

Adaptive Teaching of Fractions: A Comparative Educational Approach in the United States and Spain

Enseñanza adaptativa de fracciones: un enfoque educativo comparativo en Estados Unidos y España

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ABSTRACT

This comparative examination considers the conceptualization and enactment of adaptive instruction of fractions in the United States and Spain, exploring systemic, cultural, and pedagogical factors affecting instruction. Fractions, a cornerstone of math literacy, are challenges worldwide due to traditionally procedural teaching. Adaptive instruction—adjusting content, pace, and support—has arisen to meet more diverse learner needs. The study employs curriculum analysis, classroom observations, teacher interviews, and surveys of 12 schools in both countries. Results are found that American schools adopt more systemic adaptive strategies like Response to Intervention (RTI), differentiated instruction, and technology. Spanish schools emphasize inclusive ideologies but without ongoing practice, especially fraction-specific content. American teachers had improved access to professional development training and teaching resources, while Spanish teachers were limited by enormous class sizes and inflexibility in the curriculum. Both teachers identified adaptation as a high value and referred to barriers like time, training, and support. In both nations, students responded positively to adaptive practices, with greater engagement and assertiveness when instruction included visual illustrations, formative assessment, and contextual problem-solving.

Keywords: Adaptive instruction, Intercultural education, differentiated teaching, formative assessment, fragmented pedagogy

RESUMEN

Este análisis comparativo considera la conceptualización y la implementación de la instrucción adaptativa de fracciones en Estados Unidos y España, explorando los factores sistémicos, culturales y pedagógicos que afectan la instrucción. Las fracciones, piedra angular de la alfabetización matemática, representan un desafío a nivel mundial debido a la enseñanza tradicionalmente procedimental. La instrucción adaptativa (que adapta el contenido, el ritmo y el apoyo) ha surgido para satisfacer las necesidades más diversas de los estudiantes. El estudio emplea análisis curriculares, observaciones de aula, entrevistas a docentes y encuestas a 12 escuelas en ambos países. Los resultados indican que las escuelas estadounidenses adoptan estrategias adaptativas más sistémicas, como la Respuesta a la Intervención (RTI), la instrucción diferenciada

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Recibido: 28/05/2025 - Aprobado: 27/06/2025

Gallardo Herrerías, C. (2026). Adaptive teaching of Fractions: A comparative educational approach in the United States and Spain. *Revista Universitaria del Caribe*, 33(1), 17-28. <https://doi.org/10.5377/ruc.v33i1.22774>

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y la tecnología. Las escuelas españolas enfatizan ideologías inclusivas, pero carecen de práctica continua, especialmente contenido específico para fracciones. El profesorado estadounidense tuvo un mejor acceso a la formación profesional y a los recursos didácticos, mientras que el profesorado español se vio limitado por el gran tamaño de las clases y la inflexibilidad del currículo. Ambos docentes identificaron la adaptación como un elemento clave y mencionaron barreras como el tiempo, la formación y el apoyo. En ambos países, los estudiantes respondieron positivamente a las prácticas adaptativas, con mayor compromiso y asertividad cuando la instrucción incluyó ilustraciones visuales, evaluación formativa y resolución de problemas contextuales.

Palabras Clave: Instrucción adaptativa, educación intercultural, Enseñanza diferenciada, evaluación formativa, Pedagogía fraccionada

I. INTRODUCCIÓN

The topic of fractions is considered essential for students' mathematics learning, and research suggests that it is an important stepping stone in developing abstract and relational thinking. The acquisition of fractions knowledge is proven to positively predict students' success in algebra, proportional reasoning, and advanced problem solving (Andrews, 2009; Boomgaarden *et al.*, 2023). However, despite the acknowledged significance of this topic for learning mathematics, it is still regarded as one of the hardest mathematical concepts. The main reason for its difficulty can be associated with complex nature of this topic but also with the way in which it is taught, focusing on skills rather than understanding.

Adaptive and differentiated instructions emerged as pedagogical frameworks focused on meeting needs of diverse learners through adapting pace, representations, scaffolding, and assessment. Both in the US and in Spain, problems related to issues of equity, inclusion, and learning mathematics became grounds for considering adaptive instruction an appropriate strategy for improving fraction learning. Even though personalized and inclusive instruction was promoted in both cases, there are still considerable differences in curricular designs, teachers' education programs, and models of implementing pedagogy (Charalambous *et al.*, 2010; Rodríguez-Martínez *et al.*, 2023).

