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Research Article

Competency Level of Teachers' Subject Matter Knowledge as a Compulsory for Teaching Secondary School Mathematics: A Case Study on Postgraduate Diploma Trainee

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The purpose of this paper is to assess the status of mathematics subject matter knowledge competency of student teachers and show the role of subject matter knowledge in teaching secondary school mathematics. This study involved 70 student teachers attending postgraduate diploma training program of teacher training modality. An achievement test was used to collect the data from the participant. The result has shown that the overall subject matter knowledge competency of the trainee is remarkably low. However, algebra received relatively higher competency with a mean score of 2.2, and mathematics as communication and reasoning competency was considerably lower with a mean score of 0.56. In addition to these, a comparison among subject matter knowledge competency areas identified shows that there is a significant difference between algebra (higher competency) and the remaining 12 selected subject matter knowledge competency areas. This study concluded that student teachers have a deficiency in mathematics subject matter knowledge competency in general and lack uniformity within selected mathematics subject matter knowledge competency areas. Based on the findings, it is recommended that subject matter knowledge is particularly required for secondary school mathematics teaching needed in the teacher training program and the teacher training program needs amendment toward the direct purpose.

1. Introduction

The mathematics content that forms the basis for determining subject matter competence is defined as a set of subject matter requirements (SMRs) concerning mathematics that beginning teachers are expected to know. Subject matter content knowledge (SMCK) is the amount and organization of knowledge intrinsically in the mind of a teacher. The teacher's subject matter content knowledge should not be limited to knowledge of facts and procedures but should also include an understanding of both the substantive and syntactic structures of the subject matter. The substantive structures are the various ways in which the basic concepts and principles of the discipline are organized to incorporate its facts. Teachers will, therefore, be able to use appropriate materials to teach mathematics well only when they comprehend the network of fundamental concepts and principles of the subject matter at stake [1, 2, p. 4].

Here, in this study, context competencies are broad areas of content knowledge of secondary school mathematics needed for student teachers during the training program. The need for subject matter knowledge (SMK) for teaching mathematics at secondary school is not taken as optional rather it is mandatory. In circumstances where teachers' subject matter content knowledge is profound and well established, teachers tend to teach the mathematics content much better and show confidence [3].

Moreover, understanding mathematics for teaching demands a kind of depth and detailed knowledge that goes well beyond what needs to carry out the algorithm reliably to include considerations in choosing good examples for instructional purposes [4]. According to Ball et al. [5] content knowledge needed for teaching has three dimensions. They are common content knowledge like knowledge of the square of binomial $(x+y)^2 = x^2 + 2xy + y^2$ in secondary school teaching algebra. The second is specialized content knowledge, which may include knowledge of identifying students' errors in particular content in mathematics, and horizon content knowledge, which can require a teacher to understand the role of students' prior knowledge, like knowledge of factoring in the problem associated with expanding squares of the binomial [5].

Furthermore, mathematics teachers acquired from their preservice training with high SMK provide more learning situations and develop a good attitude toward teaching and learning mathematics compared to teachers with low subject matter knowledge. In line with this, studies indicated that a mathematics teacher with low subject matter knowledge is regarded as the main source of misconceptions and misunderstandings in the learning of mathematics [6]. Subject matter knowledge is also associated with attitudes and interest in teaching. Teachers with high SMK have good attitude and interest to teach than teachers having low SMK [6]. SMK may also greatly influences students' achievement and more importantly, having low SMK led to low mathematics teaching competency [7–10].

Teacher training systems or modalities affect student teachers to have higher or lower SMK in particular subject areas. In particular, the student teachers in this study are the product of the Post Graduate Diploma in Teaching (PGDT) modality. This teacher training modality implemented in some selected universities in Ethiopia since 2011 according to the Ministry of Education (MoE) of Ethiopia just following the TESO (Teacher Education System Overhaul) [11–13].

It is suggested that TESO modality lack in balancing SMK and pedagogical content knowledge (PCK) programs provided more emphasis for PCK. Graduates in this modality have shown a deficiency in SMK and this greatly affected the quality of teaching in secondary schools in Ethiopia [11–13]. Observed in many universities conducting training in the TESO modality, the trainee engagement with SMK courses was minimal [14]. The program involved more than 25 credit hours of practicum programs during these periods, for the trainee off-campus in different semesters. While they are off-campus, other registered face-to-face mathematics SMK courses were uncovered properly [14]. Teachers requested to deliver mathematics SMK courses in superblock format. It may be required to cover in 1 week after return from practice. It led the trainee to acquire shallow knowledge in the SMK courses in addition to the shortage of SMK courses in the program [14].

