A Study of Strategies to Enhance Student Engagement in Middle School Classrooms with Instructional Feedback in a Smart Paper - Pen Environment

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Abstract: In the context of educational digitization, middle school classrooms face dual challenges: nsufficient student engagement and the simplification, standardization, and rigid sourcing of traditional instructional feedback. This study, based on an analysis of feedback issues in middle school classrooms and a survey of students' feedback needs, combines the technical advantages of Smart Paper-Pen Systems in terms of scientific teaching evaluation and diversified classroom interaction. Following principles such as interactivity and continuity, it constructs a theoretical model for enhancing student engagement through instructional feedback in a Smart Paper-Pen Environment, and explores a strategic framework for improving student engagement by optimizing instructional feedback. This study provides a theoretical framework and practical pathways for integrating instructional feedback with student engagement in smart classrooms, aiding the deep integration of educational technology into classrooms, and holds both theoretical innovation and practical guidance significance..

Keywords: Smart Paper-pen System; instructional feedback; student engagement; middle school classroom

1. Introduction

With the advancement of education digitalization strategy, smart classroom has become an important way to improve the quality of education. In recent years, the education field has gradually recognized the importance of instructional feedback in the process of student learning. Instructional feedback is not only the teacher's evaluation of students' learning results, but also an important means to promote students' in-depth thinking and adjustment of learning strategies. In the middle school classroom, the problem of insufficient student engagement needs to be solved, and instructional feedback, as a key link in classroom teaching, has a potential impact on improving student engagement.

In the traditional classroom, teachers often provide feedback through verbal evaluation, homework correction, etc., but these methods have certain limitations, such as feedback is not timely enough and lack of personalization. The emergence of the smart paper and pencil system, on the other hand, provides new possibilities for instructional feedback. As an emerging educational technology tool, Smart Paper-pen System integrates the advantages of traditional paper-pen writing and modern information technology. It can record students' writing process, answer questions and other learning behavior data in real time, and transform these data into visual feedback information to help teachers more accurately understand the

students' learning status, so as to provide more targeted instructional feedback. At the same time, the Smart Paper-pen System also supports a variety of interactive features, such as classroom voting, real-time reviews, etc., which can enhance the interest of the classroom and the sense of participation of students.

This study is dedicated to exploring how to optimize instructional feedback by using the Smart Paper-pen System, which in turn enhances student engagement in middle school classrooms.

2. Definition of relevant concepts

2.1 Smart Paper-pen System

Smart Paper-pen System is an innovative educational tool system that integrates advanced information technology and traditional writing scenarios, which breaks the single mode of traditional paper-pen writing, and builds up a digital and intelligent learning and teaching ecology. The Smart Paper-pen System consists of dot-matrix digital pen, digital paper and cloud service. The system is able to collect students' learning data in real time, providing teachers with accurate instructional feedback basis, while supporting a variety of interactive methods to enhance the interest of the classroom and students' participation.

2.2 Instructional Feedback

Instructional feedback refers to the process by which teachers convey information about students' learning progress during the teaching process to promote their academic development. Its primary functions include providing correct answers, analyzing errors, offering problem-solving strategies, and guiding learning methods and strategies. Effective instructional feedback helps students understand their learning status, adjust their learning strategies, and thereby enhance learning outcomes. At its core, instructional feedback is a dynamic, two-way communication process. Teachers obtain information about students' learning through observing their learning behaviors and homework performance, and then provide corresponding feedback. Students, in turn, reflect on their learning processes based on teachers' feedback, identify issues, and implement improvement measures, thereby enhancing their learning autonomy and self-regulation abilities.

2.3 Student Engagement

Student engagement, also known as student involvement, is defined by Astin as the physical and psychological energy students invest in the learning process (Astin A W, 1984). Finn argues that student engagement encompasses both behavioral and emotional aspects. Behaviorally, it manifests in whether students frequently participate in classroom and school activities; emotionally, it refers to whether students feel they "belong" to the school environment and value outcomes related to the school (Finn, 1993). In 2001, Kuh formally defined student engagement, emphasizing that it involves the time, effort, and energy students invest in educational activities (Kuh, 2001). Chinese education scholar Professor Kong Qiping synthesized the consensus from domestic and international research, pointing out that although there are differences in terminology, scholars agree that student participation transcends overt behavior and encompasses deeper activities such as psychological, cognitive, and emotional processes. Ultimately, Professor Kong Qiping concluded that student participation involves activities across three dimensions: behavioral, cognitive, and emotional (Kong Qiping et al., 2003).

