Development of Interdisciplinary Assessment of Critical Thinking in Dental Education

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Abstract

Purpose: The purpose of this study was to introduce and assess a novel method of creating an integrated examination including interdisciplinary critical thinking questions in an undergraduate periodontics course and to evaluate students’ attitudes and perceptions toward this new examination.

Methods: An integrated examination requiring interdisciplinary knowledge and critical thinking was created and administered. An anonymous survey instrument with ten statements using a five-point Likert scale and a free-text comment section was administered to students after completion of their final periodontics examination.

Results: A total of 112 students completed the survey, with a response rate of 81%. The results showed mixed attitudes from students about this examination. Perceptions ranged from strong agreement with critical thinking clinical questions to negative perceptions including comments about its difficulty and lack of sufficient time to complete the examination.

Discussion: Exam questions requiring interdisciplinary critical thinking are challenging for students to take and for faculty to create and administer. Construction of interdisciplinary critical thinking questions made by faculty from different disciplines provides a path for faculty to promote collegiality and interprofessional communication. Applying interdisciplinary knowledge and critical thinking in clinical problem-solving questions challenges students to develop skills needed to manage patients.

Keywords: Critical Thinking; Dental Education; Interdisciplinary Question; Integrated Examination; Surveys

Introduction

Critical thinking and problem-solving are essential competencies expected in dental graduates. The Commission on Dental Accreditation of the American Dental Association states: “Graduates must be competent in the use of critical thinking and problem-solving, including their use in the comprehensive care of patients, scientific inquiry and research methodology” [1]. While critical thinking is essential in dental education, few models are available to guide dental schools to meet this standard and to train faculty on appropriate students’ assessment of critical thinking [2].

Critical thinking is defined in the literature in various ways [3]. Its goal in health professions education is to either identify further questions, get a conclusion, or solve a problem [4,5]. Studies have shown that clinical case-based learning enhances students’ critical
thinking ability [6-8] and assessments that include case scenarios questions aiming for complex problem-solving are more effective to evaluate critical thinking [9-13].

In 2009, the Joint Commission on National Dental Examination in the United States began developing a new exam format that would integrate basic, behavior and clinical sciences to assess entry-level competency in dentistry. This new exam, the Integrated National Board Dental Examination (INBDE) will replace the current Part I and Part II of the National Board Dental Examinations in the near future [14]. It will pose a challenge for students and educators alike who are accustomed to traditional discipline-specific and silo-learning approaches.

A number of studies from various fields reported significant impact of interdisciplinary learning on critical thinking [15-19]. Interdisciplinary learning experiences using clinical case studies improve critical-thinking in allied health care graduate students [20]. For example, interdisciplinary teaching encourages dental students' critical thinking in pain management and anatomy courses [21,22]. While dental interdisciplinary teaching methods have been reported in the past decades [22-25], few studies have explored specific strategies for interdisciplinary question construction and its significance in assessing critical thinking.

Therefore, this report describes how we created an integrated examination including interdisciplinary critical thinking questions in an undergraduate periodontics course and surveyed students after examinations. The main purpose of this pilot study is to introduce a method to construct interdisciplinary assessment of critical thinking in dental education and to evaluate students' attitude and perception about the assessment.

Methods

Ethical approval has been granted from the Institutional Review Board of the University of Mississippi Medical Center (December 3, 2013. Protocol Number: 2013-0267).

Constructing Interdisciplinary Critical Thinking Questions

An integrated examination including interdisciplinary critical thinking questions was constructed. The process used in creating clinical case studies questions that are interdisciplinary in nature can be summarized in figure 1. An interdisciplinary team including three faculty from clinical sciences (periodontics, general dentistry and orthodontics) and two faculty from basic sciences (microbiology and anatomy) met to construct questions. Three to five clinical cases were selected by the periodontist for each exam and discussed by the team. Each member identified two or three questions for each case based on their expertise and presented these questions to the whole group. Open discussion was organized for reciprocal questions and education. Each team member addressed the contents they taught in their courses which were related to the case or other issues the patient may have from the perspectives of their expertise. The periodontist then evaluated the recommendations from all the team members and identified common themes in the questions. Questions that require interdisciplinary knowledge and critical thinking were created and refined by the team.

