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The Effectiveness of a Technological Pedagogical Content Knowledge Based Somatic, Auditory, Visual, Intellectual Learning Model in Developing Self Regulated Learning Among Pre-Service Elementary Teachers

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Abstract. Self-regulated learning is a crucial competency that pre-service elementary teachers must possess, particularly in the face of the challenges of education in the digital era. This study aims to: (1) analyse the level and development of students' self-regulated learning (SRL), and (2) test the effectiveness of somatic, auditory, visual, and intellectual learning models based on technological pedagogical content knowledge in improving SRL. This study used a quasi-experimental design with an unequal control group. The sample consisted of 143 students in the Biophysics course. Data were collected through pre- and post-tests and an SRL questionnaire, and then analysed using paired sample t-tests and n-gain tests. The results showed a significant increase in SRL scores in the experimental group (gain = 12.7; p = 0.002), while the control group showed no significant changes. Although there was no significant difference in the final learning outcome scores, the technological pedagogical content knowledge (TPACK)-based somatic, auditory, visual, intellectual (SAVI) learning model was proven to be effective in improving SRL components, particularly in the application of learning strategies and planning. This study recommends the use of the SAVI learning model based on TPACK in pre-service teacher education.
Keywords: SAVI, TPACK, Self-regulated learning, Pre-service Teacher

Introduction

The development era demands a change in the process of education, especially in preparing pre-service teachers who possess 21st-century competencies. Education in the era of society 5.0 demands the integration of cognitive skills, digital literacy, and critical thinking skills. The development of science and technology demands adaptation from various lines in an effort to prepare the competencies of a prospective teacher. The Elementary School Teacher Education Study Program, as part of the Institution that produces prospective teachers, has implemented various learning processes to equip students with 21st-century skills. Prospective teachers must be able to create learning plans that combine teaching strategies suitable for students with diverse backgrounds and learning styles (Smith, 2017; Smith & Gess-Newsome, 2004). Students are required to learn more independently and not depend on what is presented by teachers/lecturers.

Additionally, students must be able to complete lecture assignments that require effective time management to be achieved optimally (Deasyanti & Rangkuti, 2007).

One of the essential competencies that prospective teacher students must possess is self-regulated learning *(*SRL), which involves the ability to regulate the learning process independently. Covers the ability to set objectives, plan learning strategies, monitor implementation of learning, and reflect on achievement (Kong et al., 2024). Pre-service teachers who have high SRL tend to be more adaptive, resilient, and capable learners throughout life, which will transmit learning patterns positive to participants, educating them in the future. However, the results of the observation of Elementary School Teacher Education students at University Muria Kudus show that the majority of students (78%) experienced difficulty in the process of learning, especially in managing time, discipline, and choice of learning strategies. This has an impact on low involvement in learning, as well as a lack of quality results in learning. This can be seen in their self-regulation patterns in completing college assignments. They often resort to instant methods to complete these assignments, resulting in the information obtained during the learning process and assignments becoming less meaningful. This is because students lack the skills to learn (how to know). To learn, which includes an understanding of thinking skills, thinking processes, and motivation to achieve learning goals. This ability can be described as regulated learning or self-regulation skills in the learning process.

Self-regulated learning refers to learning that occurs primarily from thoughts, feelings, strategies, and behaviours generated by the learner themselves, aimed at achieving goals. In addition, self-regulated learning can be equated with self-control, self-discipline, and self-direction. Self-regulated, self-directed learning refers to the careful planning and monitoring of the cognitive and affective processes involved in completing academic tasks. According to (Sholihah & Firdaus, 2023) Self-regulated learning is an active process where students play the leading role in mastering their learning process*.* Regulated learning is essential for students in learning activities, enabling them to organise and direct themselves, adapt, and control their own learning, especially when facing challenging tasks (Harahap, 2020). The biophysics course is a 3-credit course that covers materials related to physics, biology, and a bit of chemistry. Given the density of the material studied, students should be able to apply independent learning effectively. Students must be able to plan their learning activities well, be able to control time so that the study schedule is regular, students know how to create a good and enjoyable learning environment, students are disciplined in learning, students also learn how to make a plan to achieve goals, can utilize existing facilities, and do not delay in doing assignments (procrastination). Firman & Rahayu, (2020) added that online lectures are also able to foster student independence in learning, such as searching for information about lecture materials and assignments given to them. There are three elements of SRL, namely: (a) self-regulation, including determining goals and selecting learning resources, (b) regulation of the learning process, including the use of metacognitive knowledge and independent learning abilities, and (c) regulation of the process model, including selecting cognitive strategies.

