Concept mapping in health sciences education: Conceptualizing and testing a novel technique for the assessment of learning in anatomy

Natalia Bilton[2], John Rae[2], Patricia Logan[2], Gregg Maynard[2]

Abstract

Research has shown that students feel overwhelmed by the amount of information covered in first year anatomy and physiology subjects (Eagleton, 2015). In this paper, we present an activity designed to facilitate learning of the organization of the human skeletal system and anatomical directional terms used to help describe it. Learning styles and the effect of body painting was also investigated.

Two studies are described and each were analysed separately both quantitatively (pre- and post-test scores) and qualitatively (surveys).

Body painting did not affect the number of directional terms included in the concept maps. The most common term used was "superior" and the least was "superficial". Students applied the greatest number of directional terms to the lower limb, upper limb and vertebral column. Knowledgeable students gained no benefit from the body painting activity and from completing the concept map test a second time, whereas, the students who were naïve to the content benefited significantly from repeated testing and from body painting.

Students need scaffolding, practise and feedback to construct concept maps. Adapting the concept map tests increased student engagement and the objectivity of scoring. Learning style did not have an effect on learning outcomes of the students in this study.

Keywords: concept map; anatomy; undergraduate; body painting; learning styles

Introduction

Students working towards a degree in the Health Sciences are required to undertake a first year subject in anatomy
and physiology vary significantly in their education prior to university (Anderton, Evans, & Chivers, 2016). Unfortunately, many of these students either drop out or decide to repeat these subjects before progressing in their chosen field (Entezari & Javdan, 2016; Schutte, 2016). Students have previously stated that they underestimate the amount of content and comprehensiveness of a first year anatomy and physiology subject and that the teaching methods used can influence their ability to learn the content (Eagleton, 2015).

In the studies presented here, we wanted to design a learning activity that was efficient. A learning activity that can be undertaken in a laboratory setting and that focused on the learning of two topics simultaneously. Furthermore, we were interested to see whether adding a learning activity that contained elements of all learning styles, influenced learning about the human skeletal system.

Learning can be defined as the cognitive change that results from experience (Hay, 2007). The construction of new knowledge begins with our observations of events or objects through the concepts that we already possess. Concept mapping is a technique that can be used to help students learn meaningfully in medical education (Daley, Durning, & Torre, 2016). In concept mapping, a concept is defined as anything that can be observed and a proposition is created when two or more concepts are linked by key words. To learn meaningfully, individuals must choose to relate new knowledge to relevant concepts that they already know (Merriam & Bierema, 2013). Meaningful learning is supported when students join concepts with relevant, correct and valid linking phrases. An increase in learning quality is indicated by the integration of new information with old information using linking phrases.

Surface anatomy is a part of living anatomy. In their working life, paramedics, nurses and other health professionals will encounter the body as living anatomy as opposed to the two dimensional structures and animal specimens encountered in the traditional laboratory session. Body painting as a learning activity has previously been used with medical students (Bennett, 2014; Bergman et al., 2013; Finn & McLachlan, 2010; Finn, White, & Abdelbagi, 2011; McMenamin, 2008) and have concentrated on the muscles, facial nerves and dermatomes (Finn & McLachlan, 2010; McMenamin, 2008).

The aim of this study was to conceptualise, design and test the technique of concept mapping as applied to the organisation of the human skeletal system and to evaluate the effect that learning style has on students’ learning outcomes.

**Method**

**Participants**

The participants were first year undergraduate students undertaking an introductory subject in anatomy and physiology. The study was carried out across three campuses of Charles Sturt University. The campuses were located in Wagga Wagga, Dubbo and Port Macquarie. The participants were recruited via a written request and given an invitation to participate and an information sheet prior to the commencement of the study. Students did not receive payment or reward for their participation. This study was approved by the Charles Sturt University Faculty of Science Human Research Ethics Committee (Approval Number 400/2016/06).
Procedure

Study 1

The study was carried out during the students’ normally scheduled laboratory class. Firstly, the instructor presented a brief introduction to concept mapping then students formed into groups of four or less. Each group was given a maximum of 30 minutes to complete the first concept mapping task (Fig. 1).
Group Name: ______________________

Test 1: This first test is designed to measure how much your group already knows about the organizational structure of the skeletal system.

