Construction and Empirical Research of the Big Data-Based Precision Teaching Paradigm

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ABSTRACT

The rapid development of big data technology has attracted a variety of sectors, including tertiary education. The purpose of this paper is to construct a precision teaching mode based on big data technology in order to improve teaching quality and further promote education and teaching reform. The proposed mode, based on the theory of precision teaching in colleges and universities as well as the intrinsic properties of big data teaching activities, describes five procedures for analyzing learning situations, determining teaching goals, preparing teachers, and evaluating teachers. When the big data-based precision teaching mode is applied to the “Python Language Programming” course, the results show that students are more satisfied with the design of the teaching and more efficient in learning. It is believed that this mode will significantly improve students’ academic performance and their ability to work independently and collaboratively as a result of more frequently online and offline interactions between teachers and students.

KEYWORDS

Big Data, Blended Teaching Mode, Learning Situation Analysis, Offline Learning, Online Learning, Precision Teaching Evaluation, Precision Teaching Mode, Python Language Programming

INTRODUCTION

In 2017, the “13rd Five-Year Plan for the Development of National Education of China” highlighted that schools should utilize big data technology to collect, analyze, and provide feedback on teaching activities and student behavior to promote personalized learning and targeted teaching (The State Council, 2017). In June 2018, the National Conference on Undergraduate Education of Institutions of Higher Learning in the New Era highlighted the necessity of promoting public sharing of high-quality resources, changing the educational and teaching mode, and capturing the historical opportunities...
provided by information technology reform. Thus achieving “changing the track and overtaking” the quality of higher education (Ministry of Education, 2018).

In October 2019, the “Implementation Opinions on the Construction of First-class Undergraduate Courses” issued by the Ministry of Education in China stated that it is necessary to integrate modern information technology into teaching activities, resolve the challenges associated with innovation in teaching and learning modes, and eliminate stereotypes and formalization in the ubiquitous application of technology (Ministry of Education, 2019).

Since the corona virus disease 2019 (COVID-19) outbreak in 2020, online teaching activities have ensured that regular teaching activities continue to run smoothly during this period, as they remove the limitations of time and space (Liu & Zhang, 2020). There are, however, several disadvantages of online teaching, such as difficulties in supervision in the classroom, easy visual fatigue for students, inconvenient communication between teachers and students, and easy distraction of the students (Song & Xu, 2020). Later, blended learning, which combines online and offline teaching activities, became the mainstream teaching method. As a result, blended teaching has recently become widely adopted in two ways. The first type of teaching resource requires students to learn it independently, given that the students can learn independently. Consequently, offline teaching activities involve a lot of discussion in the classroom, resulting in an asymmetry in information between the teacher and the student. The second method relies on traditional classroom instruction with online resources utilized as supplementary materials for students to review after class and prepare lessons before class, thus making mixed teaching a mere formality.

As a result, our research examines how to acquire students’ learning performance data in time, adjust online and offline teaching designs, and implement accurate teaching. To fully exploit the advantages of new technology in teaching activities, this paper constructs a precision teaching paradigm and applies it in practice based on big data analysis of students’ learning behaviors.

BACKGROUND

Traditional Precision Teaching Modes

In the 1960s, Ogden Lindsley (1990) pioneered the precision teaching method based on Skinner’s behaviorist teaching methods (Skinner, 1968), which tracks and measures the student’s learning performance. The basic principles are as follows. Firstly, students’ learning performance is the only basis for teachers’ decision-making, in that, according to students’ learning performance, teachers adjust the formulation of teaching goals and plans promptly. Secondly, only the observable and measurable learning behavior data are recorded. Thirdly, an important indicator termed “fluency” is used to evaluate student learning performance on learning rate and accuracy. Lastly, Standard Celeration Charts (SCCs) (Kubina & Morrison, 2000) record behavior data and generate learning performance graphs.