Since science is frequently used in technology contexts, a strategy that offers students alternatives is required to prepare them for the problems of the twenty-first century (Tihasanah et al., 2025). Teaching strategies should ideally be created to actively engage students in the learning process, promoting curiosity, inventiveness, and a readiness to question preconceived notions (Susanti et al., 2024). This research presents a new approach by combining the strengths of the somatic, auditory, visual, intellectual (SAVI) model, which emphasizes somatic, auditory, visual, and intellectual engagement, with the technological pedagogical content knowledge (TPACK) framework, which ensures alignment between technology, pedagogy, and content. This approach is expected not only to improve students' self-regulation skills in planning, monitoring, and evaluating the

learning process, but also to make the learning experience more contextual, active, and meaningful, in accordance with the complex nature of biophysics material. Critical thinking abilities are crucial for biophysics education since the subject matter includes theories about the environment and natural phenomena, which helps students better connect what they study to their everyday lives (Putra et al., 2025).

Habitual learning to develop self-regulated learning needs to be conducted using effective and efficient methods so that the process of knowledge transfer can proceed as it should. With media as an object that can be manipulated, seen, heard, read, or spoken, and used effectively in teaching and learning activities, tools can influence the effectiveness of pedagogical programs (Ainni, 2023). To address this challenge, a learning model is needed that can foster students' SRL. According to (Zulfahmi & Roza, 2024) the SAVI learning model is one such model. An approach that emphasises involvement in learning, namely with the combined aspects of somatic, auditory, visual, and intellectual. Integration of the SAVI model with the TPACK framework that combines pedagogy, content, and technology can provide a deeper learning experience, Relevant and contextual. SAVI refers to learning through physical action, listening, seeing, and thinking. According to Ulpiah et al. (2024), SAVI learning encourages students to actively engage in the learning process through activities such as experiments, observations, and presentations of the material they have learned. Furthermore, students are expected to be able to solve problems by applying the knowledge or skills they have acquired during Learning (Apsoh et al., 2023).

The SAVI learning model is a learning model that combines physical movement with mental activity and the use of all senses, which significantly impacts learning. This model involves all senses, learning by actively moving, utilising all senses as much as possible, and involving the whole body and mind in the learning process (Ainni, 2023; Anas & Syafitri, 2019; Apsoh et al., 2023; Ghufroni & Dewi, 2019; Hasmi & Retti, 2022; Lestari & Suryani, 2022; Salingkat & Nihayah, 2022). The application of SAVI asks students to identify and analyse problems both individually and in groups, thus encouraging students to find their own solutions. The lecturer only acts as a facilitator in the learning process. Furthermore, the learning process also accommodates the application of technology to fulfil the need for 21st-century skills. TPACK is a learning process that utilises a combined application that prioritises technology and specific applications (content) in learning (Astari et al., 2023). TPACK is built from content knowledge, pedagogical knowledge, and technological knowledge (Chai et al., 2019). By implementing the SAVI based on TPACK, it is expected to be able to develop self-awareness abilities and regulated learning. Laskey & Hetzel, (2010)states that learners with a high level of SRL have learning strategies and consider success and failure as part of the learning process. SRL has several components, namely cognitive, affective, motivational, and adjustment of actions in achieving the desired learning outcomes (Beishuizen, 2011). There are three indicators for measuring SRL for prospective elementary school teachers, including the planning phase (setting goals, planning strategies, assessing self-efficacy, selecting learning strategies and methods, the implementation phase (focusing attention, avoiding distractions, self-instruction, self-monitoring), and the self-reflection phase (comparing the results of self-reflection with the learning objectives that have been set) (Sulisworo et al., 2020).