Although previous research has separately addressed issues related to students' struggles with fraction learning, adaptive teaching, and reform efforts in mathematics education, few studies have considered the topic of comparative research into adaptive teaching of fractions within different national contexts. More precisely, there is currently insufficient empirical knowledge regarding the way in which institutional arrangements, teachers' perceptions, and classroom dynamics impact the practice of adaptive teaching of fractions in dissimilar educational environments.

With this limitation in mind, this paper aims to compare adaptive teaching of fractions in the United States and Spain, two nations with well-established and somewhat differing educational systems (Andrews, 2009; Pereda Lorient *et al.*, 2025). This comparative perspective will allow us to explore the ways in which systemic factors facilitate or hinder pedagogic adaptation in relation to the instruction of fractions.

The research aims specifically to achieve the following goals:

- Design and contrast theoretical models of adaptation in the teaching of fractions in Spain and the US.
- Evaluate the role of national and regional curricular systems in facilitating or hindering such adaptations.
- Study classroom practices related to differentiation, manipulation, visualization, and formative evaluation of fractions.

- Discuss teachers' attitudes, preparation, and obstacles to implementing adaptive teaching methods in the learning of fractions.
- Determine students' perceptions and reactions to the application of adaptive teaching methods for fraction knowledge acquisition.

This study provides further insight into the current discourse on inclusive math education by integrating studies on fraction comprehension with adaptive instruction and cross-national educational comparisons.

II. LITERATURE

Challenges in Learning Fractions

Problems in learning fractions are not only connected to the complexity of the mathematical concept but also related to the typical methods of instruction. Often, instruction in fractions has been focused on developing procedural knowledge rather than conceptual knowledge. As a result, students are expected to learn rules like procedures for common denominators or inversions without comprehending the relationship between those actions (Boomgaarden *et al.*, 2023). While these practices can help achieve success in the short run, they do not encourage flexibility and the ability to generalize this knowledge to other contexts.

The process of learning fractions involves making a cognitive switch from operating with whole numbers to operating with rational numbers, which is known to be challenging for students. This mathematical notion contradicts previous intuitions, developed when working with arithmetic. The dual function of fractions as operators and quantities is another difficulty. Learners tend to hold misconceptions concerning the concept, such as considering fractions as two independent whole numbers or regarding a greater denominator as indicating a greater quantity.

In the past, there have been issues with fraction instruction because of its fragmentary and rote approach. Since children learn fractions after a long period of whole number instruction without adequate linking of concepts, they can view fractions as special cases rather than expansions of number systems. These issues can contribute to misunderstanding and lack of conceptualization of mathematical knowledge.

Constructivism and socio-cultural theories are useful perspectives that help in comprehending difficulties with mathematical knowledge acquisition. In constructivism and socio-cultural approaches, mathematical knowledge is built through experience, engagement, and guidance. In this regard, the construct of scaffolding from Vygotsky is highly relevant to adaptive teaching.

Adaptive Instruction in Mathematics Education

Adaptive instruction is an instructional approach that adapts and accommodates instruction to cater for individual differences among learners in terms of differentiation in content, pace, representations, and support (Bush, 2021; Prediger *et al.*, 2022). This has become increasingly popular in the realm of mathematics teaching, particularly where classrooms are diverse with regard to prior knowledge and socio-emotional skills of learners.

One important aspect of adaptive instruction is pedagogical content knowledge (PCK) by teachers, which includes recognizing misconceptions and adapting instruction accordingly. Literature indicates that although many teacher training programs consider inclusive principles in general, very few have prepared them adequately for adaptation in mathematics teaching and understanding fractions.

Some important models used to enhance understanding and application of adaptive instruction include Response to Intervention (RTI) and Universal Design for Learning (UDL).

Adaptive Fraction Instruction in the United States

In America, there have been efforts to improve education through reforms that have made teachers focus on adaptive and differentiated models when teaching subjects such as mathematics. Research studies have shown that adaptive models offer positive results when dealing with special needs children or underprivileged groups of learners, especially when it comes to teaching fractions.