![Figure 1: Process of creating an interdisciplinary critical thinking question.](image-url)
To assess higher-order thinking via multiple-choice questions, several methods were used for question construction. Students were asked to apply a rule or principle, to show understanding of cause and effect, or to identify the reasoning behind a particular choice of action. The questions emphasized the relationship between systemic and oral diseases, disease diagnosis, health and prevention, and evidence-based dentistry principles. Figure 2 shows an example of this process (Example Question I). In this example, clinical data for a case diagnosed with chronic periodontitis in a 47-year-old woman is presented. The periodontist introduced general information about periodontal disease to the team and explained the clinical history, photographs, and charting. As team members discussed the case, histopathology of tooth #29 distal area became the focus of the interests. Histopathology images were collected from textbooks and peer-reviewed articles to present different possible situations. Images were slightly edited using cropping, caption removal and insert additional information to fit the case scenario. Two more interdisciplinary critical thinking question examples are presented in Appendices A and B. The team discussion focused on critical thinking during multiple edits of each question. The answer options included one correct answer and three to four distractors. All alternatives were plausible and were presented in similar length. It was important to insure that all distractors in the questions had the potential for being selected as the correct answer in order to increase plausibility.

Figure 2: An example of a case used for construction of an interdisciplinary critical thinking questions (Example Question I). The answer key is D. 
Note: Answer options A and C are excerpted from Lindhe and Lang, Clinical Periodontology and Implant Dentistry, 6th Edition. Answer option E is excerpted from Pocket Dentistry online resource. Answer options B and D are unpublished materials.)
Administrating Integrated Examination

The Web-based testing software Examsoft (Exam Intelligence, ExamSoft Worldwide, Dallas, TX) was used to embed microphotographs, chartings, radiographs, and video clips into question stems and answer options. All clinical images were collaged using Photoshop image editor software (Photoshop CS2, Adobe, San Jose, CA, USA), and the files were saved in JPEG format. These files were later uploaded to the questions in Examsoft. In Examsoft, if multiple pictures were added to the question as single collage images, the exam taker was able to move images and adjust the magnification of a specific area of interest. This simulates how clinical practitioners select an area of interest in piece of patient record in their clinical decision making. Patient interview and surgical procedure videos were created in periodontics clinic and laboratory at our institution, edited with Microsoft Movie Maker, and then uploaded to the questions in Examsoft. Short video clips were included with different periodontal probing techniques into answer options of one question. Additionally, there was one patient interview video into a clinical case studies demonstrating how the patient describes the pain she had.

Four integrated examinations included 90-106 multiple-choice questions in each, of which 44% questions were clinical case-based questions while 56% were non-case-based. Thirty-three percent of the case-based questions, which is about 15% of the total exam questions, required interdisciplinary critical thinking. The examinations were administrated to the second-year and the third-year dental students as the final assessment of their Periodontics I and II courses. In the following year, exams with about 90% same questions were given to the different classes. The students were required to keep the confidentiality of the exam questions. One hundred and five students were recruited in the study. Those who took two exams in two consecutive years (one in their second year and the other in their third year) and participated in the survey after each exam were counted as different subjects/responses in each year. The examination lasted for 120 minutes. Students completed the examination on their laptops. Immediate feedback and review function was set in ExamSoft to allow the students to receive their scores, review questions that were answered incorrectly, and read the answer rationales behind any question.

Assessing students’ attitudes towards the examination

To assess student attitudes towards the integrated examination, a novel survey instrument including 10 statements with a Likert scale of 1 to 5 was given to students after their completion of a periodontics final examination over two consecutive years. The survey assessed students’ perspectives on the integrated exam which included interdisciplinary critical thinking questions. Study participants were asked to indicate their level of agreement with each statement in the survey shown in table 1. The dependent variable response was measured on a five-point Likert scale, using the following weight: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree and 1 = strongly disagree. In the survey, “illustrated scenario questions” stands for case-based questions, while non-case-based questions were described as “traditional questions”. An open comment section was provided in the survey to collect qualitative data.