The new program PGDT invites students who graduate in science or art fields in their first degree, mainly for industries, not generic students, and the program problem started here. PGDT program focused to prepare teachers for secondary school teaching in Ethiopia is believed to fill the gap noticed. With some additional selection criteria, BSc or BA graduates were admitted to join the program in regular or in-service training during the summer in Ethiopia. The training took 1 year time for the regular program and two summer seasons for in-service modalities. According to the training document prepared in 2009 by the Ethiopian Ministry of Education, the PGDT program mainly invites students who graduated from universities with BSc/BA degrees in nonteaching streams [11–13].

In the implementation of the PGDT program, many problems come visible in many ways. The problem arises from the program structure, program admission, and curriculum. When evaluated in a particular department as well as at the program level, its effectiveness is far below the expected standard set in the program at the ministry level. Graduates from this program lack basic skills for teaching secondary school to different criteria set by the Ministry of Education [15, 16]. It also identified that PGDT program graduates are more inclined to work with pure science degrees, and they need to train in the PGDT program just to get job access and use it to look at other jobs. As a result, their effectiveness is seen low in terms of motivation as well as social expectations [16, 17]. BSc/BA program curriculum is not well designed to prepare them for secondary school teaching directly; rather, it is well designed to prepare them for the industry [16]. As a result, according to Abie [16], such student teachers are not attentive or not interested to be a teacher. Researchers such as Stacey [18] and Watson [19] recommended that during the teacher training program, student teachers need to acquire and develop a deep understanding of the core of secondary school mathematics, including the important procedures, algorithms, and others used for direct teaching purposes. On the other hand, it is suggested that university mathematics courses should illuminate high school mathematics by providing an advanced perspective on it [18, 19].

Regarding the association of SMK and teacher training programs, much of the research has indicated that there is a strong positive correlation between teacher training of SMK and classroom practice and performance. This result is the same for PCK [20, 21]. This indicates that the balance between SCK and PCK provides better teaching performance. In line with this, there are views that indicates that much SMK is better than PCK. Teachers can not only get SMK from preservice training but also find it from various sources. Therefore, there is a research gap on the kind and amount of SMK required for teaching secondary school mathematics which addresses strong concluding remarks [22].

Here, by PCK, we mean knowledge concerned with how to integrate content and pedagogy effectively. Furthermore, it includes knowing what approaches fit the content and how elements of the content are arranged for better teaching. The PCK also includes knowledge of teaching strategies that incorporate an appropriate conceptual representation that helps to address learner difficulties and misconceptions and foster meaningful understanding; knowledge of what students bring to the learning situation; knowledge that might be either facilitative or dysfunctional for the particular learning task at hand. It combines the most regularly taught topics, the most useful forms of representation of those ideas, and the most powerful analogies, examples, illustrations, explanations, and demonstrations of the art of teaching mathematics [1, 2, p. 4].

Pedagogical content knowledge also includes ways of representing and formulating the subject matter that makes it comprehensible to students with diverse views and understandings. In teaching mathematics with an activity-oriented base and problem-solving techniques, teachers need to design and present the lesson using appropriate teaching–learning materials that can enable the students to construct their knowledge of the concept [2, p. 4].

They need to know the pedagogical strategies and techniques most appropriate for reorganizing the understanding of learners who might appear before them as blank slates. Pedagogical content knowledge also includes generic knowledge about how students learn, teaching approaches, methods of assessment, and knowledge of different theories about learning [23].

Specific to mathematics, Lannin et al. [24] categorized PCK's subscales for teaching mathematics as teachers' knowledge of the curriculum for mathematics, knowledge of assessment for mathematics, knowledge of instructional strategies for mathematics, and knowledge of student understanding within mathematics. In contrast to this, it also indicated that PCK might include knowledge of discourse, curricular thinking, anticipatory thinking, and implementation thinking [25]. It is not always consistent about the effectiveness of teaching relative to subject matter knowledge. Different researches indicate that teachers with sufficient knowledge about the subject are more effective in teaching compared to teachers with low-level knowledge of the subject matter. However, according to the research results of Lee et al. [26], there is no relation between teachers' subject matter knowledge and their teaching practices. That means teachers with high knowledge of the subject matter may be low performing in teaching, and teachers with a low level of knowledge of the subject matter may show higher effectiveness in teaching.

