Raising the Learning Effects for Learners with Low Entrance Scores using Project-Based Learning in Virtual Reality Practice

Juin-Ling Tseng

***Abstract*—With the declining birthrate, the general number of students has been continually declining; this has subsequently resulted in a decrease in the average results of the Taiwan university entrance examination. It is, therefore, apparent that students' learning ability has reduced greatly. Using a virtual-reality (VR) software-development course as an example, this study explored the methods of guiding student learning and promoting learning interest. This study introduced a project-based approach to replace the paradigm-based method of teaching, with the aim of transforming the focus of teaching from the teacher to the learner. Such an approach was found to facilitate learning progress and help students correspond to the teaching pace, thereby improving their learning performance.**

***Index Terms*—Project-Based Learning, reduction of the number of students, student quality, virtual reality practice**

I. Introduction

DUE to the declining birthrate, the quality of new students has declined over the past five years. Taking the author's affiliated department as an example, the scores of the college entrance examination have decreased annually. As shown in Table 1, the entrance examination score was 360 in 2014; however, by 2018, it reduced to 230 (a reduction of 36.11%). It can thus be observed that there is a decrease in the average quality of enrolled students.

TABLE I
The Scores of Entrance Examination in The Past Five Years

The Entrance Year	The Entrance Score	The Reduction (%)
2014	360	-
2015	286	20.56%
2016	226	37.22%
2017	241	33.06%
2018	230	36.11%

The present author has taught a VR-based practical course for the past five years. The course was initially delivered using a paradigm-based approach, wherein the teacher guided the students through each step of the learning process, to ensure that they could master the operation of each example given through a process of "learning by doing." With the exception of very few students who struggled to follow instructions, most students were found to adapt well to such a learning method. However, over the past two years, student learning has begun showing a noticeable change, including slower learning progress, inability to keep pace with the teacher, and struggling to understand the knowledge and skills taught; an increasing number of students have even made the decision to leave the course.

In order to minimize the aforementioned occurrences and improve students' learning performance, a project-based learning approach was introduced to shift the focus from a teacher-centered to a student-centered design, so that the teaching content better matches the quality of the learners, as shown in Fig. 1.

Fig. 1 Course Teaching – Virtual Reality

II. Literature Review

In recent years, engineering technology [1] and 3D information technology [2–4] have developed rapidly; moreover, in order to enhance engineering knowledge and 3D information technology learning, a number of different learning methods have been proposed for different technical fields [5], including Experimental Learning method proposed by Ramirez-Juidias et al. [1] and Micro-Flip Teaching method proposed by Morano-Fernandez for Aerospace Engineering Mathematics [6].

Traditional pedagogy generally adopts teacher-centered pedagogical models, where the teaching content and progress are defined by the teacher. In such models, the teacher is responsible for the delivery of the knowledge that should be taught, while the students are required to apply effort to

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absorb the knowledge taught. Such models pose no problems to students with a strong learning ability; however, students with a lower learning ability find it difficult to maintain a similar in-class pace.

Project-based learning [7–9] is a learner-centered approach that focuses on guiding students to obtain the knowledge and skills through the creation of meaningful projects. For students from technology colleges, the main focus is on training their practical and operational abilities. The project-based learning approach guides students to "learn by doing" and promotes confidence, teamwork, and self-learning ability, as well as active thinking.

According to the definition given by the National Academy Foundation [10], "projects" used in project-based learning should effectively guide students to consider the problems that they may encounter in the research field, so they are able to cultivate their decision-making ability. In addition, the output of the project should reflect the knowledge and skills acquired by students. A well-designed project [11–12] should include tasks that are related to problems and issues outside the classroom, help the students understand the need for learning a given piece of knowledge and skill, promote the students' ability to make decisions and generate ideas through participation in the project, and clearly reflect the knowledge and skills acquired by the students.

In accordance with the pedagogical design proposed by Larmer and Mergendoller (2012) [13], the following eight elements should be included in a student project: significant content, a need to know, a driving question, student voice and choice, in-depth inquiry, critique and revision, public audience, and 21st century competencies, as shown in Fig.2.