Precision teaching aims to record and measure the learning behavior data of primary school students. Additionally, precision teaching goals serve as indicators for evaluating the effectiveness of a teaching method (Lindsley, 1992). Moreover, precision teaching exhibits compatibility with a wide variety of teaching strategies due to the accurate evaluation of students’ learning performance. In other words, it can evaluate any subject and teaching method (Zhu & Peng, 2016). Thus, precision teaching is also attracting the attention of the higher education sector. For example, Missouri Lincoln University’s psychology course (Beneke, 1991) and Georgia Institute of Technology’s physics course (Thomas, 1993) use precision teaching techniques to cultivate students’ basic learning skills. However, albeit precision teaching has a satisfactory teaching effect, it is still not widely used. It is difficult to manually collect and analyze student learning behavior data under traditional modes. Meanwhile, traditional teaching modes tend to record more data about learning results than learning processes, which lacks the interpretability we seek.
Blended Teaching Mode

Blended learning combines the advantages of traditional teaching with online learning (Hom & Staker, 2015). As a result, teachers can guide, enlighten, and monitor the teaching process and provide students with motivation, initiative, and creativity during the learning process (He, 2004). Compared to traditional teaching methods, blended teaching has the following three advantages. First, it can improve students’ autonomous learning ability. Various online teaching platforms provide students with abundant learning resources for independent learning. Second, it can break through temporal and spatial constraints. In particular, part of the teaching content is moved to the online teaching platform to overcome space limitations. Meanwhile, an online teaching platform is being used to extend classroom teaching activities outside of the classroom. Third, it is feasible to record the learning process throughout. Students’ traces on the study of teaching resources, completion of homework exercises, and communication with teachers and classmates are all recorded on the online teaching platform, allowing for accurate teaching (Wu et al., 2021).

Big Data-Based Precision Teaching Mode

Teaching big data includes learning and teaching process data (teaching resources, preclass performance, the interaction between teachers and students, homework, test results, etc.). Recently, big data technology has significantly facilitated the collection and analysis of data during the learning process due to the rapid advancement of “Internet + education” and information technology. Precision teaching is a new form of teaching that uses big data to overcome limitations associated with traditional teaching methods. Specifically, it is intended to assist teachers in accurate academic analysis, formulating precise teaching goals and content, and selecting suitable teaching activities and timely feedback for students. As a result, the teaching process and results can be reasonably quantified, monitored, and adjusted. Similar to the typical precision teaching mode, precision teaching based on big data follows four principles (Wang et al., 2018; Xing, 2020): (1) focus on observable learning behavior data; (2) use multiple indicators to measure learners’ learning performance; (3) use academic analysis tools; and (4) take learners’ performance as the only decision for adopted teaching activities. The distinction between typical precision teaching and that based on big data is only the technical means of data collection and analysis. The latter is more accurate and easier to implement. By utilizing big data technology, teachers are relieved of heavy workloads, such as data recording and visualization, and model construction and analysis are much faster and more accurate than manual means.

Data Analysis Technologies

Correlation analysis and t-tests are the methods we use to analyze data. Correlation analysis is a statistical method that measures the correlation between two or more random variables at the same level. The t-test, also named Student’s t-test, is a statistical test that compares the means of two samples. For example, we conducted a correlation analysis between final scores and the frequency of chapter learning, between final scores and classroom participation, and between final scores and homework grades. In the experiment, the t-test was used to compare the final scores between the control and experimental groups.

MAIN FOCUS OF THE ARTICLE

Construction of the Big Data-Based Precision Teaching Mode

According to the four principles of the precision teaching mode, implementing the precision teaching mode in colleges and universities can be divided into five steps (Zhao & Tian, 2022). First, big data technology is used to analyze learners’ characteristics and then formulate the goals of precision teaching. Secondly, big data storage and distribution technologies support many online...
teaching resources. Third, the student’s learning performances associated with teaching activities are supervised, collected, and visualized by corresponding big data technology. Fourth, the collected data are analyzed and charted by various graphics. Fifth, the resulting analyses are conducted to evaluate learning performance, determining the final teaching decisions. This paper is based on the theoretical basis of precision teaching, centered on learners, combined with properties of big data technology. The paper then designs the precision teaching paradigm based on big data, which includes five links (academic analysis, teaching goal design, teaching preparation, the design of teaching procedures, and precision teaching evaluation), as shown in Figure 1.