Still, some researchers such as Yang et al. [27] and Abie [16] have found problems with the type and level of SMK acquired by preservice teachers. In mathematics, preservice student teachers usually get SMK, which is more focused on procedures and rules than conceptual knowledge, and their reasoning skills may be weak. Lacking such a deep understanding of the fundamental aspects of the SMK can affect good teaching at secondary school [28]. Research suggests that changes in teachers' SMK preparation may need, but the ultimate solution is more complicated than simply providing more subject matter courses [22].

Several other research studies such as Ochieng et al. [29] have also indicated that there is a strong positive correlation between teacher training of SMK and classroom practice and performance. This result is same for PCK [29]. This indicates that the balance between SCK and PCK provides better teaching performance. On the other hand, there are views indicating much SMK is better than PCK. Teachers not only get SMK from preservice training but also find it from varying sources. Therefore, there is a research gap on the kind and amount of SMK required for teaching secondary school mathematics to address strong concluding remarks [22]. In their review work, Wilson et al. [22] asserted the need for conducting further studies on the influence of prospective teacher SMK preparation on their effectiveness in teaching. Many results have indicated their look on it, but it relied on the knowledge related to course work. Existing research work is limited as well as they deliver contradictory output. Many of them emphasized the need for as many studies in different contexts and programs to narrow the gap existing in the literature. In addition to these, the existing study's conclusions are provocative in many aspects because they undermine the certainty expressed about the strong link between teacher preparation related to SMK at the teacher training institute and teacher quality.

Therefore, in different fields, graduates from this program are not effective for teaching secondary school mathematics [16]. Due to this, the quality of teaching at secondary schools in Ethiopia remains unchanged. PGDT has not properly addressed the gap noted by TESO and others not sure how much SMK is needed for preservice teachers to qualify for secondary school teaching. Therefore, this study is to show the level of mathematics SMK competency in student teachers in the PGDT program modality and the role of SMK in teaching secondary school mathematics, which aims to strengthen the training program deficiency. Moreover, PGDT is believed to fill some gaps observed, particularly the lack of balancing between PCK and SMK in the TESO program [11, 13].

The principals of secondary schools, supervisors, and education bureau employers witnessed the gaps observed in the occupational competence of some teachers who graduated from universities in the consecutive graduating year under the PGDT program [16]. This is even worse for recent graduates. However, finding the root causes requires intensive investigation, especially in the Ethiopian setting by scholars on policy reform initiatives. It has also been documented that the training program modality PGDT created many complications and challenges starting from program construction up to implementation [30]. The program development is not based on the existing reality on the ground; rather, it is only intended to replace the previous TESO program. Since TESO created many challenges in producing qualified teachers for secondary school, the new program PGDT believed to be a way out to resolve the problem. A more important point is the curriculum development procedure in Ethiopia is a top-down approach [31]. Due to this basic reason, consecutively developed and implemented curriculum problems identified after testing the program. Much research points out that consistently implemented teacher training programs lack a direct purpose on the ground. This has led to a continuous change in teacher training programs in the country and created academic instability.

Therefore, PGDT was also a victim of the previous program development top-down approach [31–33]. Therefore, it came across serious implementation problems of top-down policy reforms. Such a top-down policy formulation which can be called policy imposition to followers, stakeholders resisting to implement, created a low attitude to PGDT, and led to the frailer of the program [31, 33, 34]. Moreover, in a similar study, Abie [16] also indicated that the PGDT program encountered a serious implementation problem for various reasons. Some of these reasons as stated by Awayehu [35] and Wabe and Tessema [36] are the programs lack coordination and good learning environment such as physical resources, and student and teacher educator commitments are identified problems. It also lacks clarity in its entire process; it is a victim of superficial engagement with reform or change. In general, it has been seen as an ineffective improvement, contradictions, and chaos often appeared in the implementation [35, 36].

