was supported by multiple resources for learning, including lecture videos, texts, online quizzes with automated feedback, and simulations. The learners' performance was evaluated in real time, and the system provided real-time feedback to the students. Performance analytics provided by the software helped the teachers to guide the students and diagnose difficulties in the learning.

Tsai and Chu [91] developed a personalization mechanism, using Microsoft Visual Studio and C#, and constructed a database employing a Microsoft SQL server. This mechanism combined a personalized feedback system and concept maps in an FC. The students constructed their own knowledge using concept maps and collaboration with their peers. The students reported their concept maps, and the teachers provided feedback on the students' work to help address misconceptions.

McQueen and McMillan [89] introduced partially flipped lectures (so-called "quectures") that contained questions posed by the learners. These questions were discussed and then revised in interactive learning environments to personalize learning.

A few studies combined various MOOCs and FC approaches to personalize learning. For example, Wang, Wang, Wen, Wang and Tao [93] established a small private online course (SPOC) that functioned as an MOOC and provided interactive PL opportunities. Other studies [22,88,90] also reported the implementation of flipped MOOCs. The students' participation and learning behavior were recorded, and the MOOC content was optimized according to the system reports.

3.2.2. Emerging Technologies Used in FCs to Promote PL

As mentioned earlier, studies have used emerging technologies to improve PL in FC settings. The most popular technology was LA (37%, n = 15), followed by machine learning (10%, n = 4), mobile technology (7%, n = 3), big data (5%, n = 2), VR and cloud technology (2%, n = 1), and gamification (2%, n = 1).

The reviewed studies frequently used digital tools and software (described in the previous section) to gather and analyze the analytics data for the students and courses to personalize the learning in FCs. The data were frequently gathered through online analytics, and sometimes gathered through surveys. LA was focused on the students' learning performance [18,56,66,67,70,73,81,83,85–87], engagement [56,81,84,85,87,88], satisfaction [88], method of time management [87], interaction level [18,70,81,83], perceptions [77,84], and needs/deficiencies and expectations [81,83,88]. The following analytics metrics were used:

- logging into and out of the LMSs [83,86];
- the participants' demographics [88];
- the frequency of page visits, content access, and study of the learning materials, such as e-books, videos, web lectures, and applications [18,22,70,77,81,83,84,86,88];
- the time spent on learning platforms [18,22,66,70,77,88];
- the frequency of engagement in discussions on online platforms, such as posting messages on the forums and asking or replying to questions [18,77,81,83,84,86,88];
- the exam and quiz scores [18,66,67,73,77,81,84,86]; and
- the activity completion [22,66,70].

The instructors accessed important reports through LA to personalize their teaching in the FCs. In addition to automatic online feedback and assessment, the instructors could develop LA-based personalized interventions with cognitive, meta-cognitive, and affective guidance support. Karaoglan Yilmaz and Yilmaz [84] reported that LA strategies enabled (a) the identification of the students' learning needs and deficiencies, (b) a review of the students' learning progress, (c) the development of positive perceptions and attitudes towards learning among the learners in the FCs, (d) the personalization of the learning experiences, and (e) the development of personalized assessments.

A few studies (10%, n = 4) used machine learning to personalize instruction in FCs. For instance, Klochko, Fedorets, Tkachenko and Maliar [57] used machine learning techniques to increase the effectiveness of the FC and promote PL. Machine learning helped to identify the students' characteristics and learning trajectories. Then, the learning environment was adapted according to the students' needs, and academic and motivational support were provided as needed.

Matcha, Gasevic, Uzir, Jovanovic and Pardo [85] also benefitted from machine learning technology. In this study, semi-automatically generated personalized feedback messages were provided to the learners, based on an algorithm that compared the learner's level of academic performance and their engagement.

Nouri, Saqr and Fors [94] used particular machine learning methods (i.e., neural networks, naïve Bayes, random forest, kNN, and logistic regression) to predict the learners' performances on their course. With the opportunities provided by machine learning, LMSs were developed to provide automatic formative feedback. This feedback was intended to help the learners self-regulate and inform the instructors when and how to intervene and support the learners.

Qian, Li, Zou, Feng, Xiao and Ding [90] used a back-propagation neural network as an optimization model of an artificial neural network to develop a prediction model that established a relationship between the output data and expected input. The learners' past achievement data were employed to create a radar chart by using Python to predict the learners' future achievement. In sum, all the opportunities afforded by machine learning can enhance PL in FCs, as students' future achievements, needs, and behaviors can be determined in advance based on their previous activities.