Learning Situation Analysis

The purpose of learners’ situation analysis is to examine learners’ learning preparation, learning style, and learning motivation before designing subsequent instruction (Wu & Li, 2006). To analyze learners’ situations, based on big data technology, researchers first identify the problem to be solved. To achieve expected results, it is necessary to determine the specific type of data required. In the following phases, data are collected in several perspectives (e.g., preschool ability tests, learning motivation questionnaires, and learning style questionnaires) with the consent of the students. Finally, big data technology is applied for deep analysis (Zhao, 2020). To boost the accuracy of learners’ situation analysis, teachers should collect multidimensional data (e.g., basic data, behavioral data) and implicit data (e.g., psychological data and physiological data) and make full use of academic data and
curriculum information to construct learner portraits and knowledge maps to provide a fundamental basis for accurate teaching design.

**Teaching Goals**

Teaching goals are threefold, that is, first, knowledge and skills; second, process and methods; and third, emotions and attitudes. First, we must consider the behavior data of learning performance, which can be visualized using a goal tree, as shown in Figure 2. The tree’s root node is the overall goal of achieving the knowledge and skills. The overall goal is subdivided into \( n \) subgoals, which should be completed by the students step-by-step. The subknowledge and subskills are realized by more specific practices to obtain better learning and teaching performances (Nazarenko & Khronusova, 2017). To facilitate the collection of learning data, teaching procedures and methods must be quantifiable and measurable, such as the attendance rate, the completion rate of preview tasks, the accuracy rate of classroom tests, correct rate of answers, etc. The establishment of the third goal runs through the entire curriculum system, for example, curriculum ideological and political teaching and the cultivation of independent learning ability.

**Teaching Preparation**

*Choice of Teaching Platform*

Various online teaching tools have emerged as the online and offline blended teaching mode asks for a new requirement on flexible learning place and time. At present, the mainstream online teaching tools include: “Rain Classroom”, developed by the Online Education Office of Tsinghua University; the “Easy to Divide” teaching platform; the “Super Star Learning” application, which is a knowledge dissemination and management sharing platform built by Superstar company; and the mobile app “Bluemo Cloud Class,” developed by Lanmo Technology. These software programs are convenient and powerful. Moreover, they can record the whole process of students’ learning and reflect the learning status of students through big data analysis, providing a solid basis for teachers to grasp timely situations and consequently take further measures (Liu & Xu, 2020).

*Preparation of Teaching Resources*

The teaching resources include related teaching courseware, videos, an examination database, etc. Firstly, teaching courseware is the main carrier for teachers to spread knowledge and for students to complete preparatory tasks. Therefore, the appropriate courseware for preclass self-learning should be further improved based on traditional multimedia teaching courseware. Additionally, the posted contents should be enriched in the courseware. To facilitate students’ self-learning, links should be added to the courseware that provides an extended reading of difficult information.

Meanwhile, the uploaded courseware should cover a reasonable amount of knowledge, with each knowledge point requiring its course. Secondly, instructional videos serve as supplementary

![Figure 2. The tree of teaching goals](image)
courseware materials and are the main resource for self-directed learning. To raise students’ attention to online self-study, all teaching contents need to be outlined by knowledge points and instructional videos. In addition, the duration of each video should not exceed 20 minutes to ensure the efficiency of student learning. Lastly, it is necessary to establish an examination database as the primary source for homework and class tests. Thus, teachers can check the assigned tests in the classroom to guide classroom interaction and the corresponding exercises directly assigned out of the examination database after class.

**Teachers’ Preparation**

The composing form of a teaching team is typically all course teachers, including an experienced teacher, and multiple assistant teachers, some of whom analyze teaching big data. At the beginning of the preparation stage, all teachers in the teaching team first need to be trained on platform operations until they can operate the teaching platform proficiently on computers and smartphones. Then, teachers collect and analyze preclass data to design teaching aims and methods. Finally, teachers need to redesign the traditional curriculum system and detail in a list of teaching calendars, online and offline content, and teaching methods.

**Students’ Preparation**

The investigation reveals that the smartphone ownership rate of the students who selected courses has reached 100%, while wireless fidelity (WiFi) has covered the campus throughout. Therefore, the requirement of online learning is satisfactory.