1) "Significant content" in this context implies that when designing a project, the teacher should focus on important knowledge and concepts derived from students' previous knowledge and skills. In addition, the content should also reflect the basic information related to the topic that the teacher intended to deliver.
2) "Need to know" is concerned with the idea that the design of the project should ensure that the students clearly understand the reason for learning the relevant material.
3) "Driving question" is designed to trigger student learning and is the most important feature of the project-based learning design. A good driving question helps the students to comprehend the fundamental concepts of the project and permits a sense of purpose and challenge.
4) "Student voice and choice" is observed to be one of the biggest differences between project-based learning and traditional learning. An appropriate inclusion of student voice and choice facilitates their innovative performance.
5) "In-depth inquiry" means that the design of the project should guide students to conduct in-depth inquiries based on their lack of understanding, which helps them to better understand potential problems and solutions, as well as discover new insights.
6) "Critique and revision" requires the teacher to guide the students to understand the materials and information obtained at the in-depth inquiry stage and provide critique and revision feedback on their project designs, to optimize performance results.
7) In addition to the "self-initiated revision" of the projects, the students should also be encouraged to present their project to a real audience (public audience), to obtain varied feedback on their projects, thereby improving the overall quality [14].
8) 21st century competencies: "21st century competencies" include teamwork, communication, collaboration, critical thinking, and the application of technological tools. These skills can be honed during the completion of the project to meet requirements of future employment [15–16].

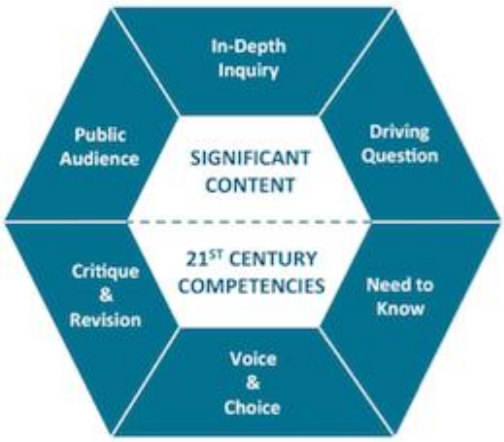

Fig. 2 Eight elements of the pedagogical design proposed by Larmer and Mergendoller

III. Methodology

This study used a VR software-design course aimed at sophomores from the author's university. In order to apply the project-based learning principles to the course, the students were divided into several groups. Each group was required to complete a VR game using the Unity3D software system. The topics covered by the project included virtual scene construction, virtual character control and interaction methods, and collision detection between virtual objects. The detailed description for each section is as follows.

1) Virtual scene construction focused on the creation of 3D virtual scenes and objects, as well as importing the created 3D virtual scenes and objects into Unity3D to build the required 3D VR game scenes.
2) Virtual character control is an essential part of VR games. Control methods are associated with interactive devices (such as keyboards, mice, and VR headset); therefore, the students were taught how to use Character Controller components in Unity3D to write interactive device programs for each device.
3) Collisions between 3D virtual characters and objects are common events in VR games. The detection methods for collisions include Box Colliders, Sphere Colliders, Mesh Colliders, and Character Controllers. In order to detect the collisions between virtual objects and scenes, the course included a section to introduce and help students understand the differences between the different Colliders.

Since the course adopted a project-based learning approach, it was characterized with methods such as learner-centered, group learning, theme-based questions, and continuous assessments, as shown in Fig. 3. Specifically, the learning process of the course was centered on the learners; while the teacher only played the role of a guide and an assistant. By asking corresponding questions, the teacher encouraged the students to seek different methods to solve their own problems, further understand the relevant knowledge, and complete the development of the project. In addition, the students were divided into groups to work on the project, so as to train their teamwork, communication, collaboration, and critical thinking abilities, as well as their application skills of various technological tools. The teacher also utilized theme-related questions to drive the knowledge construction process, such as learning to use a mouse to control the virtual objects and generating 3D objects at random location points within the 3D space. Moreover, a continuous assessment process was implemented by the present research team on a weekly basis to track the progress of the projects and any inquiries made by the students, as well as to provide responses to questions. Assistance was provided to the students accordingly, so that each group was able to complete the project on time.