Nonetheless, implementation of this method varies from one institution to another because of disparities in preparation among teachers and allocation of resources by various districts.

Adaptive Fraction Instruction in Spain

Spanish policies for inclusive education have gradually favored competencies, formative evaluation, and personalization. The adoption of LOMLOE has further strengthened these approaches, but the actual classroom implementation varies.

There are some issues regarding inclusive policies and the challenges in implementing these policies due to the use of conventional whole-class teaching methods, the lack of digital devices, and differences in teachers' preparedness, which is related to its decentralized administration (Rodríguez-Martínez *et al.*, 2023; Shih *et al.*, 2023).

Additional Factors Influencing Fraction Learning

In addition to pedagogy, language can also be a barrier to understanding fractions, especially in classrooms with multiple languages. Math language and metaphor about fractions can add complexity for emergent bilinguals. This is an issue relevant in the United States and Spain due to linguistic diversity.

Technology can also serve as either a resource or a hindrance in fraction instruction. Technologies like DreamBox, GeoGebra, and Desmos can offer assistance in visualization and personalization, though research indicates that this is only possible if integrated correctly within a sound pedagogical framework.

Affective considerations are also significant. Fractional anxiety, lack of confidence, and previous negative experiences may affect students' approach towards fractions. Adaptive instruction can contribute to motivation and autonomy through feedback and challenge, though the structure of the educational system remains a powerful influence.

Research Gap

While there has been literature on fraction difficulties, adaptive instruction, and reforms within nations, few studies have compared these topics. Only minimal literature exists regarding adaptive fraction instruction in educationally divergent settings.

The current research study seeks to fill this void by exploring adaptive fraction instruction within both the United States and Spain in order to determine how the structure of each educational system, teacher beliefs, and classroom practice influence adaptive fraction instruction.

III. METHOD

The comparative qualitative study employed a multi-method research design to explore how adaptive teaching methods to fractions are conceptualized, enacted, and experienced within United States and Spanish education systems. The study employed a combination of document analysis, classroom observations, semi-structured interviews, and teacher surveys to triangulate data and ensure validity and reliability of findings. The study was conducted over the course of one school year (2023–2024), in primary and lower secondary education settings, with particular focus on grades 4 through 6, where fractions are most intensively taught.

The sample comprised 12 public schools: six from the US (randomly selected from California, Texas, and Massachusetts), and six from Spain (randomly selected from Andalusia, Catalonia, and Madrid). These locations were chosen because of their diversity in socioeconomic, linguistic, and cultural contexts, and, in addition, due to their ability to reflect regional educational policies and autonomy. Key informants from each of those schools comprised two math teachers and one school administrator, for a total number of 24 teachers and 12 administrators. Furthermore, observations of two math lessons in each school were conducted, giving rise to the total observation of 24 classroom periods in both countries.

Participants' selection was done purposefully, focusing on individuals who had minimum five years of professional experience in teaching and who expressed some level of interest in adaptive or inclusive mathematics education. Participants provided their informed consent, and ethical approval was sought from the institutional review board of all countries involved in the study. To maximize transparency and reproducibility of the study, all the methods and techniques used in it were pre-tested before implementation.

The main tools used for data collection included

1. Document Analysis Coding Tool: Documents related to curricula, instructional policies, and assessment criteria were extracted from national and local education agencies. The documents were coded using a coding tool that was constructed based on existing literature about adaptive instruction, which includes ideas like differentiation, formative assessment, inclusive instruction, and mathematics reasoning.
2. Observational Classroom Rating Form: An observational instrument was devised in order to observe teaching methods, students' participation, use of manipulative and visual tools, student interactions, and adaptation efforts. The observations were conducted within the context of the Mathematical Quality of Instruction (MQI) framework and the Differentiated Instruction Observation Protocol (DI-OP) framework, which included fractional topics.
3. Semi-structured Interview Protocol: The teacher participants engaged in semi-structured interviews based on different interview guides with open-ended questions about their conceptual understanding of adaptive mathematics teaching, curricula support, classroom strategies, obstacles, and professional development opportunities. The interviews were performed in the first language of the interviewees (either English or Spanish). The interviews were transcribed and, when needed, translated into English.
4. Teacher Survey Questionnaire: The researchers used a teacher survey questionnaire consisting of 30 items to collect data quantitatively. The Likert-scale instrument was distributed to all the teachers who participated in the study.