A few studies used other emerging technologies, including mobile technology (7%, n = 3), big data (5%, n = 2), VR and cloud technology (2%, n = 1), and gamification (2%, n = 1), to personalize the learning in FCs.

Chaipidech and Srisawasdi [95] developed a personalized, flipped, open inquiry-based approach based on mobile technologies (e.g., a tablet PC and mobile phone). In this innovative learning environment, the students took responsibility for their learning and selected their own learning paths using a simulation on their mobile devices.

Louhab, Bahnasse and Talea [16] developed an Android mobile application that aimed to provide the students with personalized content. The proposed approach (Smart Enhanced Context-Aware for Flipped Mobile Learning) provided adapted learning resources according to the students' needs and characteristics.

In Qian, Li, Zou, Feng, Xiao and Ding [90], big data analysis was used to predict the students' future achievement in FCs based on MOOCs. Based on this analysis, a personalized learning approach was developed.

Xiao-Dong and Hong-Hui [81] used big data mining, cloud computing, and mobile technologies to create flexible personalized learning environments. Cloud technology was used to develop a desktop VR system (which requires a computer or mobile device to present the 3D virtual environment) and a distributed VR platform. The researchers upgraded the English learning software, which had situational awareness functions (e.g., identification of users' English level and location), and it was loaded with the distributed VR platform. It was available in off-class time to support mobile learning. The VR-based FC facilitated human–human and human–computer interactions and enabled communication with virtual characters. In this interactive learning environment, the students had opportunities to receive personalized content.

Lastly, Klemke, Eradze and Antonaci [22] presented a flipped MOOC based on a gamification approach, which was intended to make the learning process more personalized and interesting to the learners. The game elements were presented to the in-service teachers and teacher educators. Then, the researchers asked the participants to conceptualize the game elements and indicate which kinds of learner data they needed to support the game elements and personalize their instruction. The participants worked on the design of the personalized, flipped MOOCs using the gamification techniques.

Overall, our analysis revealed that emerging technologies can be effectively used to personalize FC. However, these technologies were rarely used in FCs to foster PL.

3.3. The Role of Personalized FC in Learning and Teaching (Research Question 2)

We analyzed studies focusing on the role of PFCs in learning and teaching. A majority of the studies concentrated on the effects of PFC on the students' learning outcomes (see Table 2). The key results are presented below.

Table 2. Focused Research Themes in PFC Approaches.

Category	**Related Studies**	**n [1]**	**%**
Achievement, learning performance, exam scores, knowledge acquisition	[19,26,57,63–75,78,80,85–87,89–93,95]	27	66
Satisfaction	[16,19,26,67,68,72,80–82,93]	10	24
Perception	[18,19,62,63,68–71]	8	20
Engagement	[18,63,64,71,79,88,89]	7	17
Learning motivation	[18,26,57,62,68,84,95]	7	17
Enjoyment	[66–69,79,88]	6	15
Challenges	[19,69,77,84,89]	5	12
Self-regulated/directed skills	[84,86,87]	3	7
Learning interest	[74,76,88]	3	7
Inquiry	[83,89]	2	5
Preference of learning in FCs	[68,89]	2	5
Collaboration	[63]	1	2
Peer-interaction	[19]	1	2
Communication	[76]	1	2
Time management	[76]	1	2
Self-confidence	[88]	1	2
Sense of responsibility	[84]	1	2

[1] n represents the number of studies.

According to our analysis, two-thirds of the studies investigated the role of the PFC approaches in the students' achievement and learning performance, exam scores, and knowledge acquisition (66%, n = 27). Almost all of these studies reported positive results regarding the efficiency of the PFCs for student achievement and learning performance. Only two studies [65,66] reported that there was no significant difference between PFCs and conventional FCs, or other blended learning approaches.

Several studies found that the majority of the participants were highly satisfied with learning in PFCs (24%, n = 10). The learners had quite positive perceptions of PFCs (20%, n = 8), and a PFC approach increased their engagement (17%, n = 7) and learning motivation (17%, n = 7). According to the reported results, the students enjoyed learning in PFCs (15%, n = 6), and their learning interest was increased (7%, n = 3). PFCs were favored by the students over other lecture formats. A few studies found significant improvements in the students' self-regulated/directed learning (7%, n = 3) and inquiry skills (5%, n = 2). In addition, a few studies pointed out that PFCs resulted in improved collaboration, interaction, communication, time management, the students' sense of responsibility, and the teachers' self-confidence. PFCs can also decrease the cognitive load and stress level of learners.

