Selection and Utilization of Multiple Teaching Tools in Blended Classrooms from the Perspective of Synergistic Effect

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Abstract—Teaching tools are playing an increasingly important role in modern education, especially in this post-pandemic era, the outbreak of Covid-19 pandemic and the social distancing policy have brought fundamental changes to the education mode in China. Fully and rationally making use of multiple teaching tools in blended classrooms is helpful in realizing teaching goals, moreover, it can increase students' interest in learning and activate classroom atmosphere. However, current studies on the teaching tools of blended classrooms fail to well exhibit teaching content in the classrooms, the existing tools only have limited functions, and such classrooms couldn't effectively train students' abilities to communicate or make self-evaluations. In view of these problems, this paper aims to study the selection and utilization of multiple teaching tools in blended classrooms from the perspective of synergistic effect. At first, this paper built an Evaluation Index System (EIS) for assessing the degree of synergy of multiple teaching tools when they are used in blended classrooms; then, it calculated the degree of order of these tools in the said classrooms; at last, this paper analyzed the effectiveness of the synergistic effect of different teaching tools.

Keywords—synergistic effect, teaching tool, blended classroom, degree of synergy, degree of order

1 Introduction

Conventional teaching tools can be roughly divided into three categories: ordinary teaching tools, special teaching tools, and preschool teaching tools. Properly selected teaching tools can exhibit the teaching content more intuitively, assist students in understanding the teaching content more profoundly, enrich students' perceptual experience, help forming clearer concepts in students, thereby increasing students' learning interest and enhancing their observation and thinking abilities [1-4]. In this post-epidemic era, the informatization of education has broken the existing conventional teaching mode in China, in this transformation process, the digitized teaching resources,

multiple teaching tools, and blended style classrooms are the keys for teachers to design, select, and use the right tools in the class to achieve the desired teaching effect [5-14]. Modern science has injected new vitality to education in multiple ways and the increasingly diversified teaching tools is one of the manifestations. Fully and rationally making use of multiple teaching tools in blended classrooms is helpful in realizing teaching goals, moreover, it can increase students' interest in learning and activate classroom atmosphere [15-25]. The selection and utilization of multiple teaching tools for blended classrooms based on synergistic effect need to match with the development of majors and specialties in colleges and universities, the features of professional knowledge, and the teaching requirements of course content, so it is of certain necessity to explore into this research direction.

Teachers of social science often use digital tools to teach data processing skills, and train students' abilities in comprehending, analyzing, and interpreting data. These tools generally include software, websites, and applications for creating charts, graphs, even timetables. They allow users to create visualized large datasets, which are usually difficult to operate without these tools. Nelson-Fromm [26] suggested to study teachers' understandings of data representation and build data visualization tools to support their understandings, so that these tools could be used easily by teachers in the classroom. Cuadrado-Gallego et al. [27] introduced their research results of improving the teaching of data visualization through two ways: developing a new system to classify different graphical techniques for exhibiting data that can be found in literatures, and using different attributes, both open source and private, to comparatively analyze most important tools and develop data graphics that can be used for the teaching of data visualization. de Matos et al. [28] argues that the current pandemic crisis demands to use digital and distance learning tools to ensure the involvement of students in class and research works, so they introduced a tool used in the management course in higher educational schools which can simulate management games, clickers, and collaborative techniques useful for online lectures; the proposed tool can help participating and giving feedback when managing a large number of students; then, the authors assessed and discussed the success of these online tools from the teachers' and students' point of views, and invited students to an online survey. Jiang [29] reviewed literatures about online teaching and introduced the application of a smart teaching tool, the Rain Classroom, in English class at Huazhong Agricultural University of China, and the teaching design before, during, and after the class; then, through comparative experiments, the author used test data to prove that students attained significant progress in learning with the help of this smart teaching tool. Lopes and Costa [30] discussed the topic of why many teachers get little educational benefit from digital resources, despite their potential to help creating learning environments with higher student participation that can stimulate intellectual challenges; their study systematically determined main factors, extended the concept of instrumental orchestration starting from the idea that any educational resource can be used as a tool, proposed to take digital resources as learning tools, and gave guidelines for making research implementation plans.