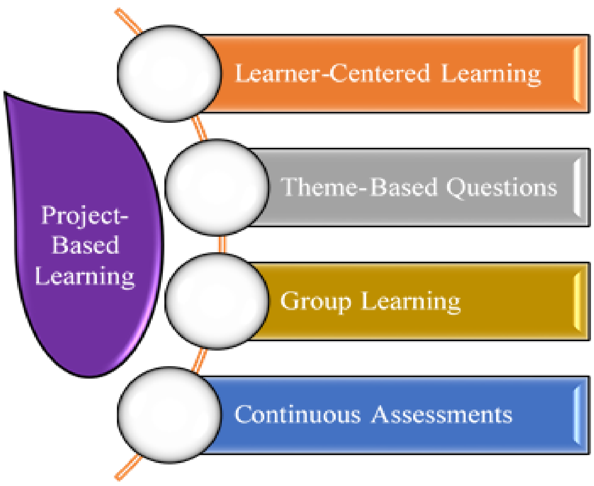

Fig. 3 Four characteristics of Project-Based Learning

IV. Implementation

The course lasted for 18 weeks and was divided into two phases (each lasting 9 weeks). An evaluation of the learning performance was conducted in the 9th (pretest) and 18th week (posttest). Two groups of students (Group A and B) participated in the study. Group A was defined as the experimental group, and Group B was defined as the control group.

A total of 76 students (42 = experimental group, 34 = control group) participated in the study by completing both the 18-week course and evaluations. The same teaching content was used for both groups. In phase 1, both groups were taught basic knowledge related to VR (prior knowledge). In phase 2, the project-based method was adopted by the experimental group, while the control group used the paradigm-based approach, as shown in Fig. 4.

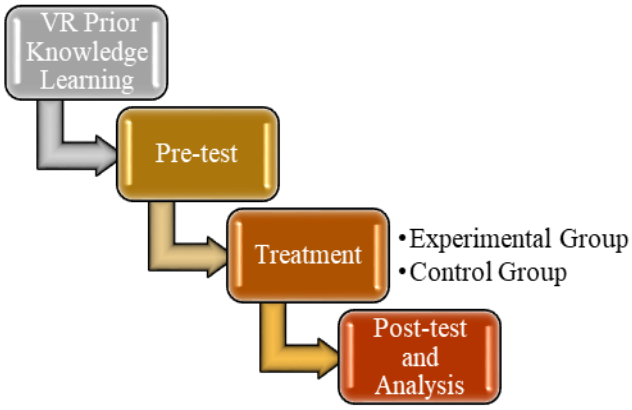

Fig. 4 Experimental Procedure

After being taught the basic knowledge related to VR (prior knowledge) for the first 8 weeks, in week 9, the students were required to complete a performance evaluation related to the knowledge imparted in phase 1 (pretest). The results of the pretest were used to analyze the homogeneity of the two groups.

The average results of the experimental and control groups were found to be 85.5952 and 83.2353 percent, respectively; the standard deviations were 9.7031 and 10.5803, respectively. The p-value of the ANOVA was 0.3146 (> 0.05), indicating that no significant differences were identified between the two groups. Moreover, the F-statistic was 1.0251 < F(0.05) = 1.7519. Therefore, the two groups were considered homogeneous, as shown in Table 2 and 3.

TABLE II
Pre-test Summary

Group	Students	Average	Standard Deviation
Experimental	42	85.5952	9.7031
Control	34	83.2353	10.5803

TABLE III
Pre-test ANOVA Analysis

	Sum of Squares	Degrees of Freedom	Mean Square	F-Test	p-value
Between Groups	104.6449	1	104.6449	1.0251	0.3146
Within Groups	7554.2370	74	102.0843		

After week 10, different methods were used in the experimental and control groups for a duration of 8 weeks. In order to guide the project-based learning process, a series of questions were designed to inspire learning. The students were expected to master the knowledge and skills by identifying their own solutions to their questions. The following are ten such examples of the questions asked by the students.

1) How do you place a 3D object in the system?
2) What is a Tag? How do you use a Tag?
3) What is a NullReferenceException? How can I handle a NullReferenceException?
4) How is OnTriggerEnter() used?
5) How do you make 3D objects collide with one another?
6) How do you make 3D objects move in the system?
7) How do you change the speed at which the 3D objects

move through the system?

8) How do you generate 3D objects at random location points in a 3D space?
9) How do you generate 3D objects at fixed intervals?
10) How do you remove objects from the scene?