In contrast, a few studies (12%, n = 5) reported that PFCs might present challenges for learners that tend to be frustrated by unexpected technical glitches, time-consuming tasks, and a lack of familiarity with the new learning tools and environments [19]. Some learners disliked or experienced difficulties in adjusting to the innovative learning modes in the PFCs [89]. It may also be challenging to stimulate the students' interest and maintain continuous engagement in the long term [19]. PFCs may negatively affect learners' motivation because they have less autonomy [69]. Van Leeuwen [77] categorized the challenges for instructors into three themes: connecting diagnoses and instructional interventions, issues with the design of the LA reports, and balancing the learners' and instructors' expectations. Moreover, the LA reports may cause stress and feelings of being monitored [84].

Overall, the majority of the studies reported that PFCs had a positive effect on the learners' academic, social, and emotional development. Thus, the use of technologically rich PL strategies, including emerging technologies, holds promise in FCs. Although all reported negative effects of PFC were related to the limited number of participants in the studies, these results must be taken into account in order to achieve successful PFC implementations.

4. Discussion and Conclusions

This systematic literature review study provides a comprehensive understanding of the current research on the development of PL strategies in FCs and the effectiveness of PFC in terms of educational outcomes. The current review can provide a roadmap for the future development of PL strategies in FCs and successful implementation of FCs.

Our analysis revealed a remarkable increase in the number of publications on PL in FCs in recent years (especially in 2020). However, the current knowledge is far from satisfactory [10,16,26].

We also analyzed the distribution of all the authors' national affiliations, as the geographical distribution of the authors provides insight into the research trends and connections between the authors' cultures and the PFC approach [3,97]. We found an inhomogeneous distribution of the researchers around the world. As it may be problematic to transfer efficient learning environments from one culture to another [98], the researchers should broaden the cultural contexts of their research and conduct intercultural studies on PL in FCs. Experts from different cultures may develop beneficial strategies to successfully flip instruction and promote PL.

Further research should be conducted on the PL experiences of students (especially students other than undergraduates) in FCs, and the PL strategies developed and enacted by teachers and educators in FCs. In particular, qualitative and large-scale studies should be conducted, considering the limited number of these type of research studies. It is advisable to ensure methodological diversity in the research, as diversity can extend current knowledge and understandings of PL from different perspectives [14].

Our results also indicated that the STEM subjects were the most popular subjects within the corpus of studies we analyzed, which is in line with the previous research on FCs [43]. The dominance of research on engineering sciences implies that the FC approach is particularly well-suited to personalized engineering education [44].

Our analysis revealed that all the included studies integrated various digital technologies in FCs. The studies aimed to first determine the learners' personal needs, interests, expectations, skills, strengths, and weaknesses, then provide personalized content based on the analytical data reports, and finally provide immediate feedback and real-time assessment. The opportunities afforded by technology assist the instructors in monitoring their students' learning progress and adapting their teaching, without wasting time [96].

We found that the majority of the studies developed adaptive courses and used various digital tools/platforms and LA to personalize the instruction. Emerging technologies (i.e., VR, machine learning, big data, cloud technology, mobile technology, and gamification) can be effectively used to personalize the instruction. However, these technologies were rarely used in the FC contexts to foster PL. Therefore, future studies should consider integrating more emerging technologies into FC environments. In addition, the feasibility and potential of particular sophisticated technologies (e.g., augmented reality, wearable technologies, and artificial intelligence) for PL in FCs was not explored, even though the literature has strongly emphasized their importance in education [48]. Flexible and creative curricula stimulate learners to engage with sophisticated technologies. Thus, it may be wise for educational institutions to integrate technology-rich PL approaches in FCs [99]. The literature emphasizes that educational technologies have great potential in the design of educational systems [100], and PL in school systems requires significant technological support [10].