After carefully reviewing related literatures, we found a few flaws with existing studies on the teaching tools of blended classrooms: 1) Teachers do not have a clear idea of how to fully and rationally utilize teaching tools in blended classrooms and the

importance of that; 2) The selected teaching tools fail to well exhibit teaching content in blended classrooms and they only have limited functions; 3) The selected teaching tools couldn't promote teacher-student interaction or train students' abilities to communicate or make self-evaluations; 4) The integration of teaching tools and teaching content in blended classrooms only stays at a superficial level, the application integration is not deep enough. To make up for these flaws, this paper took PE teaching as an example to study the selection and utilization of teaching tools in blended classrooms based on synergistic effect, the specific content of this paper is given below.

2 Evaluation of the degree of synergy of teaching tools used in blended classrooms

Figure 1 shows the synergy between class teaching goals and the selected teaching tools. The synergy between the two has a few dimensions: teaching goal synergy, teaching organization synergy, informatization degree synergy, teaching resource synergy, and teaching process synergy. These dimensions are interrelated and they can affect each other. In this paper, an EIS was built for assessing the degree of synergy of multiple teaching tools in blended classrooms. Details are given below:

First layer (evaluation objectives):

A={A_1, A_2, A_3, A_4, A_5}={teaching goal synergy, teaching organization synergy, informatization degree synergy, teaching resource synergy, teaching process synergy};

Second layer (first-level indexes):

A_1={A_{11}}={teaching goal achievement};

A_2={A_{21}, A_{22}, A_{23}}={teaching plan, knowledge point selection, teaching process};

A_3={A_{31}}={information technology compatibility};

A_4={A_{41}, A_{42}, A_{43}}={teaching resource assistance, teaching resource allocation, teaching resource abundance};

A_5={A_{51}}={teaching process management};

Third layer (second-level indexes):

A_{11}={A_{111}, A_{112}, A_{113}, A_{114}}={teaching goal consistency, teaching goal completion, teaching effect completion, teaching progress completion};

A_{21}={A_{211}, A_{212}}={rationality of teaching plan, knowledge coverage of teaching plan};

A_{22}={A_{221}, A_{222}, A_{223}}={relevance of knowledge points, importance of knowledge points, difficulty of knowledge points};

A_{23}={A_{231}, A_{232}}={completeness of teaching plan, implementation effect of reward and punishment measures in teaching process};

A_{31}={A_{311}, A_{312}, A_{313}}={standardization of information-based teaching; match and utilization of information-based teaching methods; application adaptability of IT techniques};

A_{41}={A_{411}, A_{412}}={demand for teaching resources, rationality of selected teaching resources};

A_{42}={A_{421}, A_{422}}={rationality of teaching resource allocation, flexibility of teaching resource allocation};

A_{43}={A_{431}, A_{432}}={teaching resource acquisition, teaching resource reserve};

A_{51}={A_{511}, A_{512}}={connection of teaching environment, coordination of teaching progress}.

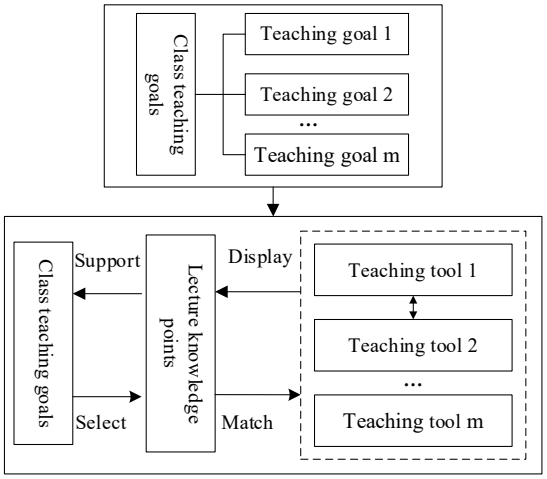

Fig. 1. The synergy between teaching goals and selected teaching tools

In order to objectively and accurately measure the synergy degree of teaching tools used in blended classrooms, this paper employed the entropy weight method to calculate the weights of the evaluation indexes: assuming: there're n teaching tool combinations and m evaluation indexes, then an initial evaluation index matrix could be constructed as:

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix} \tag{1}$$

Assuming: A_{ij}(i=1,2,..., n;j=1,2,...,m) represents the value of the j-th evaluation index of the i-th teaching tool combination, to eliminate the influence of different dimensions of evaluation indexes on the synergy degree evaluation results, dimensionless processing was performed on positive and negative indexes based on the following formulas:

$$a_{ij}^{'}=\frac{a_{ij}-min\left\{a_{ij}\right\}}{max\left\{a_{ij}\right\}-min\left\{a_{ij}\right\}} \quad Positive\ indexes \tag{2}$$

$$a_{ij}^{'}=\frac{max\left\{a_{ij}\right\}-a_{ij}}{max\left\{a_{ij}\right\}-min\left\{a_{ij}\right\}} \quad Negative\ indexes \tag{3}$$

The proportion ($b_{ij}^{'}$) of the i-th teaching tool combination $a_{ij}^{'}$ of the j-th evaluation index could be calculated using the formula below:

$$b_{ij}^{'} = \frac{a_{ij}^{'}}{\sum_{i=1}^{n} a_{ij}^{'}} \tag{4}$$

The information entropy value (DW_j) of the i-th evaluation index is:

$$DW_j = -\frac{1}{\ln n}\sum_{i=1}^{n} b_{ij} \ln b_{ij}, \left(j = 1, 2, ..., m\right) \tag{5}$$

Assuming: $1/ln\ n$ is greater than 0, and $0 \leq e_j \leq l 0 \leq d_j \leq k$; specifying: when $y_{ij}b_{ij}=0$, $y_{ij}ln\ y_{ij}=0 b_{ij}lnb_{ij}=0$, calculate the weight $w_j\eta_j$ of each evaluation index:

$$\eta_j = \frac{1-d_j}{m-\sum_{j=1}^{n} d_j}, \left(j = 1, 2, ..., m\right) \tag{6}$$

3 Calculation of order degree of teaching tools used in blended classrooms

By rationally selecting and utilizing teaching tools used in blended classrooms and effectively matching different teaching tools with different knowledge points to achieve the synergistic effect, we could better exhibit teaching content in class, increase students' interest in learning, and activate the classroom atmosphere. Figure 2 shows the matching logic of teaching tools used in blended classrooms. When selecting and utilizing the teaching tools, the synergy between knowledge points and teaching tools is the key to teaching planning and class management. Figure 3 gives a diagram of the model of knowledge point/teaching tool selection. According to the figure, in order to present the ideal effect in the classroom, teachers need to fully understand the features of different types of teaching tools, and be able to select the right teaching tool combination that can match with the teaching goals, teaching organization, teaching resources, and teaching process. The selected tools should also match with the students' knowledge acquisition process (understand, comprehend, apply, analyze, and evaluate) and the various knowledge in the teaching content (including conceptual knowledge, skill knowledge, work principle knowledge, professional knowledge related to actual problems, knowledge for solving actual problems), and tools that can better exhibit knowledge points, attract students' attention, promote student participation, have better teaching effect, and cost lower should be selected for the modern classrooms.