Please peruse the concept map below.

Working in groups, your task is to add to this concept map to include as many of the concepts on the left hand side as you can. But wait! Before you start…. There is one rule you should follow when building the concept map. Each concept must be linked to another concept at least once.

Here are some examples of linking phrases that you could use.

- Is comprised of
- Are superior to
- Is inferior to
- Is anterior to
- Is lateral to
- Is medial to
- Are posterior to
- Is proximal to

It doesn’t matter what linking phrase you use as long as it says something about the relationship between the two concepts. You have 30 minutes to complete this test.

Once your group has finished, please give your concept map to your lab demonstrator.

Figure 1: The concept map test that was administered to students in Study 1.

When the testing time was over, the instructor collected all of the concept maps and then randomly assigned each group of students into either the experimental or control condition.
The students in the experimental condition undertook a series of body painting activities that included identifying bones using surface anatomy and painting the underlying structures (see Appendix 1 for details of this activity). The students in the control condition followed the exercises as described in a laboratory manual which included labelling diagrams, answering short answer questions and inspecting models of the human skeleton. Students undertook their assigned learning activity for approximately one hour. After this, all of the groups were given Test 2, which was identical to test 1 and a brief survey. The students were asked the following questions: Does the first concept map look different to the second? If yes, how? Did you enjoy today's learning activity? If so, why? / If not, why not? Did today's activity help you in your learning of the skeletal system? If yes, how? / If not, how did it not? How do you learn best? Choose the answer which best explains your preference and tick the box next to it. Please tick more than one if a single answer does not match your perception.

- **Visual** – This preference includes the depiction of information in maps, spider diagrams, charts, graphs, flow charts, labelled diagrams, and all the symbolic arrows, circles, hierarchies and other devices that people use to represent what could have been presented in words.

- **Auditory** - This perceptual mode describes a preference for information that is "heard or spoken." Learners who have this as their main preference report that they learn best from lectures, group discussion, radio, email, using mobile phones, speaking, web-chat and talking things through.

- **Read/Write** - This preference is for information displayed as words and emphasizes text-based input and output – reading and writing in all its forms but especially manuals, reports, essays and assignments.

- **Kinaesthetic** - By definition, this modality refers to the "perceptual preference related to the use of experience and practice (simulated or real)." It includes demonstrations, simulations, videos and movies of "real" things, as well as case studies, practice and applications.

Each concept map was scored using a modified version of Novak and Gowin's (1984) scoring method. Our measure of meaningful learning was the extent to which students correctly linked concepts with linking phrases in their concept maps. One point was assigned to each occurrence of this.

**Study 2**

At the beginning of the class, each student completed the VARK questionnaire. The questionnaire was scored and each student wrote their learning style on a whiteboard. Next, all students were given a scaffolded concept mapping activity (Appendix 2) then they were given 20 minutes to complete Test 1 (Fig. 2). The questionnaires and tests were then collected. After this, the class was split into two groups, each containing approximately the same number of students in each learning styles category. Then one group was designated the control and the other as the experimental group. The students in the experimental and control conditions undertook the same activities as describe in study 1. After this, the students were given Test 2, which was identical to Test 1 and a short survey. Finally, all students swapped activities to ensure equity in their learning.
Results

Study 1

A total of 46 groups of students volunteered their concept maps and survey data to study 1. One group of students submitted the first but not their second concept map. There were 22 groups in the control condition and 24 groups in the experimental condition. One group in the control condition and three groups in the experimental condition did not add to the concept map as instructed. These groups listed bones in point form, some in no logical order and another lacked hierarchical organisation (Fig. 3A). Four groups in the control condition and 5 in the experimental condition attempted the concept mapping task but their concept maps did not contain any linking phrases. These groups joined concepts with lines and others showed limited hierarchical organisation (Fig. 3B).
Figure 3: Samples of student work illustrating that some participants did not create a concept map at all (A). Samples of student work showing that some groups did not link the concepts with linking phrases when adding to their concept maps (B).