Concerning the potential of PFCs for education, the majority of reviewed studies reported that PFC has positive effects on the students' learning outcomes, in line with the literature [3,14,99]. The growing body of empirical research on PL indicates that technology-rich PFCs improve human–human interaction and human–computer interaction, and foster not only students' academic development (e.g., learning performance, exam scores, and conceptual understanding), but also their emotional (e.g., motivation, satisfaction, and enjoyment) and social development (e.g., social interaction, and communication). Educational technologies can make PL practical by reducing the time required to differentiate the instruction, providing unlimited access to the learning content and alternative learning pathways, and automatically assessing the learning progress [23]. In addition to real-time assessment, technological tools can provide students with immediate feedback [23,48,99], which is one of the most powerful intervention strategies to personalize instruction and optimize the students' learning performance [101,102]. These results are promising and encourage the use of technologically rich PL strategies in FCs.

However, a few studies reported challenges related to PFCs for the learners and instructors (e.g., technological glitches, time-consuming activities, and lack of familiarity with new learning environments and tasks). These challenges must be taken into account in order to successfully implement PFCs [3]. Our review suggests that PFCs must be engaging and motivating for the learners; if activities are performed in a prosaic way, without taking innovative advantages of new technologies, it might be challenging for the learners to remain engaged [22].

One criticism of the PFC approach might be related to the prescriptive algorithms generated by the technological systems (e.g., LA and machine learning systems) [14]. These systems often explore the limited design features of PL and pay little attention to other important contextual factors [14]. Considering the limited features of digital tools, instructors need to be careful when receiving feedback from students about their personal needs by means of these tools. The instructors should check the accuracy of the analytical data reports and reconsider the main characteristics of the students and related learning context, rather than using these reports directly. One study [24] suggests expanding the features of adaptive intelligence tools to produce more comprehensive academic analytics, which enable the creation of rich PL environments.

Another criticism relates to the structure of the conventional FC. The pre-class learning activities associated with conventional FCs rely on lecturing, which may not be an effective method to personalize the instruction and engage the learners [103]. This criticism does not exactly apply to the modern applications of FC because the technological tools allow for interactive learning, beyond lecturing, outside the classroom. Our systematic review yielded promising results regarding the potential of technologically rich FCs for personalized instruction.

Shemshack and Spector [10] claimed that PL approaches gain more attention from policymakers and governments than from researchers and educators. The authors suggest focusing on solutions to come up with robust PL strategies. The limited research on PL in FCs indicates not only a lack of interest among researchers but also a lack of knowledge and experience in using modern technologies in the classroom among instructors. Therefore, instructors, educational technology experts, software engineers, and field researchers should be involved in the establishment of systematic collaboration to produce efficient PL models [10].

5. Implications for Future Research on PFC

The following implications of PFCs may be beneficial for future researchers in creating robust designs of FC and its successful implementation. These implications can also motivate future studies to close the identified research gaps in the field.

- The current systematic review confirmed that the use of emerging technologies (e.g., VR, cloud technology, machine learning, big data, learning analytics, mobile learning, and gamification) in FCs are promising to enhance PL. Therefore, future studies can use innovative digital technologies and investigate the role of various technologies (e.g., augmented reality and artificial intelligence) in promoting PL in FC settings.
- As the contribution of the countries to the PFC field is not homogeneous, we invite researchers, particularly from underrepresented countries, to focus on fostering PL in FCs.
- The lack of qualitatively oriented research on PFCs suggests concentrating on in-depth qualitative studies on innovative methods to enhance PL in FC environments.
- Our review also yielded a limited number of large-scale studies. Large-scale studies may be advantageous to investigate the efficiency of personalized instructional strategies used in FCs on learning outcomes. Not only in-depth qualitative studies, but also large-scale quantitative studies, should be the focus of future studies on PFCs, which may contribute to methodological diversity.
- Future studies need to focus on the ways of the PFC, especially in primary education.
- There is a huge need for research on PFCs conducted in the life sciences.
- Future studies may explore barriers to personalized instruction in FCs, which may be beneficial to produce robust designs of FC.

To sum up, this systematic review study may provide researchers and educators with insight into how innovative technologies can be used to personalize instruction in FCs and the efficiency of the PFC approach in terms of the learning outcomes. However, more research studies are needed to evaluate the opportunities and pitfalls of modern technologies to support PL in FCs.

Author Contributions: Conceptualization, M.C. and G.K.; methodology, M.C. and G.K.; software, M.C.; validation, M.C. and G.K.; formal analysis, M.C.; investigation, M.C.; resources, M.C.; data curation, M.C.; writing—original draft preparation, M.C.; writing—review and editing, G.K.; visualization, M.C.; supervision, G.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data were retrieved by WoS, SCOPUS, and ERIC and can be replicated.

Conflicts of Interest: The authors declare no conflict of interest.

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