Furthermore, political, social, and institutional factors are also contributing factors that contributed to the failure of the PGDT training program in Ethiopia [13]. Some study has also shown that the previous TESO program was better in this regard and believed as good but suddenly terminated at the early phase [31]. However, this TESO program lacked genuine modern policy rhetoric (narratives) and the managerial approach to leaders, it more focused on socialization, created chaos, and collectively contributed to its frailer [37].

2. Objectives of the Study

The main objective of this particular study is to investigate the status of mathematics subject matter competencies of preservice trainees in PGDT modalities.

3. Method

This study aims to investigate the mathematics subject matter knowledge competency of student teachers in their preservice training to teach secondary school mathematics. To achieve this, a quantitative descriptive survey as a research design is involved.

It is an appropriate design for the current study since it allows describing the status, student teachers' competency in mathematics, and the contents for teaching secondary school. This study involved 70 mathematics student teachers attending their training in PGDT modalities as a sample of the study. All of them were selected as samples by the availability sampling technique.

4. Instrument of Data Collection

In this study, to achieve the stated objective, a mathematics achievement test was used to gather data to measure their competency. Moreover, the test included 13 selected SMK competency areas in mathematics, and it is mainly based on a mathematics student textbook from grade 7 to 12, in the Ethiopian context. Specific SMK content competencies are algebra, function, geometry, synthetic perspective, geometry–algebraic perspective, trigonometry, statistics, probability, discrete mathematics, calculus, number sense, mathematics as communication, reasoning, instruction, and assessment [38]. These specific competencies are presented in the particular test items. In the achievement test, three items for each category of SMK are involved in measuring competencies. Therefore, an achievement test composed of 39 multiple-choice item questions was prepared.

A typical competency test item looks like the following with some of the competency areas stated:

(1) *Algebra*: Expand the following expression $(q-2r)^3$.
(2) *Function*: For $f(-2)=b,f(0)=e$, and $f(2)=t$, find the value of $b+e+t$ for the polynomial function, $f(x)=3x3+x-17$.
(3) *Geometry synthetic perspective*: If a right-angled triangle has legs of length 5 units and $x+2$ units and a hypotenuse of length $x+3$ units. What is the perimeter of the triangle?
(4) *Geometry algebraic perspective*: Determine the equation of a circle with a center $(4,-2)$ and a radius of 6 units.
(5) *Trigonometry*: The vertical support in the center of the suspension bridge is 50 feet tall. The angle of elevation of the top of the support from either end of the bridge is 35°, and then requested to find the distance across the bridge.
(6) *Statistics*: Find the median of the following list of data points: 25, −2, −3, 10, −10, 25, −4, −4, 26, 11, −4, −20, 12, 8.
(7) *Probability*: If two ordinary dice are rolled, what is the probability that the sum of the dots will be 9?
(8) *Discrete mathematics*: Find the 16th term in the geometric sequence 1,024, −512, 256, ….
(9) *Calculus*: Find the derivative of the function $y=\ln x$.
(10) *Number sense*: $-\sqrt{64}$, $\sqrt{25/9}$, $\sqrt{81}$, $\sqrt{1}$ The numbers represented in this set can all be classified as: whole numbers, integers, rational numbers, or irrational numbers.

The validity and reliability of test items are conducted. The main thing is the content validity of the instruments of data collection tested. In this context, the test focused on the mathematics content that student teachers expected to teach. This study considered the contents of grades 7–11 mathematics student textbooks in Ethiopia. The composition of items within categories is also kept balanced. Therefore, the adequacy with which the test items sample the content area measured is adequately and representatively.

Construct validity is conducted to ensure that the measure is what it is intended to measure [39]. The validity of the instrument is judged based on comments given by subject experts in the area. In particular, one experienced mathematics teacher and one mathematics educator are involved in this judgment. Some corrections, particularly to algebra competency questions, were revised before data collection. Moreover, for the reliability of the instrument, Cronbach's α on SPSS version 20 was used to see the internal consistency of items in the test [39]. In this way, the reliability test result was 0.86. It is accepted as reliable since it is >0.7 [39, 40]. To this end, the test given to the participants can last 2 hr and judge the right or wrong answers based on their responses. During data analysis, the student–teacher response was marked and changed to 100%. During data analysis, SPSS version 20 package was utilized. Descriptive statistics, as well as inferential statistics, was involved in the data analysis process.