The remainder of the concept maps that were volunteered to the study were constructed as instructed. Figure 4 shows an example of one group's work. These concept maps were analysed with respect to the inclusion of general and directional terms in correctly linked concepts. General terms were defined as "comprised of", "is composed of" and "is made up of". Directional terms were superior, inferior, proximal, lateral, medial, anterior, posterior, distal and superficial.
Figure 4: An example of the type of concept maps that were produced by the students in study 1. The use of general terms in correctly linked concepts are coloured green and directional terms are coloured red.

The students that did the body painting activity used a lower number of general terms in their concept maps (Mean Rank = 12.38, n = 16) when compared to those that were constructed by the students that undertook the regular laboratory activities (Mean Rank = 21.35, n = 17, U = 62.00, z = -2.70 (corrected for ties), p = .007, two-tailed). This effect can be described as between "medium" and "large" (r = .47), and is illustrated in Figure 5A.

Both groups of students, whether they did body painting or not, constructed concept maps that contained an average of between 6 and 8 directional terms, t(31) = -0.960, p = .344, two-tailed (Fig. 5B).

Given the finding above, the remainder of our analyses include data from the entire cohort of students. The most common directional term used in the concept maps constructed by the students was "superior" and the least common term used was "superficial". Figure 5C shows how often each directional term was used in the concept maps that were analysed in study 1 (H = 64.81, df = 8, N = 33, p = .00).

Finally, we wanted to establish where the students applied the most directional terms in their concept maps. Our analyses showed that students applied the greatest number of directional terms to the lower limb, upper limb and vertebral column. Figure 5D shows how often each area was found to contain the highest number of directional
terms. A chi-square test on this data was significant $X^2 (2, N = 27) = 6.22, p<.05$, indicating that the highest number of directional terms were found in the lower limb branches of the skeletal system concept maps.

The learning style of the student did not affect the number of directional terms included in their concept map. To estimate the proportion of variance in directional terms used that can be accounted for by preferred learning style, a standard multiple regression analysis was performed. It was found that, in combination, preferred learning style accounted for 11.7% of the variability in the number of directional terms used, $F (4,25) = 1.964, p = .131$.

Figure 5: The distribution of general terms used in each condition of study 1 (A). The average number of directional terms used in the experimental and control conditions (B). The ranking (from the least popular to the most) of the directional terms used in the concept maps (C). The part of the concept map where most directional terms were used as a percentage of the entire sample (D).

Study 2

A total of 99 students participated in study 2. The number of students in each condition were 39 and 46 in the control and experimental groups, respectively. Fourteen students were excluded from the analyses due to missing data.
Table 1 shows the mean values for each of the variables in study 2.

**Table 1.** The average scores for each VARK category and the correct number of bones and directional terms in each test and condition in study 2.

<table>
<thead>
<tr>
<th></th>
<th>Visual</th>
<th>Auditory</th>
<th>Read/Write</th>
<th>Kinaesthetic</th>
<th>Test 1 Bones</th>
<th>Test 1 Terms</th>
<th>Test 2 Bones</th>
<th>Test 2 Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.94</td>
<td>4.09</td>
<td>4.47</td>
<td>7.34</td>
<td>9.53</td>
<td>3.63</td>
<td>10.69</td>
<td>4.88</td>
</tr>
<tr>
<td>Experimental</td>
<td>3.76</td>
<td>3.79</td>
<td>5.08</td>
<td>6.47</td>
<td>9.55</td>
<td>3.42</td>
<td>10.87</td>
<td>5.24</td>
</tr>
</tbody>
</table>

A mixed model ANOVA was conducted using the following factors. The between subjects factor "Group" had two levels (control vs experimental). The within subjects factor "Test" had two levels (Test 1 vs Test 2). The dependent variables were the number of correctly labelled bones and the number of correctly used terms in Test 1 and Test 2.