**The Design of Teaching Procedures**

As part of a precision teaching paradigm based on big data technology, teaching procedures are designed in three stages: before, during, and after the class. In detail, teachers arrange online preparatory tasks through the aforementioned teaching platforms (i.e., Rain Classroom, Super Star Learning, etc.) before class. The tasks based on rudimentary knowledge are conducted through diverse activities, including watching the courseware, completing preclass exercises, and participating in discussions. Then, the feedback from the online preparatory tasks provided by the platform is used to design classroom teaching activities. In class, important and difficult knowledge is stressed using different teaching methods (e.g., teacher-student interaction, group discussion, and case teaching) as offline teaching methods. Finally, after class, based on the assigned homework, students’ overall learning performances (e.g., preclass preview, interaction in class and homework, etc.) on the platform are collected and analyzed in a timely manner to gain a reflective summary.

The online self-learning of students is enforced to enrich behavioral data, which includes the performance of preclass previews, the duration of online learning, the time on the page, the number of platform logins, resource visits, discussion replies, the completeness of homework, etc. (Zhao et al., 2021).

**Precision Teaching Evaluation**

Traditional teaching evaluation of students’ learning activities is often limited to test results (Zhang et al., 2021), but precision teaching emphasizes accurate evaluation throughout the student’s learning process in a timely and dynamic manner via complex data analysis using online teaching platforms (Li & Wang, 2019). Specifically, the platform analyzes the performance data of each student (e.g., study habits, lecture exercises, etc.) and generates personalized data resources. Teachers and students can assess whether the teaching goals have been achieved and the knowledge or skills have been mastered. Based on student feedback, teachers can predict students’ future learning performance and provide targeted guidance and suggestions. In the classroom, interactive questions and answers can be conducted on teaching platforms, and the real-time performance of each student can be tracked. As a result, process evaluation can be effectively integrated into teaching and learning activities.
EXPERIMENT

In the second semester of the academic year 2020–2021, we implemented a precision teaching paradigm for the public course, Python Language Programming, for 239 sophomores (preventive medicine majors) enrolled in two arranging classes. Each arrangement class has four natural classes. In this section, we differentiate between classes that are arranged in the same classroom and classes that are natural classes, from an administrative perspective. In our study, we take one arranging class (1–4 natural classes) as the experimental group, with a total of 120 students, and the other (5–8 natural classes) as the control group, in which we implemented the traditional blended teaching mode, with a total of 119 students.

Preliminary Investigation

Various aspects are considered prior to the implementation of precision teaching, including the hardware environment, the mastery of basic computer knowledge, and the learning status of the learners. The investigation shows that all learners hold mobile phones or computers, and the campus is fully covered by WiFi, providing an adequate hardware environment for precision teaching. Before the course, we issued 239 questionnaires related to the two groups of students learning habits, learning motivation, and mastery of related knowledge and skills. There were 235 copies recovered. Firstly, the experimental and control groups had subjects in the same grade and major. In the experimental group, there were 61 boys and 59 girls, while in the control group, there were 60 boys and 59 girls. The ratio of male to female learners was approximately 1:1. Furthermore, the data analysis results on the basic computer knowledge test demonstrate that the experimental and control group have no significant difference in the mastery of basic computer knowledge ($t = 0.641$, $p = .522$), as shown in Table 1. Finally, in terms of learners’ learning status, which includes investigations on preclass preview, postclass review, attention maintenance, learning interest, etc., there is no significant difference between the two groups of students.

Implementation Process

The Design of Teaching Goals

For the experimental group, we draw the goal tree first and then determine the overall goal of the chapter content. After elaborating the goal, for example, in the “for” loop part of Python, we use the mind map to outline the overall knowledge framework and teaching goal, which entails the six applications of the “for” loop, as shown in Figure 3. The framework and goal can be refined to six subgoals, as shown in Figure 4.

For the control group, we only designed the chapter’s overall goal.

The Teaching Preparation

The experimental and the control group in this study had common teaching preparations. First, “Super Star Learning” was selected as the online teaching platform with the same online teaching resources. Then, teachers uploaded related courseware, exercises, and videos before the course. The courseware is based on chapters, while the videos are based on knowledge points. The duration of each video

| Subjects          | The experimental group (120) | The control group (119) |
|-------------------|------------------------------|-------------------------|
| Average           | 74.27                        | 73.37                   |
| $t$ value         |                              | 0.641                   |
| $p$ value         |                              | .522                    |
was controlled to less than 15 minutes. In the study, 66 related videos for this course were recorded, with a total duration of 14 hours and 27 minutes and an average duration of 13 minutes. Meanwhile, we also uploaded many exercises, which were convenient for teachers to conduct offline teaching activities, preview tasks, and homework assignments.