The novelty of this research lies in the integration of the SAVI learning model with the TPACK framework to develop SRL in PGSD students for the Biophysics course. This approach differs from previous research because it combines multisensory learning with the use of 21st-century technology, thereby not only improving mastery of the material but also student learning independence. Through this strategy, students are encouraged to be more disciplined, skilled at time management, choose the right learning strategies, and engage in continuous self-reflection. This study aims to analyse how self-regulation in learning in students and to determine the effectiveness of the SAVI learning model based

on TPACK to develop SRL for prospective elementary school teachers, especially in the context of biophysics learning, which is known to be complex and dense in material.

Methods

This research uses a quantitative approach (Creswell & Creswell, 2018) with a quasi-experimental design and a non-equivalent control group (Shadish et al., 2002). The subjects were students of the Elementary School Teacher Education Study Program who took the Biophysics course in the even semester of the 2024/2025 academic year. This research uses purposive sampling techniques (Fraenkel et al., 2019) because the sample selection is done intentionally based on specific considerations. The sample consists of four classes: one control class (D) and three experimental classes (E, F, G), with a total of 143 students. The selection was based on the equality of initial characteristics, a relatively balanced number of students, and its relevance to research objectives. The purposive sampling technique is considered appropriate for quasi-experimental research designs because the researcher cannot randomly assign individuals to groups but rather uses existing classes. This approach allows researchers to evaluate the effectiveness of interventions by comparing changes that occur within these groups over time (Könen & Karbach, 2021).

The research steps included an initial study of the preparation stage related to the characteristics of prospective elementary school teachers/instructors, and a description of self-regulation in students taking the Biophysics course in the 2024/2025 academic year. The researchers developed learning tools that integrate the SAVI and TPACK models, as well as developing SRL questionnaires and learning outcome test instruments. Validation was carried out by material and methodology experts (Taherdoost, 2018). The implementation stage of the research included validating the learning tool questionnaire and implementing the model. The next stage was implementing the SAVI learning model based on TPACK. The experimental group received treatment in the form of learning with the SAVI-TPACK model for four meetings. Activities included creating digital comics, video presentations, online simulations, and utilizing the *Sunan (Sinau Temenanan)* learning management system (LMS) platform. The control group used conventional lecture and discussion methods. In the final stage, analysis and evaluation were carried out at the implementation stage.

Data collection techniques were carried out using several methods. First, learning outcome tests in the form of pretest and posttest were used to measure students' learning achievement before and after treatment in the control and experimental classes. Second, an SRL questionnaire developed by the researcher was used to measure students' self-regulation abilities, which include three main phases: planning, implementation, and self-reflection. In addition, expert validation was conducted on the learning materials, the SRL questionnaire, and the learning outcome test instruments by content validity of the research instruments. The validity of the instruments was assessed through expert evaluation of material substance, learning design, visual communication display, and software utilization (Suhadah & Mufit, 2023). Furthermore, a questionnaire was employed to gather supporting data regarding student activity and motivation, along with an observation checklist to assess psychomotor aspects of student engagement. Data was collected through pretest and posttest, as well as the distribution of SRL questionnaires after the implementation of the learning model.

The data obtained were analysed using a quantitative statistical approach with the help of SPSS software. The data analysis techniques used included the paired sample t-test to determine the significant difference in student learning outcomes before and after treatment was given in each group. Calculating the N-gain to determine the improvement in student learning outcomes from pretest to posttest in each group and using an

independent samples t-test to compare learning outcomes between the experimental and control groups after the treatment. This analysis aims to evaluate the influence of implementing the TPACK-based SAVI learning model on student learning outcomes and self-regulation skills.

Results and Discussion

This section serves as a results findings study related to the effectiveness of the SAVI learning model based on TPACK in increasing student SRL among prospective school teachers. The results were analysed based on two main focuses, namely improvement of SRL capabilities and achievement results of students studying biophysics. Analysis done through comparison of pre-test and post-test scores on the SRL questionnaire, as well as measurement results learn from the values at the end of the course. In addition, it is carried out in a more detailed way against SRL indicators to know which components are experiencing the most significant improvement. Discussion focused on the comparison between the group experiments that receive the intervention SAVI-TPACK model and the control group that receives learning conventional.

This study shows that there is a significant difference between group experiments and controls in terms of improvement in abilities. The average SRL score of students was analysed before and after treatment using a paired sample t-test. Complete results are presented in Table 1.