After 8 weeks of teaching, a posttest was implemented in week 18. The distribution of the scores of both the experimental and control group also had some variations. It can be observed from Tables 4 and 5 that the distribution of scores in the experimental and control group displayed significant differences, with a P-value of $0.0021 < 0.05$. Specifically, the average result of the experimental group was 41.7381 percent, 36.58% higher than that of the control group (30.5588). The distribution of the scores in the posttest (Table 6 and Fig. 5) revealed that the performance of the experimental group was significantly higher than that of the control group.

TABLE IV
POST-TEST SUMMARY

Group	Students	Average	Standard Deviation
Experimental	42	41.7381	15.8300
Control	34	30.5588	14.3362

TABLE V
POST-TEST ANOVA ANALYSIS

	Sum of Squares	Degrees of Freedom	Mean Square	F-Test	p-value
Between Groups	2348.2350	1	2348.2350	10.1879	0.0021
Within Groups	17056.5	74	230.4933		

TABLE VI
DISTRIBUTION OF THE NUMBER OF STUDENTS IN THE POST-TEST SCORE

Group	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
EG	0	1	9	16	7	5	1	2	0	1
CG	1	12	4	10	4	3	0	0	0	0

EG: Experimental Group; CG: Control Group

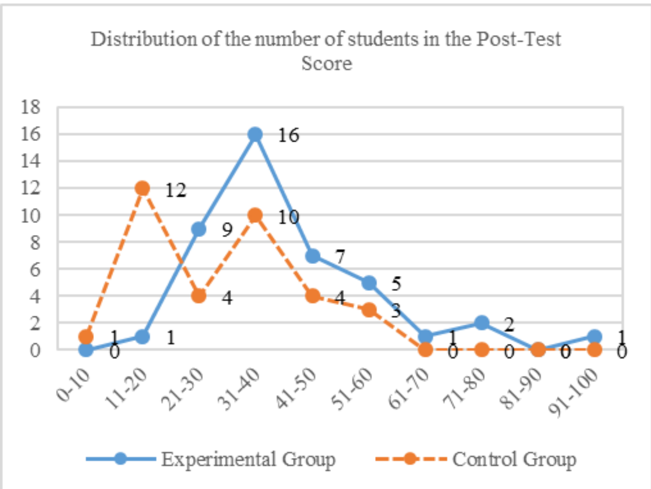

Fig. 5 Distribution of the number of students in the Post-Test Score

To compare the differences between the two groups in the same criteria, this study divided the number of students in each score interval by the number of the group and calculates the percentage value of the score interval in the group to which it belongs, as shown in Tables 7 and Fig. 6. According to this percentage distribution chart, the Project-Based Learning effectively reduced the percentage of students with 0-20 points, and even some students can reach the highest score range of 91-100. In addition, in order to make it easier to observe changes in student achievement, the study divided the two groups into three score intervals: low-score partition (0-30), medium-score partition (31-60), and high-score partition (61-100), and counted as shown in Table 8. Among them, the learning method proposed by this study effectively reduced the percentage value of low-score partition by 26.2%, and increased by 16.7% and 9.5% respectively in the medium-score and high-score partitions.

TABLE VII
PERCENTAGE DISTRIBUTION OF THE NUMBER OF STUDENTS IN THE POST-TEST SCORE (%)

Group	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
EG	0	2.38	21.43	38.10	16.67	11.90	2.38	4.76	0	2.38
CG	2.94	35.29	11.76	29.41	11.76	8.82	0	0	0	0