5. Result

The overall mean score for mathematics SMK 13 categories of competencies for 70-sampled student teachers is presented in Table 1.

Table 1: Descriptive data of overall competency.

Category of competency	Mean score
Algebra	2.27
Function	1.44
Geometry synthetic perspective	1.24
Geometry algebraic perspective	1.69
Trigonometry	1.04
Statistics	1.10
Probability	1.09
Discrete mathematics	0.79
Calculus	1.41
Number sense	1.19
Mathematics as communication and reasoning	0.56
Instruction	0.81
Assessment	0.69
Overall competency	1.18

Table 2: ANOVA within and between groups.

	Sum of squares	*df*	Mean square	*F*	Sig.
Between groups	177.132	12	14.761	25.659	0.000
Within groups	516.029	897	0.575		
Total	693.160	909			

Dependent variable: SMK of student teachers on selected competency areas of mathematics.

$N = 70$ (participant trainee), each category has three questions with multiple choices. However, right or wrong answers are used for responses during data organization in this study. The mean score is calculated from three, so the mean competency score is required to be ≥ 1.5. From the table, the overall competency of the trainee to teach secondary school mathematics is low (mean score 1.18). This indicated that the trainee has a shortage of subject matter content competency to teach secondary school mathematics. If we consider particular categories of competency, algebra received a higher competency with a mean score 2.27, this indicates the trainee has better competency to teach algebra in secondary school. On the other hand, the trainee competency in mathematics as communication and reasoning is considerably below the minimum (mean score of 0.56). This is, in fact, an important aspect of mathematics. Without sufficient skills in mathematical communication and reasoning, teachers are not able to guide students properly (Table 1).

According to the analysis of variance in Table 2, there was a significant difference in the mean categories of competency areas of the trainee for teaching secondary school mathematics ($F(12, 897) = 25.66$, $P \leq 0.001$) between the categories of competency. This shows that student teachers' subject matter knowledge competencies lack uniformity. Higher competency in one category does not imply higher competency in the other competency categories (Table 2).

Among multiple comparisons, tests made the competence of algebraic seen with the others. The Tukey HSD table (Table 3) indicates that there is a significant difference between the competencies of algebra relative to other categories of competence. It is described by the P-value and the mean value $P(0.000) < 0.05$ and the mean differences ranging from 0.586^* for the competency of geometry algebraic perspective to 1.714^* for the competency of mathematics as communication and reasoning. This result can also particularly describes that student teachers with a higher level of competency in algebra may not indicate higher competency levels in the other categories. Therefore, such differences in the different concept areas and minimum competency levels in the entire SMK indicate student teachers have a deficiency in this regard for teaching secondary school mathematics.

6. Discussion

This study specifically described the mathematics SMK competency of student teachers during their preservice training under the PGDT program. This study employed several statistical analyses to arrive at a valuable result. In this section, the discussion based on the results obtained will follow.

In general, from the results, the overall competency of mathematics subject matter knowledge (SMK) of student teachers across different categories of competency is minimal for teaching secondary school mathematics. However, the result further shows that student teachers have shown better in "Algebra competency" than in other competency areas for teaching secondary school mathematics. On the other hand, student–teacher competency in "mathematics as communication and reasoning" is relative to other competency areas at a minimum level. That means, student teachers relatively have shown better competency in algebra. On the other side, student teachers have shown a significant gap in mathematics as communication and reasoning.

Moreover, within a minimum level of overall competency, the results also indicated a significant variation in competency level among the selected categories. It shows that there is a lack of uniform understanding across competency areas. Minimal SMK affects the teaching of mathematics differently. According to Barlow and Cates [6], minimum SMK is the main indication for students to encounter misunderstandings and misconceptions about mathematics and teachers with low interest in teaching mathematics. On the other hand, low SMK competency is the source of students' low mathematics achievement [9, 10]. However, the study of Lee et al. [26] showed that there is no relation between teachers' subject matter knowledge and their teaching practices. It is against many of the research works in literature. Many studies have found that there is a positive correlation between subject matter knowledge and performance in teaching. That means student teachers with a higher level of subject matter knowledge perform efficiently in teaching mathematics. The problem related to low-minimal SMK may result from the modality of the training program [16]. Program similar to the student teachers included in this study contributed much.