This survey instrument was validated and tested for content validity. It was tested for content validity and validated through two main methods: a) a panel of five faculty members with significant experience in survey construction provided feedback on each statement’s wording and the survey’s overall format and structure; and b) three respondents pilot tested the survey, and provided feedback on the survey’s content, Likert scale, overall structure, and clarity of items. Based on the feedback obtained from faculty members and respondents, the information in the survey was then modified and finalized.

The survey was conducted on paper after completion of the examination. Results were then manually entered into SurveyMonkey (SurveyMonkey Inc., Palo Alto, CA) for analysis. Student participation in the survey was anonymous and voluntary, and no identifiers were collected. For statistical analyses, responses were then imported into an IBM SPSS software for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). For analysis of the qualitative data, responses from the comment sections of the survey were collected in one Microsoft Word document. Comments were then coded to identify common themes presented by students.
Results and Discussion

One hundred and twelve survey responses were received over two consecutive years (a response rate of 81%). Attitudes of students regarding each statement are shown in Table 1. The survey instrument’s Cronbach’s alpha (reliability coefficient) was used to measure its internal consistency, and the coefficient was calculated at 0.718, indicating good reliability.

<table>
<thead>
<tr>
<th>Strongly Agree (5)</th>
<th>Agree (4)</th>
<th>Neutral (3)</th>
<th>Disagree (2)</th>
<th>Strongly disagree (1)</th>
<th>Average Rating</th>
<th>Standard Deviation</th>
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<tr>
<td>9 (8%)</td>
<td>39 (34%)</td>
<td>32 (28%)</td>
<td>31 (27%)</td>
<td>4 (3%)</td>
<td>3.16</td>
<td>1.02</td>
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<td>25 (22%)</td>
<td>56 (48%)</td>
<td>16 (14%)</td>
<td>14 (12%)</td>
<td>5 (4%)</td>
<td>3.71</td>
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<td>6 (5%)</td>
<td>51 (45%)</td>
<td>34 (30%)</td>
<td>22 (19%)</td>
<td>1 (1%)</td>
<td>3.34</td>
<td>0.88</td>
</tr>
<tr>
<td>49 (42%)</td>
<td>27 (23%)</td>
<td>9 (8%)</td>
<td>2 (2%)</td>
<td></td>
<td>3.81</td>
<td>0.96</td>
</tr>
<tr>
<td>6 (5%)</td>
<td>34 (29%)</td>
<td>34 (29%)</td>
<td>36 (31%)</td>
<td>6 (5%)</td>
<td>2.98</td>
<td>1.01</td>
</tr>
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<td>62 (53%)</td>
<td>20 (17%)</td>
<td>12 (10%)</td>
<td>4 (3%)</td>
<td></td>
<td>3.67</td>
<td>0.98</td>
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<td>3 (3%)</td>
<td>44 (38%)</td>
<td>38 (33%)</td>
<td>11 (9%)</td>
<td></td>
<td>2.71</td>
<td>0.95</td>
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<td>15 (13%)</td>
<td>78 (68%)</td>
<td>14 (12%)</td>
<td>6 (5%)</td>
<td>1 (1%)</td>
<td>3.88</td>
<td>0.73</td>
</tr>
<tr>
<td>8 (7%)</td>
<td>54 (47%)</td>
<td>34 (29%)</td>
<td>19 (16%)</td>
<td>1 (1%)</td>
<td>3.42</td>
<td>0.88</td>
</tr>
<tr>
<td>3 (3%)</td>
<td>59 (51%)</td>
<td>32 (28%)</td>
<td>18 (15%)</td>
<td>4 (3%)</td>
<td>3.34</td>
<td>0.89</td>
</tr>
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</table>

Table 1: Responses of students (n=112) in the study, by number and percentage of respondents to each statement.