Table 1. Comparison of average scores of self-regulated learning

Group	Average score pre-test	Average score pre-test	Gain	Significance value (p-value)	Information
Experiment	68.5	81.2	+12.7	0.002	Significant
Control	69.1	71.5	+2.4	0.415	Not significant

Data shows that, as presented in Table 1, the group experiment experience, the average increase in SRL scores from 68.5 to 81.2, representing an improvement of 12.7. Paired-reference statistical test, sample t-test confirms that this increase is very significant statistically ($p = 0.002$), far below the threshold alpha limit of 0.05. On the other hand, in the group control that follows learning conventionally, although there is A little increase in score from 69.1 to 71.5 with an improvement of 2.4, this change is not statistically significant ($p = 0.415$). This result is statistically significant, showing that the treatment given is the main factor in improving the ability of regulations in a group experiment. The results imply that multisensory and technology-based learning can overcome the limitations of conventional methods. While students in the control group still tended to be passive, the experimental group showed greater involvement in planning, implementation, and self-evaluation. Thus, the TPACK-based SAVI model is not only effective in improving self-directed learning perception but also strengthens self-regulation ability as a core metacognitive competency needed by prospective teachers.

To measure the self-regulated variable and to comprehensively assess the SRL approach, this study used a questionnaire instrument developed based on Zimmerman's (2002) three-phase theoretical framework. This questionnaire was designed to measure students' perceptions and behaviours related to their learning process before, during, and after learning activities. Students provided answers on a Likert scale of 1 to 5 (1 = Very Disagreeable, 5 = Very Appropriate). The following is the analysis of the increase in SRL scores per indicator in Table 2. The results are shown in Table 2

Table 2. Recapitulation of SRL score improvement per indicator

SRL phase	Measured indicators	Average pre-test score	Average post-test score	Gain
Planning	1) Goal setting	3.45	4.10	+0.65
	2) Strategic planning	3.20	4.25	+1.05
Performance	3) Use of learning strategies	3.15	4.30	+1.15
	4) Self-monitoring	3.40	4.15	+0.75
Self-reflection	5) Self-evaluation	3.35	3.95	+0.60
	6) Adaptive reaction	3.30	4.05	+0.75

In measuring self-regulated learning, student self-regulated learning is calculated using a questionnaire instrument. This instrument is divided into three main parts according to the self-regulation phase, which includes: 1) Planning Phase, 2) Performance *Phase, and* 3) Self-*Reflection Phase*.

The highest increase occurred in students' ability to apply various learning strategies actively. A score increase of 1.15 occurred, and this was not by chance, but rather a direct result of the learning design that demands multi-sensory engagement and the use of technology using TPACK-based SAVI learning. The jump in scores from 3.15 to 4.30 indicates that students shifted from passive learners (reading and memorizing) to active learners who consciously choose and use various techniques to process information. Students not only read texts, but also visualise data, collaborate online, and present information creatively. This directly trains and accustoms them to using various strategies in the learning process (Azizah & Nasrudin, 2021; Guo, 2022; Lim et al., 2023; Otero Trujillo & Solano Peláez, 2024; Van Alten et al., 2020).

Activities carried out by students with the SAVI learning framework based on TPACK can be exemplified as follows: in the somatic & visual aspect, instead of just reading about the water cycle, students are assigned in groups to create digital comics using applications such as canva (TPACK). This process forces them to use visualization strategies, summarize, and organize information creatively. In the auditory & TPACK aspect: to understand the concept, students are asked to create a short explanatory video on the digestive system material using their mobile phones. This activity trains them to use elaboration strategies, where they have to re-explain the concept in their own words so that others can understand it. This is in line with research from (Khasawneh, 2024), which shows that learning that integrates various modalities (multi-sensory) with the support of technology significantly diversifies student learning strategies, which ultimately increases student engagement and self-regulation.

The next indicator that saw an increase was strategic planning. An increase of 1.05 from 3.20 to 4.25 indicates that students have become more skilled at analysing assignments, breaking them down into manageable chunks, and planning their workflows both individually and in groups. This activity can be seen in the final project assigned to create a digital comic (concept of the human digestive system) using the Canva application, which was then uploaded to a website they developed with Google Sites. This assignment cannot be done impulsively and suddenly. Students are forced to do strategic planning: (1) Research content, (2) Create a media flow storyboard, (3) Choose the platform or tools (TPACK) to be used, such as Google Sites, (4) Divide the tasks within the group, and (5) Set internal group deadlines. Project-based Technology-enriched Learning can effectively foster strategic planning skills in prospective teachers. The process of designing, implementing, and evaluating a project forces students to think systematically and

proactively, which is the essence of strategic planning in SRL (Carella & Colombo, 2024; Liang & Luo, 2024; Azizah et al., 2021; Zimmerman, 2002).