In terms of the research procedure adopted for the study, the first process entailed conducting the analysis of the relevant curriculum documents at the national and regional level to get an insight into the situation at hand at a macro level. In addition, an investigation was conducted to establish the training standards as well as policies on how teachers are evaluated regarding the teaching of mathematics. The

second phase involved classroom observations carried out over four months, each lasting 90 minutes. During these observations, observers took notes, filled in the observation rubric while videos were being recorded.

Following classroom observations, interviews were conducted among the teachers as well as the administrative personnel to gain insights into why certain practices occur and also understand the reasoning behind decisions made during instruction. These interviews were scheduled within two weeks from when the observations occurred to enhance accuracy. The data obtained were analyzed using NVivo software with the use of inductive and deductive codes.

Questionnaires were distributed online through a protected web interface and filled out by participants over a period of two weeks. Data obtained from questionnaires were analyzed using SPSS, with descriptive statistics performed to detect any trends, and cross-tabulation being performed to detect differences between U.S. and Spanish participants. The internal consistency of all subscales was checked using Cronbach's alpha, and its value was more than 0.85 in all cases.

Participant member checks and peer debriefing sessions were used during the research to confirm the validity of interpretations, while an extensive audit trail consisting of documentation on instrument development, coding procedures, analysis memos, and correspondence logs was established. Such a high level of transparency regarding methodology allows replication or further extension of the research by other scholars who may be interested in comparing the effectiveness of adaptive mathematics instruction across nations.

The combination of several sources and methods made it possible to achieve a triangulated understanding of the process of implementing adaptive teaching of fractions across the whole instructional system. By placing classroom practice in the context of curriculum intentions and teacher beliefs, the study sought to reveal not only the nature of instruction adaptation but also the factors that affect it.

IV. RESULTS

Results of the comparative study indicate that there are some noteworthy differences and similarities between Spain and the United States in the use of adaptive teaching practices in fraction instruction. This section provides a summary of data that was obtained through curriculum analysis, classroom observations, interviews, and surveys and responds to each of the primary research questions and objectives of the study.

Document analysis showed that Spain and the U.S. incorporated differentiated and adaptive instruction into their national curriculum. However, the degree of operation and specificity in employing these approaches had varied considerably. In the case of the U.S., Common Core State Standards (CCSS) emphasize the mastery of conceptual understanding and the utilization of more than one representation of mathematical ideas. However, how these standards are interpreted and implemented becomes overwhelmingly diverse from state to state. By way of contrast, Spain's LOMLOE national curriculum does include principles of inclusive education but provides less directive indication of precisely how teaching is to be differentiated for specific mathematical topics such as fractions. Spanish textbooks situate adaptation more broadly within a "attention to diversity" that encompasses both students with special educational needs and students with different learning styles.

In the United States, on the other hand, adaptation will more likely be paired with Response to Intervention (RTI) and Individualized Education Programs (IEPs) that establish more formalized avenues for working with struggling learners. Both systems, however, demonstrate inconsistencies in moving the frameworks to discipline-specific practices in fractions, as most documents do not offer explicit examples or pedagogical models.

Teacher interviews and observations of classrooms showed that the adaptive instructional practices were more evident in the U.S. than in Spanish classrooms, particularly in the domains of flexible grouping, utilization of tactile and visual manipulatives, and use of technology.

U.S. teachers used fraction tiles, number lines, computer software, and daily formative checks to inform instruction and make adjustments as needed. For example, in one California school, a rotation system was used where students rotated through stations that included independent work, peer tutoring, and teacher-led practice. In Spain, while manipulative use was observed, it was confined to the lower primary years, with more extensive use of whole-class teaching being the norm.

Teachers were firmly invested in inclusive practices but indicated that large student-teacher ratios and insufficient training in differentiated instruction created challenges for them to adapt successfully. According to one Andalusia teacher, "We want to reach all students, but with 25 in a class and only one of me, it's hard to reach everyone." Spanish teachers also implicated that despite some scaffolding strategies provided by textbooks, they used procedural teaching due to time and curricular pressures. In Catalonia, however, there was a greater promotion of project work and student-led investigation, some difference in adaptive strategies throughout Spain.

