


Question Formulation Skills Building Among Dental Hygiene Students: A Randomized Controlled Trial

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Purpose: Dental hygiene students at our institution learn Evidence Based Practice skills during their first year. We noted over the years that students markedly improved their formulated questions after training and application of their skills with the assistance of a rubric.

Research Question: How much training do students require in order to use the question formulation rubric effectively: a brief 5-minute overview or a 25-minute training that includes a student peer assessment application exercise?

Methods: Randomized controlled trial. All pre-randomized 24 students took the question formulation pre-test on the first day of the course on January 22nd. As expected, there were no statistical differences between the Intervention or Control group pre-test scores. The instructors administered the post-test on February 19th after the Intervention group had received the training and rubric with the Control group only having received the rubric with a brief explanation.

Results: The investigators employed a paired t-test to analyze the pre- and post-test score differences for each student in the Intervention and Control groups. Surprisingly, the students' average post-test scores were 41.75 for the Control group and 43.67 for the Intervention group on a 70-point scale, which were not markedly different. The initial paired t-test of the post-test scores confirmed no statistical difference either. Further analysis revealed that six (6) students in the Control group scored considerably higher than their classmates. Interviews discovered that four (4) of these students collaborated with their fellow students in the Intervention Group following the instruction so they actually did benefit from peer instruction. In other words, some contamination occurred. The other two (2) students learned and practiced alone using the rubric.

Conclusions: Additional analysis suggests that dental hygiene students benefit by experiencing extra instruction, with the cautionary caveats that this study was limited by some contamination and that it took place during the Covid-19 era.

Introduction

The modern dental hygienist must be well-versed in the concepts and skills of Evidence Based Practice (EBP).¹ Dental Hygiene degree programs regularly teach EBP skills to meet this need.^{2,3,4,5} The EBP process begins with the question formulation step followed by searching for the best available evidence to answer that question. The skill of asking an EBP question that will yield an answer requires training and practice.⁶

The initial EBP step of question formulation has commonly used a four-part system known by its acronym of PICO. This system consists of identifying the Patient, the Intervention, a Comparison, and an Outcome. This system works for those EBP questions relating to treatment, but not for the other estimated 50% of questions in EBP.⁷ Most of those other EBP questions relate to diagnosis, prognosis, or epidemiological aspects of patient care.^{8,9} PICO also becomes problematic or at least inconclusively effective in positioning the practitioner for the second EBP step of searching for the best available evidence.^{10,11,12}

At the University of New Mexico, we had observed our dental hygiene students struggling

with the PICO system in our EBP training sessions for several years, lending practical credence to the aforementioned research that had found deficiencies with PICO. One reason for students struggling might be that most dental hygiene questions raised in EBP sessions related to diagnosis, epidemiology, or dental materials rather than the overriding treatment orientation of PICO. While a number of EBP question formulation frameworks exist,¹³ these seemed most relevant to health information practitioners rather than to dental hygienists. An alternative and more recent question formulation and rubric system known as FAC (Focus, Amplify, Compose) had demonstrated promising results in producing effective EBP questions¹⁴ so we tried the FAC framework and rubric with our dental hygiene students. The Center for Teaching Innovation at Cornell University defines a rubric as “a type of scoring guide that assesses and articulates specific components and expectations for an assignment.”¹⁵ Rubrics are increasingly common in health professions education to articulate criteria and expectations of student performance^{16,17} and had been used routinely at our institution for over a decade. The FAC framework and rubric seemed to work well in other curricula so we decided to test it with a randomized controlled trial with our dental hygiene students.

Our hypothesis was that our dental hygiene students, once oriented to the rubric for 5 minutes and trained for 25 minutes on the FAC question formulation approach, would score better by a statistically significant margin compared to students only oriented for 5 minutes on the rubric.

Methods

This randomized controlled trial employed a single-center, parallel-group, two-arm pre-test/post-test design to compare the effectiveness of two different training approaches involving undergraduate dental hygiene students using a question formulation rubric. This randomized controlled trial in a dental hygiene course involved 24 undergraduate students who had completed prerequisite basic sciences courses such as anatomy and physiology courses alongside hundreds of other undergraduate students. The dental hygiene course met once per week for three hours. Using a random number generator, the authors randomized 12 students into a Control group that received a brief explanation of a rubric for question formulation in a class session separate from the Intervention group. The 12 students randomized into the Intervention group received separate instruction and engaged in hands-on exercises aligned with the rubric. The authors measured student improvement in both the Control group and the Intervention group using an identical pre- and post-test. The authors received University of New Mexico Human Research Protections Office approval # 19-008 on January 10, 2019. The detailed methods description follows.