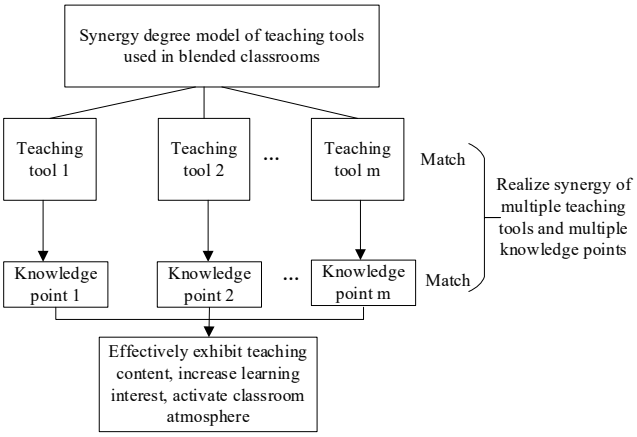

Fig. 2. The matching logic of teaching tools used in blended classrooms

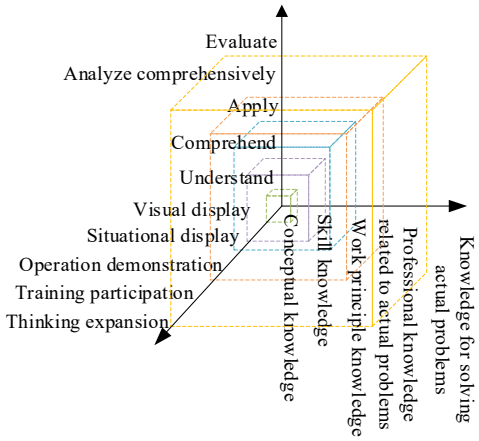

Fig. 3. The knowledge point/teaching tool selection model

This paper constructed a synergy degree model for measuring the teaching tools used in blended classrooms, containing the calculation of three levels, namely the calculation of Order Degree of the Matching (MOD) between teaching tools and knowledge points, the calculation of Order Degree of Synergy (SOD) of multiple teaching tools, and the calculation of Synergy Degree (SD) of teaching tool selection and utilization in the classroom.

The synergy of multiple teaching tools pursues an overall classroom teaching state transforming from the disharmonious disordered state to the harmonious orderly state, and this is determined by the values of MOD and SOD mentioned above, therefore, in the proposed synergy degree model for measuring the teaching tools used in blended classrooms, these two are the basis for calculating SD.

Assuming: in the target classroom (in which the teaching tools are used), the overall classroom teaching state X is a complex state containing several teaching tool combinations, which is represented as $X=\{X_1, X_2,\ldots,X_m\}$, wherein X_m is the m-th teaching tool combination in this teaching state.

Assuming: $D_j=(D_{j1},D_{j2},\ldots,D_{jm})$ represents the values of MOD; α_{ji} and β_{ji} represent the minimum and maximum values of idea MOD, wherein $m\geq k$, $\alpha_{ji}\leq D_{ji}\leq\beta_{ji}$, and $i\in[1,m]$. If D_j is a positive index, then the greater the values of $D_{j1},D_{j2},\ldots,D_{jl}$, the greater the value of MOD; if D_j is a negative index, then the greater the values of $D_{j1},D_{j2},\ldots,D_{jl}$, the smaller the value of MOD.

Assuming: the degree order of MOD component D_{jm} of combination X_m can be calculated by the following formula:

$$YX_i\left(D_{im}\right)=\begin{cases}\dfrac{D_{jM}-\alpha_{ji}}{\beta_{ji}-\alpha_{ji}}, i\in\left[1,l\right]\\ \dfrac{\beta_{jm}-D_{ji}}{\beta_{ji}-\alpha_{ji}}, i\in\left[l+1,m\right]\end{cases} \tag{7}$$

Then, the order degree ($YX_i(D_j)$) of D_j could be described by the set of order degrees ($YX_i(D_{jm})$) of the components of D_j. To simplify the calculation process, it's assumed that $q_D\geq 0$, $\Sigma^m{}_{D=1}q_D=1$, and the order degree ($YX_i(D_j)$) of D_j was calculated using a linear weighted summation method shown in Formula 8.

$$YX_i\left(D_j\right)=\sum_{d=1}^{m}q_D P_i\left(D_{jm}\right) \tag{8}$$

4 Effectiveness analysis of the synergy of multiple teaching tools

To measure the value of SD, scientific and representative indexes should be selected, so we consulted field experts and professionals for their opinions and suggestions to further analyze the effectiveness of SD via three indicators: concentration degree, dispersion degree, and coordination degree.

Assuming: JZ_j represents the concentration degree of the synergy of multiple teaching tools, then it can be calculated by the following formula:

$$JZ_j=1/e\sum\nolimits_{w=1}^{5}N_{jw}n_{jw}, j=1,2,\ldots m \tag{9}$$

Assuming: JZ_j represents the concentration degree of experts' opinions on the j-th evaluation index; JZ_{jw} represents the score of the importance of the j-th evaluation index given by experts, the score is divided into 5 levels of Level-I, Level-II, Level-III, Level-IV, and Level-V, which respectively represent not important at all, not important, average, important, and very important; n_{jw} represents the number of experts who score the j-th evaluation index as Level-w, then, Formula 10 gives the formula for calculating the dispersion degree ς_j:

$$\varsigma_j = \left[\sum_{w=1}^{5} \frac{n_{jw} \left(JZ_{jw} - JZ_j \right)^2}{e-1} \right]^{\frac{1}{2}}, j = 1,2,...m \tag{10}$$