Figure 6. (A) shows the number of bones correct in tests 1 and 2 for the two conditions of study 2. (B) is the number of terms correctly placed in the concept map tests 1 and 2 for each condition of study 2.

Overall, the students did better in their second test compared to the scores in their first test. This was true for both the bone labelling ($F(1, 78) = 30.93$, $p < .01$) and the anatomical directional terms ($F(1, 78) = 33.25$, $p < .01$). It was clear that the body painting activity did not have an effect on test scores in our study when the data set was analysed as a whole.
The higher you score on the Visual learning style category on the VARK questionnaire, the more bones you correctly label in the first test. Furthermore, higher scores in the kinaesthetic category were associated with higher bone labelling scores in the second test (Table 2). It must be stated, however, that when we plotted the data we found that our test scores had a clear ceiling. We found that 34% of the students got all of the bones correct and 11% got all of the terms correct in Test 1. Nine percent of the students got all of the bones and all of the terms correct in Test 1. In order to determine if the ceiling in our data influenced possible outcomes, it was decided to split the entire data set into two groups. The students who got all of the bones or got all of the terms correct in the first test were denoted "Knowledgeable" and analysed separately to the rest of the student cohort, which were denoted "Learners".

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<table>
<thead>
<tr>
<th>Variable 1</th>
<th>Variable 2</th>
<th>r</th>
<th>p</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Learning Style Score*</td>
<td>Number of bones correct in Test 1</td>
<td>.258</td>
<td>.024</td>
<td>76</td>
</tr>
<tr>
<td>Kinaesthetic Learning Style Score*</td>
<td>Number of bones correct in Test 2</td>
<td>.248</td>
<td>.038</td>
<td>70</td>
</tr>
<tr>
<td>Number of bones correct in Test 1</td>
<td>Number of directional terms correct in Test 1</td>
<td>.602</td>
<td>.000</td>
<td>88</td>
</tr>
<tr>
<td>Number of bones correct in Test 1</td>
<td>Number of bones correct in Test 2</td>
<td>.648</td>
<td>.000</td>
<td>80</td>
</tr>
<tr>
<td>Number of bones correct in Test 1</td>
<td>Number of directional terms correct in Test 2</td>
<td>.552</td>
<td>.000</td>
<td>80</td>
</tr>
<tr>
<td>Number of directional terms correct in Test 1</td>
<td>Number of bones correct in Test 2</td>
<td>.287</td>
<td>.010</td>
<td>80</td>
</tr>
<tr>
<td>Number of directional terms correct in Test 1</td>
<td>Number of directional terms correct in Test 2</td>
<td>.575</td>
<td>.000</td>
<td>80</td>
</tr>
</tbody>
</table>

* From the VARK Questionnaire

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Figure 7. The number of bones correct (A) and directional terms (B) for each of the two student cohorts identified.
in study 2.

The students that already knew all of the bones and directional terms gained no benefit from the body painting activity and from doing the concept map test a second time. For the bone data, we found that the main effect of Test was significant only in the Learner group (F (1, 50) = 42.19, p <.01). The students that were unfamiliar with both the bones and the terms, significantly benefited from doing the test a second time and from the body painting activity. The main effect of Test was significant for both the Knowledgeable (F (1, 26) = 5.56, p <.05) and Learner students (F (1, 50) = 28.00, p <.01).

There were 83 students that contributed their VARK scores. Seventy four fell into one category, 8 fell into 2 and one student scored the same across three categories. A 2 x 4 mixed ANOVA was conducted to determine if learning style influenced bone recall or the use of directional terms. For the bone data, the only significance was in the main effect of Test (F (1, 61) = 8.93, p <.01, Fig 8A). A similar result was found for the term data, where the only significant main effect was in the Test within subjects factor (F (1, 61) = 13.25, p <.01, Fig8B). In our study, whilst learning style did not have an effect on test scores, an interesting trend was observed. A clear rank of learning styles was observed that described the test scores from highest to lowest. The ranking followed this pattern: kinaesthetic (highest), visual, read and auditory (lowest).

Figure 8. The number of correct bones (A) and directional terms (B) attained in each concept map test study 2. The data is divided into learning style categories which are based on student's responses on the VARK Questionnaire.