Pre-Test

The authors asked students on the first day of the course on January 22nd to formulate a question prompted by a baseline clinical vignette that served as the pre-test, identifying themselves with unique four-digit numbers known only to them:

You are a dental hygienist at a rural clinic in northern New Mexico. Today you are enjoying your career, even though you miss your dental hygienist student friends back at the University of New Mexico. You are caring for Chris Garcia, age 38, who has multiple sclerosis (MS). Chris is wheelchair bound and experiences muscle weakness with occasional episodes of losing coordination in one or the other arm. This is a moderate form of MS according to the McDonald

diagnostic criteria scale. Chris has never smoked tobacco and only drinks socially on an occasional basis. Chris' vital signs are 120/70 mmHg blood pressure, pulse 74 beats per minute, and 15 breaths per minutes for respirations. You are trying to determine the best way to assess and treat Chris' plaque buildup due to a lack of access to any dental services over the past five years.

The students were directed to: "Formulate a question based on this clinical vignette that, when answered by the dental hygienist or other colleagues, will lead to the best treatment of this patient. Take no longer than five (5) minutes. Write legibly."

Intervention

On February 5th the students received their introduction to EBP. In a separate classroom apart from their other classmates, the Control group students received a 5-minute overview of the rubric and then trained on EBP searching skills during the remaining class time. The Intervention group met separately for their own group's training. Intervention group students first answered on their own the question, "Why do you think that formulating answerable questions will be important for your individual professional education and for your career?" Five students shared their answers with other members of the Intervention group. The Intervention group then received the identical search training as the Control group. In addition, the Intervention group also learned question formulation skills during a separate 25 minutes training session that aligned with the rubric (Figure 1) in an active learning^{18,19,20} environment with hands-on application, student peer assessment, and peer coaching elements. David A. Kolb's Experiential Learning Cycle²¹ of concrete experience, reflective observation, abstract conceptualization, and active experimentation informed creation of these learning experiences.

UNM School of Medicine
Dental Hygiene 205 Course
EBD Question Formulation
Jon Eldredge, PhD

Rubric for Evaluating Formulated EBD Questions

Element	Points
Focus	
Identifies and focuses upon the main problem or disease	15
Minimizes “noise” in formulated question by removing unneeded elements	5
Amplify the signal in the question, only if applicable, with:	
• Descriptive Adjectives (Examples: acute/chronic, reversible/irreversible, proximal/distal, sharp/dull)	5
• Scale: stages or levels of disease. Examples: staging of caries or periodontal disease	2
• Temporality (Examples: duration of illness; length of treatment; seasonality, etc.)	2
Describes the population aspects: age, geography, ethnicity, income, comorbidities, etc.	6
Composition:	
Question accurately reflects any relevant contextual details, <i>if applicable</i> : Examples: • Two or more diagnostic methods or types of treatment • Measures or exposure • Key details from a vignette or patient presentation Others	5
The final formulated question “stands by itself”	10
TOTAL POINTS (out of 50 possible points)	<u> </u> /50

Comments:

If Not Applicable: Full points given in the above rubric if item does not apply to the scenario or question prompt.

Assignment:

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Scale and Population amplification criteria updated during discussion with Dental Medicine faculty and residents 8/5/22
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Figure 1. Rubric for Evaluating Formulated EBD Questions

Post-Test

Two weeks later on February 19th, the instructors administered the post-test to measure the amount of improvement in question formulation skills that had been retained beyond only a few hours or days in the Intervention and Control groups. All students had ongoing access to the rubric the two-week interim and during the post-test assessment. Following the post-test, all students received the question formulation training in class that only the intervention group initially had received to adhere to the ethical principle of equalizing the treatment between groups. Students in the Intervention group paired up with Control group students to practice question formulation skills by writing questions of their own. All students completed a question formulation exercise as part of a graded course assignment once both Control and Intervention groups had received the same training. The two authors scored the pre- and post-tests using the rubric depicted in Figure 1. On the few occasions where their scores

differed, the authors discussed and resolved their scores. The campus Clinical and Translational Center statistician and the authors analyzed total pre-test and post-test scores using a t-test with the Stata statistical packageTM.