According to this formula, the smaller the value of ς_j, the lower the degree of dispersion of the evaluation scores given by the experts. Assuming: U_j represents the variation coefficient of the expert evaluation results of the j-th evaluation index; Q represents the coordination coefficient which describes whether there're large opinion differences in the expert evaluation scores, then there is:

$$U_j = \varsigma_j / JZ_j \tag{11}$$

U_j describes the consistency degree of expert evaluation scores, the smaller the value of U_j, the higher the consistency degree of expert evaluation scores of the j-th evaluation index. Assuming: R_j represents the consistency degree of expert evaluation scores of the j-th evaluation index; JZ_{lj} represents the score of the j-th evaluation index given by the l-th expert; D_{rj} represents the arithmetic mean of the evaluation scores given by all experts, R_j-D_{rj} represents the deviation from the mean of the j-th evaluation index; R represents the sum of the squares of the deviation from the mean of the EIS, then there are:

$$R_j = \sum_{l=1}^{e} JZ_{lj} \tag{12}$$

$$D_{rj} = \left(\sum_{j=1}^{m} R_j \right) / m \tag{13}$$

$$R = \sum_{j=1}^{m} \left(R_j - D_{rj} \right)^2 \tag{14}$$

Assuming: YX_l represents evaluation indexes in a same layer; k represents the number of same evaluation group of the l-th expert; v_l represents the number of same level in the k groups, then there are:

$$Q = \frac{12}{e^2 \left(m^3 - m \right) - e \sum_{l=1}^{e} YX_l} R \tag{15}$$

$$YX_l = \sum_{l=1}^{k} \left(v_l^3 - v_l \right) \tag{16}$$

5 Experimental results and analysis

In modern online-offline blended PE class, there are various teaching tools with multiple functions, and there're differences in the features of different type teaching tools. This paper summarized the features of 5 type teaching tools, including the PPT, audio, video, software, and material object, see Table 1.

Based on the calculated weight values of second-level indexes in the proposed EIS, the coordination degree of the synergy effectiveness of multiple teaching tools could be attained, details are given in Table 2.

Table 1. Features of different teaching tools

Feature \ Teaching tool		PPT	Audio	Video	Software	Material object
Situation reproducibility	Real time	√	√	√	√	√
	After event				√	√
Visual display	Space					√
	Time	√	√	√	√	
	Motion		√	√	√	√
	Color	√		√	√	√
	Sound		√	√		
Participatory	Yes				√	√
	No	√	√	√		
Operation demonstration	Easy	√	√	√		√
	Hard				√	
Thinking expansion	Yes	√				
	No		√	√	√	√

Table 2. Coordination degree of synergy effectiveness of multiple teaching tools

Evaluation index		Class hour 1	Class hour 2	Class hour 3	Class hour 4
A_1	A_{11}	0.5214	0.6415	0.6314	0.6284
A_2	A_{21}	0.5847	0.6859	0.6859	0.6958
	A_{22}	0.5621	0.6325	0.6251	0.6325
	A_{23}	0.5985	0.6472	0.6783	0.6142
A_3	A_{31}	0.5418	0.6295	0.6259	0.6285
A_4	A_{41}	0.6258	0.6142	0.6481	0.6247
	A_{42}	0.5748	0.5147	0.6285	0.6417
	A_{43}	0.4162	0.6285	0.6748	0.6748
A_5	A_{51}	0.5147	0.6478	0.6385	0.6942

Further, the MOD could be calculated as well, see Figure 4.

Figure 5 shows the calculation results of dispersion degree of the multiple teaching tool synergy system under conditions of different class hours, specifically, it contains three aspects: MOD, SOD, and SD. As can be known from the figure, under the conditions of different class hours, the differences of dispersion degree of the multiple teaching tool synergy system were relatively small, and all were positive. Compared with the dispersion degree of SOD, the dispersion degree of MOD under different class hours was lower; under the condition that the teaching tools have been properly chosen and utilized, the dispersion degree of SD exhibited a relatively ideal state.