3. The Basis for Constructing Strategies

Traditional instructional feedback, due to its overly foundational nature, group-based feedback, and fixed sources, makes it difficult for students to achieve knowledge transfer,

often neglecting individual learning needs and leading to reduced learning engagement (Li Maoshen et al., 2022). The lack of peer feedback and self-reflection limits the development of students' self-reflection and metacognitive abilities (Wang Yun et al., 2021).

Therefore, this study conducted a needs survey on 88 first-year middle school students at a certain middle school in Guangzhou using the Instructional feedback Scale (Mo Muzhen et al., 2012). The data showed that in terms of feedback content, students desired timely feedback and targeted analysis, while also expecting positive recognition. Students of different academic levels had varying feedback needs: struggling students focused on filling gaps in foundational knowledge, average students focused on guidance in problem-solving approaches, and high-achieving students sought cross-disciplinary expansion and improvement. In terms of emotional needs, most students indicated that teachers' praise can enhance their willingness to speak up, and they prefer private feedback on mistakes rather than public criticism.

Based on the above results, the smart paper-pen system precisely meets students' feedback needs through four functions: scientific teaching evaluation, diversified classroom interaction, instant classroom feedback, and visualization of learning thinking. Specifically, it visualizes students' mastery of knowledge points through learning situation data; stimulates learning motivation through diversified interactive modules such as quick response and voting; provides timely feedback through real-time tracking of answer progress and grading; and displays the logic of problem solving through screen sharing and handwriting playback.

The principles of instructional feedback are based on Bandura's ternary interaction decision theory, the Hurlock effect, and Vygotsky's zone of proximal development theory, and are constructed from four dimensions: interactivity, continuity, positivity, and flexibility. The Smart Paper-Pen System collects and analyzes student performance data to drive teachers to dynamically adjust their teaching strategies; A comprehensive feedback system covering pre-class, in-class, and post-class phases is established to avoid fragmented teaching interventions; by reducing the frequency of negative feedback and stimulating students' intrinsic motivation (John Hattie et al., 2015); implementing dynamic tiered feedback—providing step-by-step guidance for students with weaker foundations and delivering cross-disciplinary extension tasks for advanced learners—ultimately maximizing the effectiveness of precise teaching.

Based on the above foundation, this study constructed strategies for improving student engagement in middle school classrooms through instructional feedback in a Smart Paper-Pen Environment.

4. Theoretical Models for Smart Paper-Pen Environment

The model of instructional feedback to enhance student engagement in middle school classroom under the Smart Paper-Pen Environment is shown in Figure 1, which refers to the "Emotional Design Supported Instructional Agent Feedback Model" proposed by Liu Qingtang and other scholars (Liu Qingtang et al., 2024), and is based on the theory of feedback teaching, the constructivist learning theory, the theory of emotional response, and the theory of ternary interaction decision-making.
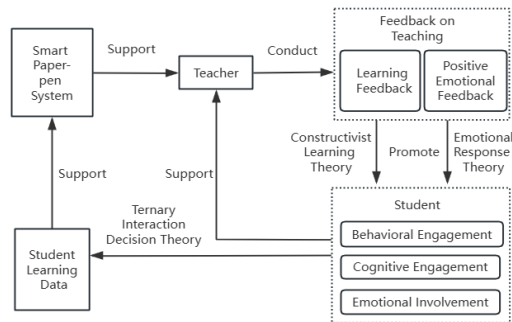
Feedback-based teaching theory emphasizes the irreplaceable role of instructional feedback in learning motivation, cognitive development, and behavioral change during the teaching process. Smart paper-pen systems, which integrate information collection and interaction, cover all stages of teaching, including lesson preparation, instruction, interaction, and assessment. By efficiently integrating learning data, these systems provide a scientific basis for instructional feedback, which can be categorized into learning progress feedback and emotional feedback.