Qualitative Analyses

Body painting is considered to be more fun than traditional, albeit engaging, teaching methods amongst health professional undergraduate students who would otherwise focus more on the actual tasks of the learning activity.
The student experiences for the control groups and the experimental groups were similar. That is, lessons were generally considered to be enjoyable and were perceived to have assisted the students in their learning of anatomy. This may not be surprising since the learning activities offered to both groups were relevant and interactive, just in different ways.

### Student experience

#### Study 1

<table>
<thead>
<tr>
<th>Did you enjoy today's learning activity?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control group</strong></td>
<td><strong>Experimental group</strong></td>
</tr>
<tr>
<td>Yes</td>
<td>17</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>Partially</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Did today's activity help you in your learning of the skeletal system?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control group</strong></td>
<td><strong>Experimental group</strong></td>
</tr>
<tr>
<td>Yes</td>
<td>19</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
</tbody>
</table>

#### Study 2

| Do you think that today's activity helped you in your learning of the skeletal system? |  |
|--------------------------------------------------------------------------------||--|
| **Control group** | **Experimental group** |
| Yes | 17 | Yes | 18 |
| No | 4 | No | 3 |
| Partially | 3 | Partially | 2 |

### Themes

#### Study 1

<table>
<thead>
<tr>
<th></th>
<th><strong>Control group</strong></th>
<th><strong>Experimental group</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fun (2)</td>
<td></td>
<td>Fun (8)</td>
</tr>
<tr>
<td>Learning (10)</td>
<td></td>
<td>Learning (4)</td>
</tr>
<tr>
<td>Visual (3)</td>
<td></td>
<td>Visual (6)</td>
</tr>
<tr>
<td>Practical/hands-on (3)</td>
<td></td>
<td>Practical/hand-on (5)</td>
</tr>
<tr>
<td>Interactive (2)</td>
<td></td>
<td>Interactive (2)</td>
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</table>

#### Study 2

<table>
<thead>
<tr>
<th></th>
<th><strong>Control group</strong></th>
<th><strong>Experimental group</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiz (5)</td>
<td></td>
<td>Fun (12)</td>
</tr>
<tr>
<td>Looking at bones (11)</td>
<td></td>
<td>Remembering (2)</td>
</tr>
<tr>
<td>Laboratory manual (11)</td>
<td></td>
<td>Interactivity (4)</td>
</tr>
<tr>
<td>Visualisation (4)</td>
<td></td>
<td>Visualisation (4)</td>
</tr>
<tr>
<td>Learning style assessment (3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. Outcomes from the qualitative research analysis of the survey data from studies 1 and 2.
When student comments were themed, the data suggest some similarities between control groups and experimental groups, especially in study 1. However, an outstanding feature, especially in study 1, was that ‘fun’ was more often referred to by members of the experimental (body painting) group, and 'learning' was more frequently referred to in the control group. ‘Fun’ was referred to frequently by experimental group participants in the second experiment too, but not at all by control group participants in that experiment. Instead, those control group participants referred to ‘looking at bones’ and also the ‘laboratory manual’.

Discussion

Students need practise, time and feedback to successfully construct a concept map, and when they do, their creations may look very different to what you would be expecting. Combining the concept map with a fill-in-the-blank activity increased engagement with the task and made scoring it more objective. The learning style of the student had no effect on the learning outcomes in this study. Students that were naïve to the content were the ones that benefited most out the concept mapping and body painting techniques.

There is limited literature where concept mapping was used to teach biology in the tertiary setting. Concept maps have been used to teach exercise physiology (Henige, 2012) and work has been undertaken to automate the scoring using Cmap (Correia & Cicuto, 2014). One study examined how student's concept maps can be compared to those of experts (McGaghie, McCrimmon, Mitchell, & Thompson, 2004) and other work has focused on teaching concept mapping and analysing the outcomes qualitatively (Briscoe & LaMaster, 1991; B. J. Daley, 2002). No study to date, has combined the teaching methods that are described in this paper. Quantitative analysis of learning data in controlled conditions such as in our study is absent from the literature.