Figure 6 shows the calculation results of concentration degree of the multiple teaching tool synergy system. According to the figure, regardless of the class hour, experts

agreed more with the teaching organization synergy, followed by the teaching goal synergy; in contract, the informatization degree synergy, teaching resource synergy, and teaching process synergy were of lower degrees, teachers should find problems and causes from these three aspects and summarize experience of teaching tool selection, that is to say, they should deepen their understandings of the features of the different type teaching tools and utilize them properly in their teaching plans and decisions.

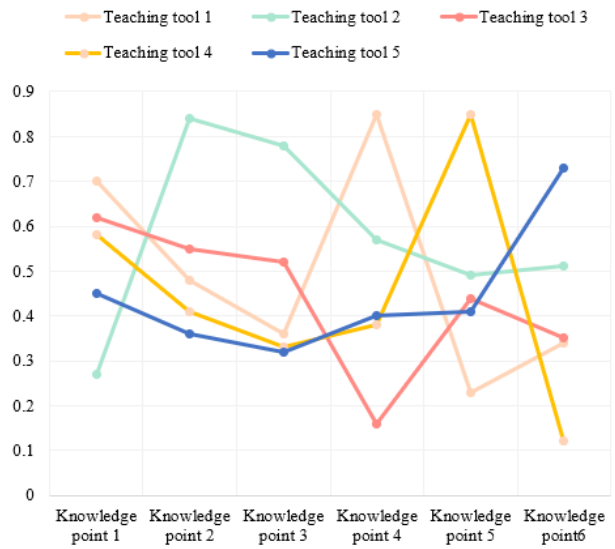

Fig. 4. Order degree of the matching between teaching tools and knowledge points

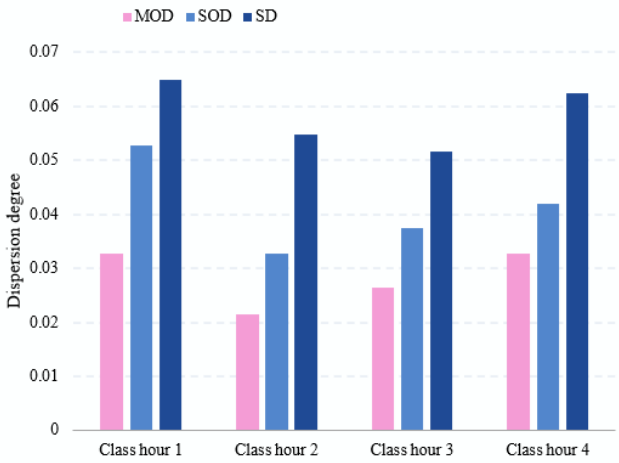

Fig. 5. Calculation results of dispersion degree of the multiple teaching tool synergy system under different class hours

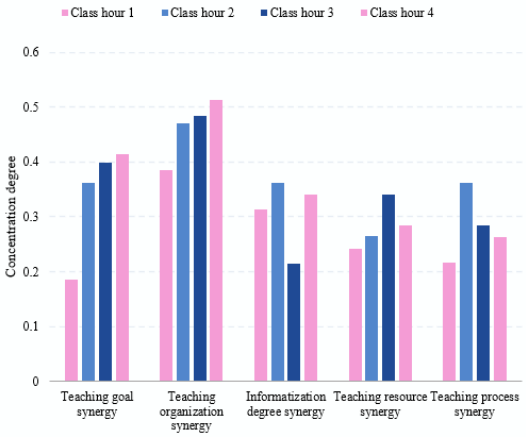

Fig. 6. Calculation results of concentration degree of the multiple teaching tool synergy system

6 Conclusion

This paper conducted a research on the selection and utilization of teaching tools for blended classrooms from the perspective of synergistic effect. At first, with PE teaching as an example, it built an EIS for assessing the synergy of multiple teaching tools in blended classrooms, calculated the MOD and analyzed the effectiveness of the synergy of different teaching tools. In the texts, the information-based teaching tools were divided into 5 types of PPT, audio, video, software, and material object and their features were summarized; then, the coordination degree and MOD were calculated, and the dispersion degree and concentration degree of the multiple teaching tool synergy system under different class hours were given. At last, based on the experimental results, this paper proposed several suggestions for teachers to use different teaching tools to make teaching plans and decisions.

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