Both countries' students responded well to adaptive pedagogy, particularly when teaching was interactive and student-centered. Students in the United States who were taught with differentiated instruction were more engaged and rated themselves as more confident in mathematics. Student engagement was evidenced through increased eagerness to take risks, ask questions, and utilize different strategies of solving fraction problems.

Student engagement in Spain was more variable and seemed to be highly related to teacher practice. In the classrooms where teachers used small-group instruction and use of real contexts for solving fraction problems, students were more engaged and learned more. In the more didactic classrooms, however, students expressed confusion and lack of engagement, with a desire for memorization rather than conceptual understanding.

These findings were confirmed by survey results. In America, 79% of teachers agreed that students showed greater understanding when they used adaptive practices whereas 62% of Spanish teachers agreed. Furthermore, 85% of American teachers were confident in changing instruction from formative assessment, yet only 58% of Spanish teachers were confident to do this.

All nations prioritize professional development as the means to enable adaptive instruction, but they do so differently. Larger percentages of U.S. teachers reported more frequent access to workshops, online modules, and instructional coaches. Professional support was most robust in districts with mature RTI systems. Teachers reported that greater access to timely data in conjunction with co-work with special educators maximized their potential to differentiate.

By contrast, Spanish teachers reported less professional development in adaptive teaching or math. The training was most frequently delivered in the one-size-fits-all format without subject matter content. Some territorial projects, and indeed in Catalonia and the Basque Country, could promote teacher-led research and innovation in the teaching of mathematics.

Resource provision was also important. There was greater provision of technology, manipulatives, and supporting material for differentiated instruction in American schools. In Spain, there were greater disparities between schools, with some schools having a very dependence on textbook teaching and few or no materials for hands-on learning.

Cultural learning and educational beliefs appeared to influence the adoption of adaptive pedagogies. In America, the emphasis on individualism, accountability, and innovation would encourage teachers to individualize learning and experiment with different methods. Conversely, the Spanish system's emphasis on collective solidarity and conformity occasionally suppresses divergence from the norm even when teachers can recognize the need for differentiation.

Institutional organization also influenced practice. In the United States, data systems and school-based intervention teams existed to enable a more responsive mode of addressing student needs. In Spain, there were perceptions that bureaucratic processes for launching support measures, such as curricular adaptations or extra personnel, were slow and inflexible. Teachers in both countries lamented a lack of autonomy and support to make decisions in the moment.

Despite differing conditions, teachers in both nations identified the same challenges: time, large class sizes, few resources, and a lack of training. But they also showed a willingness to meet student needs and identified adaptive instruction as a critical component of effective math teaching.

Certain effective practices appeared in more than one setting. They included the use of formative assessment to guide teacher instruction, the inclusion of real-world contexts for fraction problems, and co-teaching with co-teachers or aides. Cross-cultural learning and collaborative research can aid both nations in the further development and dissemination of effective practices.

V. DISCUSSION AND CONCLUSIONS

The findings from this comparative analysis offer an important interpretation of how adaptive instructional strategies to fractions are enacted and interpreted in two distinct schooling contexts. By analyzing the implementation of adaptive instruction of fractions in Spain and the United States, and contrasting these findings with the wider literature, the study returns convergences and divergences in terms of systemic, cultural, and pedagogical considerations.

One of the strongest correlations with past research exists in the acknowledgment that conceptual understanding of fractions necessitates instruction based on individual student needs (Andrews, 2009). The teachers in Spain and in the U.S. evidenced more sensitivity to the importance of tapping students' prior experience and intuitive knowledge. While U.S. teachers more and more employed open-ended tasks and formative assessment to diagnose what students were thinking, Spanish teachers depended more on system procedural approaches, although with increasing use of visual supports.

The differential use of manipulatives and visual representations is in line with previous studies (Bush, 2021) that number lines, area representations, and pie charts can possibly bridge concrete and abstract thinking. Within the United States, manipulatives were incorporated within inquiry-based learning settings, as mandated by NCTM (2000) standards. In Spain, manipulatives were present but applied more teacher-directed and within the framework of a traditionally paced curriculum. This aligns with outcomes from Charalambous *et al.* (2010), which report that Spanish teachers are unable to utilize creative resources due to tight curricular pacing and centralized testing.