Further improvement occurred in the reflection and self-monitoring phase. Indicators in the self-reflection phase, such as self-evaluation, showed a more moderate increase of 0.60 from 3.35 to 3.95, indicating that students can objectively and critically evaluate their own work results. These abilities are advanced metacognitive skills that often take longer to mature. Meanwhile, the goal setting indicator saw an increase of 0.65 from 3.45 to 4.10, although this increase is likely due to being more influenced by students' intrinsic motivation. This model facilitates the achievement of goals, but the drive to set goals still comes from within the students (Rubenstein et al., 2018). Essentially, students are beginning to develop metacognitive awareness, but these skills are more complex and therefore require more time to mature and develop. Metacognitive maturation is a dynamic process of interaction between three main factors: (1) effective teaching strategies, (2) a supportive learning environment, and (3) active student participation. This finding aligns with the idea that the complexity of metacognitive skills requires sufficient time and the right climate for their full development (McCormick et al., 2012; Sitasi: Callan, 2020).

In the self-monitoring & evaluation indicator, after the group presentation, the lecturer implemented a peer feedback session using Google Forms. Students are asked to assess other groups' presentations based on a clear rubric. This process indirectly trains them to use the same rubric to evaluate their own performance. Based on the feedback received, each group is required to create a reflection paragraph and upload it to LMS. *Sunan's* learning system explains what they would improve if they had to do a similar task in the future. Reflective skills and self-evaluation are components of advanced SRL. While active interventions can quickly increase strategy use, the ability to reflect deeply on the learning process often requires more sustained exposure and practice throughout the semester (Carella & Colombo, 2024; Panadero, 2017; Zimmerman, 2002).

Overall, the data indicate that SAVI-based TPACK learning has a real impact on improving students' SRL, particularly in the use of active learning strategies and strategic planning. However, the improvement in self-reflection aspects is still moderate, requiring long-term and sustainable intervention. In addition to measuring SRL improvement, this study also evaluated the intervention's impact on learning outcomes. Students' final grades in the Biophysics course were analysed using an independent sample t-test.

Table 3. Comparison of statistical data description of learning outcomes

Data description	Control group (Grade D)	Experimental group (Class E, F, G)
Number of students (n)	29	114
Average value (Mean)	79.80	81.04
Standard deviation (Std. Dev)	6.78	5.92
Minimum value	66.76	56.01
Maximum value	89.16	89.03
Median	81.88	81.63

As presented in Table 3, the mean score of the experimental group (81.04) was slightly higher than that of the control group (79.80). However, the statistical test results showed that the difference was not significant ($p = 0.284$). This means that improving SRL does not have a direct impact on academic outcomes in the short term. Improvement is

significant in SRL aspects, showing that model TPACK-based SAVI learning is successful create learning experiences active, structured, and reflective learning experiences. The SAVI strategy allows students to be involved in a somatic way, absorbing information in a visual and auditory way, as well as honing their critical thinking in an intellectual way. Integration with technology (TPACK) strengthens this process through various learning media such as videos, infographics, digital comics, and quizzes. Online learning. Learning activities such as creating digital comics, group video presentations, and self-reflection using online rubrics help students set goals, design strategies, and independently reflect on their learning performance. Furthermore, the use of digital learning platforms like Sunan LMS and Google Sites expands student access to content, collaboration, and evaluation.

The SAVI model, with its four pillars, inherently requires students to practice the self-regulation cycle described by Zimmerman (2002) and Panadero (2017).

a. Somatic aspect (learning by moving and doing) encourages students to be directly involved in experiments, which requires them to plan and self-monitor.
b. Auditory aspects (learning by speaking and listening) through discussions and presentations, train students in the articulation of thoughts and evaluation of arguments, a form of self-reflection.
c. Visual aspect (learning by observing), which is strengthened by TPACK-based media, helps students organize information and build mental models, which are the core of effective learning strategies.
d. Intellectual aspect (learning by solving problems) directly challenges students to apply knowledge, evaluate strategies, and adapt—all at the heart of SRL.