Results

All 24 students took the question formulation pre-test on the first day of the course on January 22nd. The two instructors scored the students' formulated questions with the students' identities concealed. Table 1 describes the average age, the gender, and final course grade for each student allocated aggregated into either Control or Intervention groups. Table 1 indicates that the two groups were demographically the same. As expected, there were no major differences between the Intervention or Control groups' pre-test scores (Table 2). On a 70-point rubric, Control group students scored 14.67 and the Intervention Group students scored 18.25 ($p=0.2859$).

Table 1. Demographic Characteristics

Characteristic	Control	Intervention
Males	1	0
Females	11	12
Average Age	24	24
Final Course Grade	A	A

Table 2. Pre-Test Results

Group	N	Mean	Std Dev	Std Error	Minimum	Maximum
Control	12	14.6667	7.84	2.26	5.0	33.0
Intervention	12	18.2500	8.20	2.37	5.0	30.0

$p=0.2859$

The instructors later administered the post-test after only the Intervention group had received the 25-minute instruction session with student peer instruction using the rubric while the Control group only had received the introduction to the rubric. The instructors scored the Intervention and Control groups' post-tests with the students' identities concealed using the same scoring rubric. All students' scores on the post-test following the intervention of control treatments demonstrated that students markedly improved their scores between baseline and spot-check post-test. The Control group improved from 14.67 to 41.75 while the Intervention group improved from 18.25 to 43.67, representing 27.08- and 25.42-point increases, respectively, on the 70-point scale. This resulting improvement for both groups was consistent with a previous quasi-experimental study.²²

Unexpected Result

Surprisingly, the initial average spot check post-test scores on a 70-point scale between the Intervention and Control groups were similar. The average scores on Table 3 amounted to 41.75 for the Control Group and 43.67 for the Intervention Group. An initial analysis using a paired t-test furthermore suggested no statistical difference between the Intervention and

Control groups. The instructors closely examined the de-identified scores one-by-one and noticed a bifurcation in the results data. Six students in the Control group scored noticeably higher than their fellow classmates in the Control group.

Table 3. Initial Post-Test Results

Group	N	Mean	Std Dev	Std Error	Minimum	Maximum
Control	12	41.75	29.18	8.42	10.0	70.0
Intervention	12	43.67	21.09	6.09	18.0	70.0

p=0.8554

One instructor interviewed these six students to learn about their experiences. Two of these six Control group students decided to learn how to use the rubric on their own in order to score highly on a graded assignment using the same skills later in the course. The other four of these Control group students had sought peer instruction from their classmates in the Intervention group. After removing these contaminated four Control group students from the analysis of scores, the overall average scores of Intervention and Control group post-tests became 43.67 and 27.63, respectively as noted in Table 4. These differences between the Intervention group and Control group approached statistical significance using a paired t-test with a p value of 0.1428. Still, the contamination muddled any clear result.

Table 4. De-Contaminated Post-Test Results

Group	N	Mean	Std Dev	Std Error	Minimum	Maximum
Control	8	27.63	25.57	9.04	10.0	70.0
Intervention	12	43.67	21.09	6.09	18.0	70.0

p=0.1428

Discussion

This randomized controlled trial in a larger dental hygiene degree program tested the hypothesis that an extra 25-minute training on EBP question formulation would result in statistically different scores on a rubric compared to a Control group. Both Control and Intervention groups benefited from receiving a 5-minute explanation of the scoring rubric. They scored higher than their baseline pre-test scores on their spot-check post-tests. The Control and Intervention groups' scores of 41.75 and 43.67 on a 70-point rubric were similar and not statistically significantly different using a paired t-test. Most hypothetical students likely would have wanted the higher average scores of 1.92 points more (almost a 3-point difference on a 100-point scale) by belonging to the Intervention group even if we had obtained similar results without removing the contaminated students in the analysis. This difference might raise their score by half a grade in some instances. The average scores were not markedly different and not statistically different, however. Perhaps this experiment presents an instance where a lack of statistical significance still has a meaning for competitive students conscious of their grades?