The findings also highlight differences in the systemic supports for adaptive teaching. U.S. teachers were supported with professional learning communities (PLCs), access to a variety of technology tools, and differentiation strategies within curricula materials. These findings support Boomgaarden *et al.* (2023), who emphasize the importance of ongoing professional development and available resources to facilitate effective differentiation. In contrast, while Spanish teachers reported high commitment towards inclusive education, they also reported fewer structural supports for adaptive teaching, as found in earlier research by Misquitta (2011), which condemns the lack of structural consistency in applying inclusive pedagogy within Spain.

More importantly, this study refutes the hypothesis that adaptive instruction is purely a discretionary or pedagogical matter. Surveys and interviews reveal wider policy and cultural context influences over what may be possible in practice. As an example, the U.S. emphasis on individualized teaching, resulting from wider neoliberal education policies as reported by Polydoros & Antoniou (2025), causes teachers to pursue highly individualized teaching pathways that may sacrifice curriculum coherence. The collectivist stance within the Spanish system embraces the concept of collective responsibility, albeit at the expense of flexibility due to its standardized demands. In this case, the clash within the culture reflects Pereda Loriente *et al.* (2025) individualism-collectivism construct, thereby demonstrating how deep these orientations can run in shaping instructional practices.

The findings add to the existing literature regarding formative assessment as the basis for adaptive instruction. Exit tickets, self-reports, and computer software were used by American instructors to gauge the students' comprehension in real-time, in line with the learning feedback approach of Prediger *et al.* (2022). Spanish teachers, despite endorsing the need for formative assessment, admitted that they did not have enough time or support from the school authorities to employ these approaches systematically.

In addition, the unexpected difference comes from the way of conceptualizing fractions. While American teachers mentioned many times about research-based learning progressions, such as Rational Number Project, and talked about numbers of a line when presenting fractions, Spanish teachers, while implementing more conceptual approach to teaching fractions, relied on traditional European part-whole relationships, which are also pointed out by Shih *et al.* (2023) as a multi-dimensional subject and warned against using too many approaches simultaneously. In turn, this can affect the meaning that is going to develop among students when learning fractions.

At the same time, it was found that students in both countries learned more effectively when teachers made clear links between symbols, diagrams, and the context, supporting the ideas of Rodríguez-Martínez *et al.* (2023). Still, as it is shown by Charalambous and Pitta-Pantazi (2007), not all the teachers had enough pedagogical content knowledge (PCK) to make these links properly. Thus, teachers in both cases showed signs of the need for more focused PCK training in teaching fractions.

Within inclusive education specifically, this research is in line with the arguments of Shih *et al.* (2023), who argue that pedagogy for inclusion requires faith in the educability of all pupils and with that, practical approaches to supporting them. Teachers in both countries embraced inclusive policies but varied in readiness and availability of resources to implement them. Teachers in the U.S. had more frequent exposures to co-teaching models and differentiated curriculum material resources, while Spanish teachers reported use of support staff that were not always available within the classroom. Such structural differences may influence the degree to which adaptive fraction teaching can adapt to diverse learners' needs.

Furthermore, one must note that even though the research focuses on fraction instruction, there will be some elements which will certainly be applicable to other areas of mathematics. Indeed, the research findings confirm the importance of adaptive instruction as a continual compromise between the interests of the teacher, curriculum, institutions, and culture. Within the framework of that goal, the findings contribute to the global discussion on the best way of organizing and supporting instruction.

The research investigates the uptake and impact of adaptive instruction in fraction lessons in both the US primary and lower secondary schools and Spain. It attempts to demonstrate how adaptation becomes an element of the curriculum design, how adaptation finds its realization through pedagogical instruction, and what is the reaction of teachers and learners to this kind of instructional approach in a particular institutional and cultural setting. Through observation of classes, interviews with teachers, analysis of curricula and surveys, the comparative research demonstrates not only the subtleties of adaptation of instructional practices for fraction instruction but also the social and cultural dynamics of such instructional processes.

The research first shows that despite the similar understanding of the problems encountered in teaching fractions in the two countries, the solutions adopted to tackle the issues differ due to their approach towards adaptive teaching. In the USA, adaptive fraction teaching is becoming increasingly driven by federal and state-level policies aimed at standardizing outcomes, accountability measures, and use of technology-enabled instructional resources. However, in the case of Spain, the strategy focuses more on overall development and group learning, making the process more locally initiated in accordance with local value priorities.