**Learners’ Self-Learning Before Class**

Teachers handed out preparatory tasks on the platform approximately a week in advance for the experimental group. The preparatory tasks are mainly based on students’ comprehensive online learning on videos and corresponding exercises. As shown in Figure 5, to ensure effective online self-learning, each video is set to several task points, and various anticheating methods are embedded, such as antidragging, antiwindow switching, and antidouble-speed viewing. In addition, teachers embedded a test at the end point of each video. If the test answer is wrong, the video needs to be watched again, which greatly improves the students’ attitude toward watching videos. For the control group, students should consciously complete the preview without teacher supervision.

**Offline Teaching in Classroom**

In the experimental group, teachers adjusted the offline teaching contents in time by evaluating students’ performances on the preview. As a result, the basic knowledge that all the students have mastered may not be taught in the classroom. For the subgoals that more than 80% of students had not achieved, teachers focused on corresponding teaching contents to help students understand
difficult knowledge in sequential executions (i.e., teachers’ lectures, exercises’ delivery, teachers’ guidance, achievement display, and the summary). For the subgoals that approximately 30%–80% of students fail to achieve, teachers should cultivate students’ collaborative learning ability in sequential executions (teachers’ guidance, group discussions, group reports, and teachers’ evaluations). For the knowledge that 30% or fewer students fail to understand, teachers strengthen students’ self-learning ability by two sequential methods (supplementary resources delivery and teachers’ counseling). For the control group, traditional offline teaching activities of “basic knowledge - key knowledge - difficult knowledge - summary teaching” are adopted by teachers.

**Knowledge Consolidation After Class**

For the experimental group, knowledge consolidation after class was mainly conducted in two ways: group discussion and homework exercises. During the group discussion activity, teachers proposed approximately five discussion topics. Each group grabbed topics through “quick response” action. First, the group leader establishes a discussion group in which teachers must participate. Then, the leader records the main discussion points and submits the final report. After the discussion, teachers evaluated the performance of each group and individual based on the report’s presentation and group members’ participation. One or two exercises for each subgoal were assigned as homework, and the students’ performances determined the achievement of the subgoals. A combination of online resources and individual tutoring should be pushed for students who failed to achieve the subgoals. For the control group, the teachers posted homework on the “Super Star Learning” platform without supervision.

**ANALYSIS OF RESULTS**

**Analysis of Overall Effects of the Precision Teaching Paradigm**

At the end of the course, 239 questionnaires were issued, and 234 valid questionnaires were returned, where 118 pieces were returned from the experimental group and, 116 pieces were returned from the control group to measure the implementation effects of the precision teaching paradigm in terms of the learning goals achievement, learning duration, teaching activity design, and ability improvement. From the perspective of learning duration, the average weekly learning time that students spend after class under the precision teaching mode is approximately 140 minutes, compared to 30 minutes in the traditional teaching mode. This phenomenon shows that students preferred autonomous and cooperative inquiry-based learning in the precision teaching mode, which is consistent with the goals of cultivating students’ comprehensive learning ability in emotion and attitude. In terms of participation in teaching activities, under the precision teaching mode, 90 classroom activities were released on the “Super Star Learning” platform, including quizzes, responders, and group discussions. Thirty-eight percent of students participated more than 60 times. Regarding the teaching effect, 85.6% of students believed that the precision teaching model could help achieve the learning goals and improve the efficiency of independent learning through strategies, including refining goals and directional push of corresponding exercises on the platform. A total of 72.0% of students could master basic knowledge through online learning before class, indicating that online learning, as the enrichment of classroom teaching activities, provides an effective way for students to learn knowledge resources with moderate difficulty. A total of 90.7% of the students thought that compared with the traditional teaching mode, the precision teaching mode had a more adequate preclass preview and diverse classroom teaching methods, such as inquiry learning, group discussions, and flipped classrooms, which activated the teaching atmosphere in the classroom and greatly improved students’ interest in learning. A total of 80.5% of the students argued that they like group discussion as a teaching method, which rendered them more guidance and target.
The Analysis of Study Effects

Furthermore, the final grades of these two arranging classes were compared to examine how the big data-based precision teaching mode differed from the traditional teaching mode.