Note: Percentages may not total 100% because of rounding

The majority of students (81%) agreed that illustrated scenario questions required them to evaluate data from several disciplines. When asked about taking illustrated scenario questions, 49% of students disagreed that case scenario questions were less stressful than traditional questions. Sixty-two percent of students agreed that illustrated scenario questions helped them develop a personal strategy for handling complex interdisciplinary exam questions.

When surveyed about course content, half of the students agreed that all important concepts were covered during the course classes and assigned readings. Approximately half of students agreed that they were able to understand what the questions were asking. When asked if the exam measured their understanding of periodontics only 34% thought the exam did this.

Students submitted twelve comments all expressing concerns about the examination, including statements that the examination was stressful, difficult, and confusing. A synopsis of themes and examples of student comments is shown in Table 2.

Major challenges in current educational methodologies include lack of cooperation between disciplines in health care education and difficulty in preparing objective assessments [26]. The current system of dental and the other health care education is still largely based on traditional discipline-specific and silo-learning approaches [25,27]. Students are not given sufficient guidance during their education to find the connections between disciplines and integrate basic and clinical sciences in clinical problem-solving. Lack of interdisciplinary faculty cooperation and faculty’s unfamiliarity of other courses could be associated with this failure, although lack of time and resources could also be reasons [26,28]. Using an interdisciplinary team to create interdisciplinary questions promotes interprofessional communication and faculty collegiality. Basic science faculty appreciate the significance of their discipline knowledge to clinical problem-solving, which should help them emphasize contents in class that can be applied in clinic. Clinical faculty benefit from this opportunity to refresh basic sciences knowledge and update scientific concepts, which would be fundamental for their evidence-based clinical teaching.

Methods to guide and assess critical thinking are essential in dental education. In this study, we intended to promote students’ critical thinking by implementing clinical case scenarios into questions that require interdisciplinary knowledge. In Example Question I (illustrated in Figure 2), students were required to read patient’s history, charting, photograph and radiograph and collect useful data for diagnosing, such as tissue inflammation, attachment loss, angular bone defect on distal of tooth #29. Healthy periodontal tissue from Option A needed to be recognized using knowledge from histology. In Option B, long junctional epithelium extends apically to the bone crest, which is usually not the result of non-surgical therapy. This pathological/physiological change needs to be identified, and combined with knowledge from periodontics, and Option B needed to be eliminated. Understanding the nature of inflammation and having microscopic vision into the tissue would help students narrow the options down to Options D or E, both of which containing infiltration of leukocytes in the gingiva. However, Option E presents the classic morphology of Fusospirochete in tissue smear which is typically associated with necrotizing ulcerative periodontitis. By integrating knowledge of microbiology and periodontics, the student should exclude this option. Therefore, the correct answer is Option D. Missing one or more of these thinking steps or interdisciplinary knowledge could lead to the wrong answer. In the other two question examples (Figures 3 and 4), clinical periodontal cases are integrated with medical laboratory diagnosis, pharmacology and pathophysiology. Students are supposed to be able to integrate the information they’ve learned from different courses to solve the clinical problems.

A new patient presents to you in the clinic. After review of the medical history the patient reports the following conditions and medications. Hypertension (Lisinopril), Hypercholesterolemia (Simvastatin), Arthritis (Mobic), Hypothyroidism (Levothyroxine), and Chronic Pain (Norco 5/325 prn). The patient states they take some other medications, but cannot remember the name of them or the reason they are taking them. A physician is consulted and testing is undertaken. Based on the below lab report you can determine what is the most likely medication the patient failed to report?