Limitations

This study had three limitations. First, it took place as the US was emerging from the Covid-19 Pandemic with its psychosocial, clinical, and logistical preoccupations. Dental profession education programs with their sustained close physical proximity to patients during clinical training posed challenges due to the continuous threats caused by the Covid-19 pandemic and its reoccurrences.^{23,24,25} Second, while our dental hygiene program was on the larger end of the enrollment continuum nationally, our study would have always had power issues with reaching statistical significance. An unexpected limitation, one that we had thought that we had sufficiently guarded against, was the contamination involving four Control group students who collaborated with students in the Intervention group.

Failure Caused by Contamination

Contamination between Intervention and Control groups occurs in an educational or behavioral experiment when members of the Control group learn about and adhere to the instruction intended only for the Intervention group. The contamination that unfolded in the present study of dental hygiene students possibly reduced the differences in results to suggest no different effect to the Intervention group. Contamination appears to be a far more widespread issue across randomized controlled studies. One systematic review of behavioral interventions in Type 2 diabetics revealed that 13 of the 20 studies examined were vulnerable to contamination between groups and that 45% of the studies did not acknowledge possible contamination.²⁶ One possible solution would be for all students at a single site to receive only the Intervention or the Control while all students at another site might receive the opposite treatment in a cluster form of randomized controlled trial.^{27,28} The small size of the grant for this study would have not afforded a multi-site randomized controlled trial, particularly when the researchers at the University of New Mexico thought they had managed to avoid contamination with the study design. A Delphi study expert consensus confirmed that while “Efforts to avoid or minimize contamination can be incorporated into the design, conduct or analysis of trials. . . such strategies may be ineffective. . .” [Page 196].²⁹ Their Delphi study further found that, “Contamination was thought most likely in trials conducted in settings where respondents worked, lived or interacted closely together.” [Page 200].²⁹ Congruently, this dental hygiene program provided numerous interactive opportunities among its students.

Lessons Learned

This randomized controlled study provides a model for others to adapt to their particular educational or behavioral interventions to gauge the relative benefit of the intervention over the benefits of a control. The control need not be a placebo in the form of simply doing nothing; the standard education or behavior treatment could prove to be a worthy control. This study also offers the possibility of using a less complex quasi-experiment with its pre- and post-tests, provided the researchers recognize the greater possibilities of confounding in a quasi-experiment. This study tended to still validate the use of active learning. Beyond these positive lessons, there are several cautionary lessons to be learned from this study:

1. Even with a keen awareness of and experiences in mitigating the dangers of contamination, the researchers did not foresee this instance of contamination.
2. The researchers did not recognize the current undergraduate student experience that caused the student cohort in this dental hygiene program to have many existing regular

interactions among the students in their class due to:

- Enrollment by some dental hygiene students in a first-semester first-year course for potential future health professionals;
 - Pre-dental career club membership by most students;
 - Pre-existing study group dyads and triads within the classmates;
 - Cross-cutting undergraduate organization (Hellenic, sports, social, social justice clubs, etc.) affiliations already existing among these dental hygiene students.
3. While some statistical adjustments can be made in isolated instances of contamination, the small total numbers of students ($n=24$) in each cohort pushed the usable number of non-contaminated students downward, lowering power so statistical significance could no longer be achieved.
 4. In an active learning environment that encourages students to engage regularly in peer instruction, the challenges to avoiding contamination multiply.
 5. Vigilance must be practiced to guard against contamination in randomized controlled trials when the intervention and control groups are in interactive social, behavioral, or educational contexts.

Conclusion

Contamination between the Intervention and Control groups apparently equalized the results between the groups, thereby neutralizing the hypothesized benefit of a longer, more in-depth training for the Intervention group. Although the authors made reasonable efforts to avoid contamination between the groups, they did not recognize the pre-existing social and academic relationships of students across the Intervention and Control groups.

Additional active learning training among students in the Intervention group for 25-minutes beyond a brief 5-minute introduction provided to the Control group still appears to have yielded higher scores for the Intervention group students. Given the importance of the question formulation step in the EBP process and the limitations of this study, it should be replicated at other dental hygiene programs.

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CRedit

Jon Eldredge conceptualized the project, secured funding and human subjects research board approval as principal investigator, conducted and administered the study, validated the rubric, analyzed the results, curated the data, and wrote the original draft of the manuscript.

Christine Nathe, provided the resources in terms of allowing students she supervised in her course to participate in the study, analyzed the results, and edited the final manuscript.

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