EG: Experimental Group; CG: Control Group

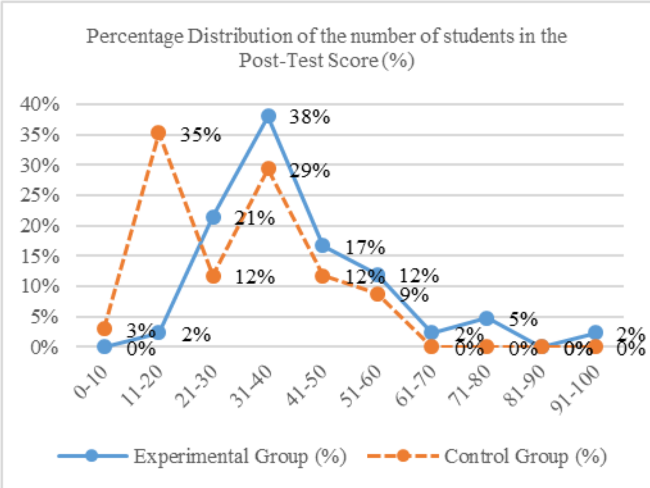

Fig. 6 Percentage Distribution of the number of students in the Post-Test Score

TABLE VIII
PERCENTAGE DIFFERENCE OF LOW-SCORE, MEDIUM-SCORE AND HIGH-SCORE PARTITIONS IN THE POST-TEST SCORE (%)

Group	Low-Score Partition (0-30)	Medium-Score Partition (31-60)	High-Score Partition (61-100)
EG	23.8%	66.7%	9.5%
CG	50.0%	50.0%	0.0%
Difference	-26.2% ↓	+16.7% ↑	+9.5% ↑

EG: Experimental Group; CG: Control Group

In addition, most of the students who enrolled for the "Virtual Reality Practice" course had registered for the "Game Design" course in the previous semester. This course was a pre-assigned course for the virtual reality practice. To completely determine the effectiveness of learning virtual reality using the project-based learning method, the students who passed the Game Design course were evaluated.

Among the students who participated in the virtual reality practice, 64 students passed the Game Design course in the previous semester; 32 were in the experimental group and 30 were in the control group. Tables 9 and 10 show the one-way analysis of variance (ANOVA) of the pre-test results. The pre-test average and standard deviation of students in the experimental group were 86.4063 and 8.6355, respectively; whereas for the control group, the pre-test average and standard deviation were 83 and 11.1107, respectively. Table 10 shows that the F-test value is 1.8295 < F(0.05) = 1.8482 and the p-value is 0.1813 (>0.05). From the results, it can be observed that there is no significant difference between these two groups.

TABLE IX
PRE-TEST SUMMARY

Group	Students	Average	Standard Deviation
EG	32	86.4063	8.6355
CG	30	83	11.1107

EG: Experimental Group; CG: Control Group

TABLE X
PRE-TEST ANOVA ANALYSIS

	Sum of Squares	Degrees of Freedom	Mean Square	F-Test	p-value
Between Groups	179.6522	1	179.6522	1.8295	0.1813
Within Groups	5891.719	60	98.1953		

After conducting the experiment on the project-based learning method, a post-test analysis was performed in this study and the results are shown in Tables 11 and 12. The post-test average and standard deviation of the experimental group were 44.4063 and 16.7426, respectively; whereas for the control group, the average and standard deviation were 29.5 and 13.9821, respectively. In case of the one-way ANOVA, the F-test value was 14.3760 > F(0.05) = 1.8482 and the p-value was 0.00035 (<0.05). Therefore, the two groups demonstrated significant differences. Additionally, the score of the experimental group was 44.4063, which is 50.53% higher than the score of 29.5 of the control group, and 13.95% higher than the improvement rate of 36.58% for all the students, as shown in Table 13. In conclusion, the implementation of the project-based learning method in the Virtual Reality Practice course effectively improved the learning for the students who passed the Game Design course in the previous semester.

TABLE XI
POST-TEST SUMMARY

Group	Students	Average	Standard Deviation
EG	32	44.4063	16.7426
CG	30	29.5	13.9821

EG: Experimental Group; CG: Control Group

TABLE XII
POST-TEST ANOVA ANALYSIS

	Sum of Squares	Degrees of Freedom	Mean Square	F-Test	p-value
Between Groups	3440.459	1	3440.459	14.3760	0.00035
Within Groups	14359.22	60	239.3203		

TABLE XIII
POST-TEST SUMMARY
(THE STUDENTS WHO PASSED THE COMPUTER GAME DESIGN)

	The Students who Passed the Computer Game Design	All
EG	44.4063	41.7381
CG	29.5	30.5588
Raised rate	50.53%	36.58%

EG: Experimental Group; CG: Control Group

V. CONCLUSIONS

With the increasingly critical situation of the declining birthrate, the results for the Taiwan university entrance examination have decreased annually, and the students' learning has shown noticeable changes, including a slower progress and trouble in keeping pace with the teaching speed during class. In order to effectively improve the learning performance of the new students who displayed a lower performance than those of the past, this study introduced a project-based learning approach in an operational-based course (VR-based software development). The results indicate that, since the project-based learning method focused on the learners, the teacher had more time to encourage student thinking and assist students to resolve problems independently. As a result, despite the low scores in the entrance examination, the students' learning performance was effectively improved.