To make sure all students benefit from these activities, more terms and bones should be added to the concept map test. This would serve to remove the ceiling that we observed in our data.

Take Home Messages

- The organisation of the human skeletal system can be learnt in conjunction with anatomical directional terms in one learning activity.
- Students that are naïve to the content are the ones that benefit the most out of concept mapping and body painting.
- Scaffolding tasks, practise and feedback is needed to teach students how to construct concept maps effectively.

Notes On Contributors

Natalia Bilton received her PhD from the University of Newcastle. She has 16 years’ experience teaching student cohorts ranging from first year science to third year medical students. She currently lectures at the School of Biomedical Sciences and her research interests are grounded in alternative pedagogies and creative teaching in anatomy and physiology.

Dr. John Rae is a Senior Lecturer and Associate Head in the School of Biomedical Sciences, Charles Sturt University, Australia. John uses art as a teaching strategy for these courses and applies arts-based research to his
main topic of investigation, the creativity of health services.

Dr. Patricia Logan, PhD, SFHEA UK. Patricia has been teaching anatomy, physiology, pathophysiology and introductory pharmacology for more than 15 years. Her main research areas are related to tertiary science education for health practice

Gregg Maynard's first lecturing position was at Sydney University in the Faculty of Pharmacy. As of 2010, he has been employed at Charles Sturt University as a lecturer in pharmacology. During this time he has been involved in Pharmacy, Dentistry, Paramedic and Nursing education in pharmacology and related disciplines.

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Appendices

Appendix 1

Student Guide to Body Painting

1. Decide who will be the artist and which one will be the canvas to start with. If you prefer, both of you can alternate between these roles! It’s entirely your choice.
2. Use Figures 1 – 3 to identify the cranium, facial bones and skull on your canvas. Use the body paint or marker to label these.
3. Use Figures 4 and 5 to identify the approximate location of the vertebral regions on your canvas. Use the stickers to label these and stick these on top of the canvas’s clothing. Include the region and the number of vertebrae in your label.
4. Use Figure 6 identify the ribs, sternum and thoracic cage on your canvas. Use the stickers to label these as in step 3 above.
5. Use Figures 7 and 8 to identify the clavicle, scapula and pectoral girdle on your canvas. Use the paint or marker to label these.
6. Use Figures 9 and 10 to identify the bones of the upper limb. Draw the outline of the bones on your canvas with the marker, paint them white and label them.
7. Use Figures 7, 12 and 13 to identify the bones of the lower limb. Draw the outline of the bones on your canvas, paint them white and label them.
8. You’re all done! Step back and admire your beautiful artwork.

Appendix 2

What is concept mapping?
Concept maps are graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts.

We are going to use concept maps to explore human anatomy and learn key anatomical terms.

Relational terms

When we are mapping a geographical location we use directional terms like east, west, north and south. We say, for example, that Uluru is east of Perth but west of Sydney. A concept map about Uluru's location might look something like this:

![Concept Map of Uluru's Location]

When we talk about anatomy we use specific terms to describe how different parts of the anatomy relate to each other.
Match the term to the correct definition:

1. Superior  
   a. Nearer to the front of the body
2. Inferior  
   b. Away from the surface of the body
3. Anterior  
   c. Farther from the attachment of a limb to the trunk
4. Posterior  
   d. Towards the head
5. Medial  
   e. Farther away from the midline of the body
6. Lateral  
   f. Away from the head
7. Proximal  
   g. Nearer to the back of the body
8. Distal  
   h. Nearer to the midline of the body
9. Superficial  
   i. Nearer to the attachment of a limb to the trunk
10. Deep  
    j. Towards the surface of the body

Starting our mapping: the anatomy of the upper limb

We are going to start by mapping the anatomy of the upper limb. Use the word bank below to fill in the blanks in this concept map.

Word Bank → Is lateral to     are proximal to        the carpals
What score did you get out of 3? Write your score here: _____________

**Declarations**

*The author has declared that there are no conflicts of interest.*

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