According to constructivist learning theory, learning is a process in which learners actively construct knowledge. Based on instructional feedback, learners are able to generate cognitive conflict and reflection, and behavioral, cognitive, and emotional involvement occurs so as to actively construct their personal knowledge system.
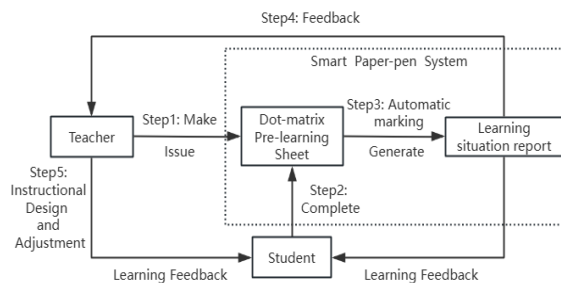
Emotional response theory asserts that teachers' language and emotions can directly influence students' emotional states and engagement levels (Sean M et al., 2012). Therefore,

instructional feedback should present positive emotional feedback. The reprocessed and integrated student learning data from the smart paper-and-pen system can serve as the basis for teachers' subsequent feedback, while also incorporating teachers' intuitive judgments of students' classroom participation.

Ternary interaction decision theory believes that there is mutual interaction and influence between the environment, the individual, and behavior. In teaching scenarios, teachers, students, teaching behaviors, and the environment engage in multiple interactions. In the whole process, the smart paper-pen, as the teaching environment and medium, interacts and dynamically generates with the teacher, the students, and the behaviors of the teacher and students.

Figure.1 A model for improving student engagement in middle school classrooms with instructional feedback in a Smart Paper-pen Environment
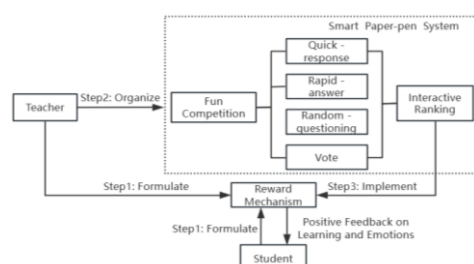

Figure.2 Flowchart of the guided learning strategy for the dot-matrix pre-learning sheet

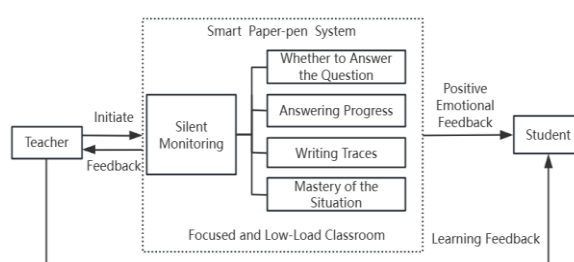## 5. Strategies for Improving Student Engagement in Middle School Classrooms

Based on the theoretical models for Smart Paper-Pen Environment, this paper proposes five strategies with instructional feedback to enhance student engagement in middle school classrooms.

5.1 Dot Matrix Pre-learning Sheet Guided Learning Strategy

Dot Matrix Pre-Learning Sheet is a pre-learning sheet presented in the form of dot matrix paper in Smart Paper and Pen. This guided learning strategy is primarily used before class, as shown in Figure 2. Teachers must design the pre-learning worksheet in advance and print it as a dot matrix paper version. The dot matrix pre-learning worksheet leverages the smart pen and paper system's automatic grading, generation of learning progress reports, and analysis functions to help teachers quickly and scientifically assess students' starting points. By understanding students' prior knowledge levels, teachers can design and adjust their teaching plans accordingly, making the teaching more targeted. Additionally, after completing the pre-learning worksheet and receiving feedback, students can gain a clearer self-awareness, focus more intently on the lesson, and enhance their behavioral and emotional engagement.