TPACK integration, in line with the findings of (Rahmadi et al., 2020a) functions as an accelerator that speeds up the process of students' internalizing learning skills. Technology serves as an intermediary that enables students to independently search for, evaluate, and utilize various relevant learning resources. Through the utilization of digital platforms, students also have the opportunity to collaborate online, discuss ideas, and manage projects in a more structured and efficient manner. This technology-rich learning environment provides students with appropriate stimulation to practice self-regulation skills, from planning and monitoring to reflecting on the learning strategies employed. The use of the SAVI-TPACK model not only strengthens theoretical understanding of concepts but also bridges the gap between theory and practice in the context of real-world learning.

Overall, this per-indicator analysis confirms that the implementation of the SAVI-TPACK model is highly effective in shaping students who not only know what to learn but also understand how to learn in a structured, strategic, and reflective manner. This is important because structured and independent learning skills are the main assets for prospective teacher students to face the challenges of 21st-century learning, which demands independence, collaboration, and critical thinking abilities.

The results of data analysis, paired-sample t-test, and N-gain calculations show that significant improvements in SRL were not followed by significant increases in final grades. This indicates that SRL is a high-level metacognitive competency. Mastering SRL skills does not necessarily translate into higher grades immediately. The process of internalizing and automating SRL strategies requires time and sustained cognitive effort. Students may already know what to do, but are not yet proficient enough to perform them efficiently without sacrificing cognitive resources that should be used to understand the material itself. This requires continuous practice until the strategy becomes an automatic habit (Panadero, 2017; Zimmerman, 2002; Zimmerman & Martinez-Pons, 1990). Four sessions are sufficient to build an initial foundation, but are likely insufficient to produce significant improvements in academic achievement. While SRL interventions are generally effective, longer and more intensive programs are needed to see a substantive impact on academic outcomes. Short-term interventions are excellent for increasing metacognitive awareness, but to achieve real changes in performance, students need more opportunities to apply, reflect on, and

refine their strategies in repeated, authentic task (Papanikolaou et al., 2022; Rahmadi et al., 2020b; Sulisworo et al., 2020) .

The introduction of a completely new, activity-rich learning model like SAVI-TPACK can create additional cognitive load on students. Students must not only process course content (intrinsic load) but also learn how the new learning model works (extrinsic load). Their cognitive energy is divided, so the model's full potential for enhancing content comprehension may be temporarily overshadowed by the adaptation load (Brockbank, 2025; Thai et al., 2020). It is likely that if this research were to continue, once students become fully accustomed to the SAVI-TPACK model, extrinsic cognitive load would decrease, and a significant positive impact on final grades would begin to emerge (Fidan, 2023; Karataş & Ataç, 2025; Martin et al., 2020; Mourlam et al., 2021).

Thus, the lack of statistical significance in learning outcomes is not an indication of model failure, but rather a reflection of the reality of the complexity of the learning process. This emphasises that the goal of education is not merely to achieve numbers (grades), but also to develop process competencies (such as SRL) that will benefit students in the long term, long after the course is completed. However, the lack of significant learning outcomes indicates that the effect of SRL on academic achievement requires time and consistent implementation. As Zimmerman (2002) points out, SRL is a metacognitive skill that develops gradually through repeated and reflective practice. Therefore, learning that emphasises SRL is better implemented sustainably. This finding also supports the opinion of Panadero (2017) that SRL's success lies in the process, not only the results. In the context of education, prospective teachers building SRL is an investment for the long term to produce independent, innovative, and reflective educators.

Conclusion

Based on the research results, data analysis and discussion, it can be concluded that there is an indication of a positive influence from the implementation of the SAVI learning model based on TPACK, which is indicated by the higher average final score of the experimental group (81.04) compared to the control group (79.80) and based on the hypothesis test (independent samples t-test), the difference in learning outcomes between the two groups is not statistically significant ($p = 0.284$). This study concludes that the SAVI-TPACK model has the potential as an effective learning method, but further research is needed with a longer intervention duration, stricter control of moderator variables, or a larger sample to prove its impact definitively and statistically significantly.

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