One of the most important findings that have emerged is that of adaptation being incorporated into the new curriculum. For instance, in America, documents of policy, as well as curriculum designs like the Common Core, actively encourage the provision for differentiated instructions and tiering of the system, thus integrating the use of adaptive techniques. On the other hand, since high-stakes testing often limits the degree of application of the strategy by teachers, the actual process becomes difficult. While, Spanish curriculum designs incorporate the philosophies of inclusive and adaptive instruction, but in the absence of standard implementation procedures and teacher training, the execution remains difficult.

The second main discovery deals with teacher agency and professional development. The American teachers described empowerment together with frustration with the need for adaptation in teaching, which was normally achieved through the use of computer applications and data-oriented methods. On the other hand, their colleagues from Spain, who utilized technology less frequently, identified co-planning, peer mentoring, and experiential learning as mechanisms that helped foster adaptation. Indeed, research evidence suggests that intense and long-term professional development is essential to foster content knowledge and reflection on how to implement adaptive strategies effectively. Furthermore, schools that encourage teacher autonomy and cooperation are more likely to support adaptive innovations than hierarchical structures.

The second key finding relates to teacher agency and professional development. According to American teachers, empowerment is associated with frustration due to the necessity of adapting to teaching by means of computer applications and data-driven approaches. In contrast, Spanish teachers, who used technology less often, viewed collaboration in planning and mentoring along with experiential learning as facilitators of adaptation processes. Actually, empirical research shows that continuous and prolonged professional development plays a vital role in fostering knowledge about content and strategies for implementing adaptation approaches. Besides, educational institutions where teacher autonomy and teamwork are encouraged will have an easier time adopting innovative approaches to adaptation.

The role of cultural context in mediating pedagogy should not be underestimated. As mentioned earlier, American educational philosophy emphasizes efficiency, accountability, and individuality, which explains why technology plays an essential role in adaptive pedagogy there through quantitative measures. In Spanish education, social integration, flexibility, and learning through processes prevail, and hence there is a greater emphasis on relational, or embedded adaptive teaching. These cultural ideologies are not only expressed through classroom practices and students' expectations but also define teachers' understanding of adaptation. Thus, this paper proves the importance of cultural sensitivity in educational reforms that cannot disregard transshipments of ideas across country contexts.

Among the issues that stand out is the one connected with how the problem of adapting the curriculum and maintaining its coherence can be solved. Instructors from both countries noted the concern about possible adverse effects of over-individualization of education on either the group process or coherence of knowledge structures. It happened especially in cases when due to budget constraints, it was impossible to pursue personalized teaching in classrooms. The suggestion is that adaptive pedagogy must be tightly controlled so as to keep its conceptual integrity in response to individual needs—a tricky pedagogical move indeed.

Methodologically speaking, the study shows how comparative qualitative research is effective in uncovering complex dynamics within policy, practice, and context. Through comparison of two different

alternative education systems, one gains not only knowledge of how other places do things differently but also how and why they do so. The study foregrounds the underlying assumptions, structures, and historical precedents that inform educational choices. It also facilitates self-reflection on one's own educational world with room for reflexivity and international exchange.

Above all, however, lie the implications this research has for educators, policy makers, and researchers. To educators, the research emphasizes that adaptation involves relating such actions to curriculum objectives and needs. As far as this research shows, adaptation should involve not only technical resources but also an in-depth understanding of mathematics, students' development, and teaching plans. To policy makers, the research emphasizes the necessity of having specific policy directives that guide the autonomy of teachers, involve the availability of adequate assistance, and guarantee equal access to such adaptations. This research also warns about the dangers of making blanket statements and stresses the necessity of contextually oriented reforms. To researchers, the research offers new avenues of cross-disciplinary research.

The study also implies a number of future research directions. To start with, longitudinal research could be undertaken in order to determine the effects of adaptive instruction in fractions on students' development. The second direction for further investigation might be conducting a more thorough analysis of classroom discourse and work in order to understand microgenetic mechanisms of enhancing comprehension through adaptation. Another option would be comparative research in other countries, which will make it possible not only to widen the scope of research but also to distinguish universal features from those that are context-dependent.

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