A. Acyclovir  
B. Boniva  
C. Coumadin  
D. Plavix  
E. Insulin

<table>
<thead>
<tr>
<th>Tests</th>
<th>Results</th>
<th>Units</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBC</td>
<td>6.9</td>
<td>x10^3/uL</td>
<td>4.0 - 10.5</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>29</td>
<td>%</td>
<td>14.0 - 46.0</td>
</tr>
<tr>
<td>Neutrophils</td>
<td>62</td>
<td>%</td>
<td>40.0 - 74.0</td>
</tr>
<tr>
<td>Lymphocytes (absolute) ALC</td>
<td>2.0</td>
<td>x10^3/uL</td>
<td>0.7 - 4.5</td>
</tr>
<tr>
<td>Neutrophils (absolute) ALC</td>
<td>4.3</td>
<td>x10^3/uL</td>
<td>1.8 - 7.8</td>
</tr>
<tr>
<td>Monocytes</td>
<td>7.0</td>
<td>%</td>
<td>4.0 - 13.0</td>
</tr>
<tr>
<td>RBC</td>
<td>4.59</td>
<td>x10^3/uL</td>
<td>3.8 - 5.10</td>
</tr>
<tr>
<td>Hemoglobin (Hg)</td>
<td>12.2</td>
<td>g/dL</td>
<td>11.5 - 15.0</td>
</tr>
<tr>
<td>Hemoglobin A1c</td>
<td>8.0</td>
<td>%</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>International Normalized Ratio (INR)</td>
<td>2.8</td>
<td></td>
<td>Therapeutic range 2 - 3</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>37.6</td>
<td>%</td>
<td>34.0 - 44.0</td>
</tr>
</tbody>
</table>

Figure 3: Example Question II of interdisciplinary critical thinking question. The answer key is C.
A 56 year old African American male patient presents to clinic. His medical history includes back and neck pain (for about 10 years), hypertension (diagnosed in 2010) and type II diabetes (diagnosed in 2014). He takes Naproxen, Metoprolol and Metformin. The dental record shows the patient had scaling and root planing in 2008 followed by 3 month maintenance visits until 2010 when he moves out the state. After you did a full perio chart, you noticed drastic changes since his last visit in 2010. What are the biological mechanisms that are most likely to contribute to this patient rapid decline in periodontal health?

A. Increased chemotaxis of fibroblasts in response to platelet-derived growth factor
B. Changes in collagen synthesis, maturation and turnover
C. Elevation of host-derived matrix metalloproteinases
D. A and B only
E. B and C only
F. A and C only
G. A, B and C

Figure 4: Example Questions III of interdisciplinary critical thinking question. The answer key is E.

Since a variety of knowledge needed to be recalled and integrated, only 20% of students thought that these “illustrated scenario” questions are “less stressful than traditional questions” (Table 1). Interestingly, 81% of students agreed that illustrated scenario questions required them to evaluate data from several disciplines. This indicates that students are aware that interdisciplinary knowledge is necessary for solving complex clinical problems, and this awareness has the potential to inspire self-directed interdisciplinary learning habits [29].

Nevertheless, some students had concerns about this integrated examination. As qualitative data demonstrate in table 2, several concerns were voiced that the examination was stressful, difficult, and confusing. This finding is consistent with the perspectives of dental students about the upcoming Integrated National Board Dental Examination, being stressful for senior students who are challenged to recall basic science information form earlier years in their training [30]. However, this definitely should not deter dental educators from integrated examinations that require students to memorize information learned in earlier years. Senior students are expected to assimilate information from earlier years and should not be granted their doctorates or dental license if they are unable to assimilate basic and clinical sciences into their clinical decision making processes.

In addition to commenting on the challenging nature of the integrated examination, four students in this study commented that they were not given enough time for the exam, even though approximately 1.2 minutes in average were allotted for each question. The students likely spent more time on case-based questions, which are less than half of the total questions. We speculate that a challenge of this sort of question to the students may not be related to the complex information in clinical scenario cases, but rather in how to look for useful and relevant data, and analyze the data in order to solve the problem. Some dental educators may choose to provide more time for each question since some students may be challenged by online exam technology or slow in their navigation of the multimedia embedded in the questions (i.e., images, video clips, etc.).