Figure.3 Fun Competitive Strategy Flowchart

Figure.4 Silent Monitoring Strategy Flowchart

5.2 Fun Competitive Motivational Strategies

The fun competition motivation strategy is mainly used in the classroom. As shown in Figure 3, the essence of this strategy lies in utilizing the interactive leaderboard feature of the Smart Paper-Pen System, ensuring that every student interaction triggers a reward mechanism to enhance learning motivation. The quick response, fast response, and random question modules all include a reward star feature. The quick response feature displays the names of other students who attempted to answer when one student successfully answers, allowing teachers to award stars to these students to alleviate the frustration of those who failed to answer. Conducting tests through voting can help assess students' mastery of knowledge. Teachers distribute stars to students based on their test performance, and the stars earned by students are aggregated into an interactive leaderboard. Skinner's reinforcement theory suggests that intermittent reinforcement (as opposed to continuous reinforcement) can lead to higher response rates and lower extinction rates. Therefore, teachers can implement rewards based on the interactive leaderboard on a weekly or monthly basis. The frequency and magnitude of rewards should be mutually corresponding to give students a sense of "leveling up" participation. It is worth noting that competition and incentive mechanisms jointly developed by students and teachers are more effective.

5.3 Silent Monitoring Strategies

The silent monitoring strategy is mainly used in the middle of the class. As shown in Figure 4, this strategy uses the monitoring and voting functions of the smart paper-and-pen system to monitor students' learning progress in real time. The system allows teachers to view students' answers in real time from the podium, such as their progress in answering questions. Additionally, the handwriting replay function helps teachers quickly identify students' errors and areas of weakness. The voting function includes both named and anonymous voting, anonymous voting encourages students to express their true thoughts, and the system's real-time data statistics enable teachers to accurately understand the learning situation.
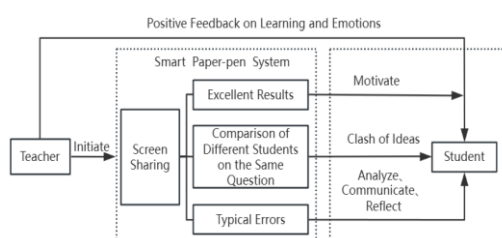

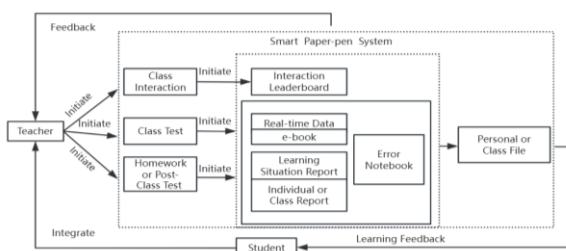Figure.5 Achievement Display Strategy Flowchart

Figure.6 Comprehensive Evaluation and Feedback Strategy Flowchar

5.4 Achievement Display Strategy

Achievement display strategy refers to the use of the same-screen display function of the Smart Paper-Pen System to carry out feedback, which is mainly used in the middle of the lesson. As shown in Figure 5, this strategy primarily encompasses three key components: firstly, showcasing students' outstanding achievements, such as assignments with high accuracy rates, neatly organized exams, and innovative projects; Secondly, collectively analyzing and correcting errors. For simple errors, encourage students to point them out and correct them among themselves; for complex errors, let students discuss and encourage them to use the system to replay the writing process and explain their problem-solving approach. Thirdly, display and compare different solution methods on the same screen. Through this approach, students can clearly see the similarities and differences between different solutions and provide feedback to each other as equals, fostering divergent and exploratory thinking.

5.5 The comprehensive evaluation and feedback strategy

The comprehensive evaluation and feedback strategy can be flexibly applied before, during and after class. As shown in Figure 6, the comprehensive evaluation and feedback strategy collects students' multi-dimensional learning data through the Smart Paper-pen System, and eventually converges to form digital learning files, realizing the effective combination of process evaluation and summative evaluation. Together with the diagnostic evaluation implemented with the help of dot-matrix pre-learning sheet Guided learning strategy, comprehensive evaluation and feedback can be realized.

6. Summary of the study

This study demonstrates the unique advantages of smart paper-pen system in instructional feedback through the deep integration of technology and education. It not only provides practical strategies for improving student engagement in middle school classrooms, but also offers frontline teachers an operational model for technology-integrated teaching, laying the theoretical foundation for future empirical studies or classroom trials.

Acknowledgements

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