The experimental group obtained an average score of 73.75, significantly higher than the 66.55 the control group achieved (see Table 2). There is a significant discrepancy between the two groups ($t = 3.85$, $p = .001$), which shows that the big data-based precision teaching mode can effectively improve students’ learning ability in the “Python Language Programming” course.

According to the discipline, completing all video/audio courses results in a full score of 100 points, and the scores of videos/audios are equally distributed. The average score of the experimental group was 85.84, whereas the average score of the control group was 11.0. In the experimental group, the average video viewing duration was 717.6 minutes with more than 100% ruminant ratio (rumination ratio = duration of viewing video/actual video duration). In this semester, the two arranging classes had 13 homework assignments. The job submission rate of the experimental group was more than 95%, with 85 the average score of the homework, while that of the control group is 56%, with 75 the average score. In the precision teaching mode, most students can complete the prestudy and homework tasks on their own, and they have a serious attitude toward online self-learning.

Statistical Product and Service Solutions (SPSSs) software was used to analyze students' learning behavior data to provide further insight into the relationship between different learning behaviors and final grades under two teaching modes (big data-based precision teaching mode and traditional teaching mode), as shown in Table 3. The analysis results demonstrate that the frequency of chapter learning has the highest correlation with the final grade ($r = 0.897$). Since the chapter learning activities include watching teaching videos and completing preparatory tasks, the aforementioned high correlation indicates that students’ performances in watching the teaching videos and completing preparatory tasks seriously, will help teachers achieve teaching objectives. In addition, the correlation

| Subjects                        | The experimental group (118) | The control group (116) |
|--------------------------------|-----------------------------|-------------------------|
| Average                        | 73.75                       | 66.55                   |
| $t$ value                      |                             | 3.85                    |
| $p$ value                      |                             | .001                    |
between students’ classroom participation and their final grades \( (r = 0.735) \) is ranked second. The explanation is that student’s participation in classroom activities reflects their learning attitude. A proactive learning attitude helps students perfect themselves in grasping important and difficult knowledge. The homework scores have the least relevance, which shows that a large part of the homework has plagiarism, and teachers need to strengthen homework management later.

Based on the results of questionnaire surveys and learning data analysis, the precision teaching mode can facilitate students’ independent learning ability and teachers’ teaching efficiency simultaneously, playing a positive role in improving academic performance.

**CONCLUSION**

The big data-based precision teaching paradigm improves students’ learning efficiency and quality by providing targeted teaching activities based on the student’s learning behavior data. The reflection on the implementation process and effects of the proposed teaching paradigm draws several conclusions: Firstly, teachers should have sufficient teaching capability to play multiple roles during the process of precision teaching. The precision teaching mode involves not only designers, organizers, and evaluators of teaching activities but also guides, listeners, and assistants. Teachers design corresponding activities according to refined goals by combining the classroom atmosphere with appropriate interactive methods. During group discussions, teachers should serve as guides and listeners for students to identify and assist those with learning difficulties and then serve as guides and listeners for those exhibiting discrepancies. Secondly, students should improve their ability to learn independently. The precision teaching paradigm has significantly improved the autonomous learning ability of students compared to the traditional teaching mode, but few students can effectively learn on their own without teacher supervision, while the majority of students continue to work on the same learning tasks under repeated teacher supervision.

This paper describes how teachers observed the precision teaching paradigm, including the design of teaching goals, classroom management, and the collection of online teaching resources. The experimental results show that this paradigm is worthy of further exploration and promotion. However, due to limited personal teaching ability, many problems remain. We will continue to assess the potential of this teaching paradigm in subsequent teaching processes.

**CONFLICT OF INTEREST**

The authors of this publication declare there is no conflict of interest.

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| The frequency of chapter learning | The students’ classroom participation | The homework |
|----------------------------------|--------------------------------------|--------------|
| Final grades                     | 0.897**                              | 0.735**      |
|                                  |                                      | 0.136**      |

Note: ** denotes a significant correlation at the 0.01 bilateral level.
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COMPETING INTERESTS STATEMENT

The authors declare that they have no competing financial interests.
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