Multiple-choice questions are one of most common formats in professional education since they’re easy to administer, quick to score and they can test wide range of content areas. The disadvantage is that they may fail to mimic reality in which options are usually presented to be chosen. Some evidence suggests that the multiple-choice questions may be less effective in assessment of critical thinking than the “open-ended” question [10,31] because it does not reveal test-takers’ underlying reasoning for choosing a particular answer. However, a successful model in nursing education was developed to create critical-thinking multiple-choice questions, in which faculty were required to write questions at the application or above cognitive level and to include a rationale for each test item for review and requires answer options to have a high level of discrimination to choose from among plausible alternatives [32]. Tractenberg, et al. also found that multiple-choice questions targeting higher-order thinking can be successfully created without changing item difficulties [33].

To enrich our multiple-choice questions and increase their similarity to real life clinical cases, we embedded multimedia including clinical radiographs, chartings, microphotographs and videos into the questions. Traditional tests which generally lack real cases rarely replicate clinical or research realism. They are succinct but “filtered” and only provide relevant data, leading and focusing the test-taker towards the correct solution. In addition, they could limit the opportunity to evaluate real life evidence-gathering (reality), critical thinking, and decision-making skills [34,35]. Therefore, embedding multimedia provides more information than needed, and the process of organizing, prioritizing, and selecting information supports the development of critical thinking [36].

ExamSoft testing software allowed embedding multimedia into our computerized test. Sixty-nine percent of students agreed or strongly agreed that the images embedded in the scenario questions were clear and easily readable. Another advantage of the computer-based exam, ExamSoft software enabled test-takers to return to the test after completion, and to review the questions by disclosing keys and reading rationales, giving students the benefit of informative and immediate feedback on their performance in the exam. In this study, 67% of students agreed that providing correct answers after the exam in an immediate review enhanced their learning of concepts.

During the construction of our examinations, every effort was made to avoid information overload. Cognitive load theory describes that learning is impaired when the cognitive load of a task is greater than an individual’s working memory [37,38]. Therefore, if students are given too much information within limited time, particularly under the pressure of a high-stakes examination, few would be able to reflect on missed questions or erroneous thinking, even with the provided keys and rationales given immediately after the test. Limited video inserts were considered to avoid overwhelming information load. In the present study, 4 – 10 images per a clinical case study and only one or two videos in total were embedded into the case-based questions. Most of the exam questions (56%) were the non-case-based questions, or “traditional questions”, which our students are more familiar with. Two thirds of the case-based questions did not require

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interdisciplinary critical thinking. The purpose of this composition was to allow students to have enough time to manage the new type of questions and self-analyze their thinking while reviewing. The student survey showed that 54% of students thought that the balance in numbers of “traditional” (non-case based) questions compared to numbers of “illustrated scenario” (case based) questions was acceptable, while only 19% disagreed.

This study has a number of limitations that should be acknowledged. First, the integrated examination was limited to multiple-choice questions. While this examination format is widely used in dental education, other forms of assessment such as constructed response (short answer, essay questions or objective structured clinical examination (OSCE) questions) could have been used to assess and promote critical thinking and problem-solving skills. Second, because the students hadn’t received training in interdisciplinary critical thinking questions on previously, including 15% of these questions on an exam with a total number of exam questions (90 - 106) within 2 hours increased student self-reported stress and may have led to students’ to have negative impression of the complex integrated clinical case exam. Third, qualitative data in this study were limited and should be interpreted as areas of concerns raised by students and not findings of the study that are sufficient to create conclusions. Further studies can be made to compare students’ performance on the different types of questions such as case-based versus non-case-based, or interdisciplinary versus non-interdisciplinary.

Conclusions

Creating interdisciplinary questions provides a path for faculty to promote communication, collegiality, and faculty development. In addition, students may benefit from thought-provoking exam questions that are based on real-life clinical case studies, a significant advantage that allows educators to promote their students’ higher-level cognitive skills. It is essential to prepare students to actively think about these situations and prepare them to analyze the types of clinical situations they will encounter in their future integrated national board examination and clinical practice.

Students appear to be accustomed to the course-by-course study mode and would benefit from integrated examinations requiring critical thinking. These examinations will encourage them to create linkages between basic and clinical sciences. Whereas integrating knowledge of basic and clinical sciences in problem-solving process is challenging or difficult for students, it remains in their best interest.

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Conflict of Interest

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Bibliography


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