REFERENCES

[1] E. Ramirez-Juidias, J. Tejero-Manzanares, J.L. Amaro-Mellado, and L. Ridao-Ceballos, "Developing Experimental Learning in a Graphical Course Using Thurstone's Law of Comparative Judgment," *Engineering Letters*, vol. 25, no.1, pp61-67, 2017.

[2] J. Arango, and J. Delgado, "Critical Points of Solutions to Semilinear Elliptic Problems in 3D Space," *IAENG International Journal of Applied Mathematics*, vol. 49, no.4, pp447-451, 2019.

[3] J. L. Tseng, "Development of a 3D Intuitive Interaction Interface for Head-Mounted Virtual Reality System," *International Journal of Advanced Studies in Computer Science and Engineering*, Vol.7, No.7, pp.19-25, 2018.

[4] J. L. Tseng and C. W. Chu, "Interaction Design in Virtual Reality Game using Arduino Sensors," *Simulation and Gaming*, Chapter 7, pp.111-127, 2018.

[5] M. Chen, B. Liu, D. Zeng, and W. Gao, "A Framework for Ontology-Driven Similarity Measuring Using Vector Learning Tricks," *Engineering Letters*, vol. 27, no.3, pp549-558, 2019.

[6] J. A. Morano-Fernandez, S. Moll-Lopez, L. M. Sanchez-Ruiz, E. Vega-Fleitas, S. Lopez-Alfonso, and M. Puchalt-Lopez, "Micro-Flip Teaching with e-learning Resources in Aerospace Engineering Mathematics: a Case Study," *Lecture Notes in Engineering and Computer Science: Proceedings of The World Congress on Engineering and Computer Science 2019*, 22-24 October, 2019, San Francisco, USA, pp222-225.

[7] J. E. Mills, D. F. Treagust, "Engineering Education – Is Problem-Based or Project-Based Learning the Answer?," in *Australasian Journal of Engineering Education*, 2003.

[8] S. Han, R. Capraro, M. M. Capraro, "How Science, Technology, Engineering, and Mathematics (STEM) Project-Based Learning (PBL) Affects High, Middle, and Low Achievers Differently: The Impact of Student Factors on Achievement," in *International Journal of Science and Mathematics Education*, Vol.13, No.5, 2015, pp.1089–1113.

[9] K. Poonpon, "Enhancing English Skills Through Project-Based Learning," in *The English Teacher*, 2017.

[10] National Academy Foundation (NAF), "Project-Based Learning: A Resource for Instructors and Program Coordinators," in *National Academy Foundation*, July 5, 2015.

[11] C. C. Chang, S. J. Lou, "Attitudes Towards Science, Technology, Engineering and Mathematics (STEM) in a Project-Based Learning (PjBL) Environment," in *International Journal of Technology and Design Education*, vol. 23, 2011, pp.87–102.
[12] A. Karsakov, A. Bilyatdinova, A.G. Hoekstra, "3D Virtual Environment for Project-Based Learning," in *2014 IEEE 8th International Conference on Application of Information and Communication Technologies*, 2014, pp.468–472.
[13] J. Larmer and J. R. Mergendoller, "8 Essentials for Project-Based Learning," in *Buck Institute for Education*, 2012, http://bie.org/object/document/8_essentials_for_project_based_learning.
[14] F. Larry, "Building a Community of Self-Motivated Learners: Strategies to Help Students Thrive in School and Beyond," in *Oxford*, 2015.
[15] S. Bell, "Project-Based Learning for the 21st Century: Skills for the Future," in *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, Vol.83, No.2, 2010, pp.39–43.
[16] R. Makaramani, "21st Century Learning Design for a Telecollaboration Project," in *Procedia – Social and Behavioral Sciences*, vol. 191, 2015, pp. 622–627.

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