Therefore, the training program PGDT does not provide much SMK for secondary school mathematics teaching. Watson [19] and Stacey [18] have demonstrated that the

Table 3: Multiple comparisons.

Categories of competency (*I*)	Categories of competency (*J*)	Mean difference (*I*–*J*)	Standard error	Sig.
Algebra	Function	0.829*	0.128	0.000
	Geometry synthetic perspective	1.029*	0.128	0.000
	Geometry algebraic perspective	0.586*	0.128	0.000
	Trigonometry	1.229*	0.128	0.000
	Statistics	1.171*	0.128	0.000
	Probability	1.186*	0.128	0.000
	Discrete mathematics	1.486*	0.128	0.000
	Calculus	0.857*	0.128	0.000
	Number sense	1.086*	0.128	0.000
	Mathematics as communication and reasoning	1.714*	0.128	0.000
	Instruction	1.457*	0.128	0.000
	Assessment	1.586*	0.128	0.000

*The mean difference is significant at the 0.05 level.

need for preservice training to align with secondary school mathematics is mandatory. These studies also show that student–teacher deficiency in SMK arises from the problem of teacher training modality. The minimum SMK directly influences PCK. If teaching entails helping students learn, then the quality of what to teach is a central requirement. Areaya [31], Gemechu and Shishigu [34], and Shishigu et al. [33] associated student inefficiency with the PGDT program as a result of a policy problem. The top-down education policy has a direct contribution to student–teacher quality in the teacher training program.

7. Conclusion

This study aims to investigate the level of mathematics subject matter and content knowledge competency of student teachers for secondary school mathematics teaching under the PGDT modality. This study finds out that the SMK of student teachers in different categories of competency areas is seen as remarkably low, and also indicated that student teachers' competency in algebra content is only seen as better than the remaining 12 content competencies. It could be the result of the teacher training modality. Much research pointed out the deficiencies of the PGDT program across different criteria. It also proposed the need to program change to other modalities as it greatly affected the quality of teaching in Ethiopian secondary schools teaching [15, 16]. More importantly, a minimum level of SMK affects individual PCK. From this study, one can say that teaching mathematics at any level involves more than the delivery of facts and information. Teachers cannot achieve aspects of teaching mathematics at secondary school with a minimum competency of SMK. Therefore, the need for teachers with high SMK competency relevant to secondary school teaching is visible in this study. In addition to this, empowering teachers with SMK for the targeted level of teaching is mandatory than optional. Teachers at first need to have mastery of subject knowledge and this knowledge helps the teacher to provide the student to have conceptual mastery of the subject matter. Moreover, such capacity is critical for knowledge development in itself and can empower students to be effective actors in their environment.

Finally, the modality of teacher training has affected the SMK competency of the trainee for teaching mathematics. Therefore, the PGDT training modality resulted in student teachers similar to the trainee in this study; we need a change to a more focused program to heal the quality of teaching mathematics in secondary school. In particular, teacher training programs need to consider growing both SMK and PCK together in the trainee. Regarding SMK mathematics courses selection for the trainee need to focus on attaining the competency areas identified in this particular study. Competencies include algebra, function, geometry, synthetic perspective, geometry–algebraic perspective, trigonometry, statistics, probability, discrete mathematics, calculus, and number sense; mathematics as communication, reasoning, instruction, and assessment shall be the focus area of the training program among others.

Data Availability

The data that support the findings of this study, in particular, participants' response data, are available from the corresponding author upon reasonable request. In addition to this, some of the findings in the literature regarding subject matter content knowledge (SCK) and pedagogical content knowledge (PCK), definitions, and descriptions used quoted from authors Atteh and Andam [2] are available and can be accessed at https://journaljsrr.com/index.php/JSRR/article/view/1535.

Additional Points

This particular study document deals with the competency of preservice trainees of mathematics teachers for secondary school. In particular, the study investigated the status of the subject matter knowledge competency of student teachers for teaching secondary school mathematics. Moreover, this study draws attention to the need for consideration of SMK in teacher training programs to fit the direct purpose of teaching mathematics at secondary schools.

Conflicts of Interest

The author declares that there is no conflicts of interest.

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