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Evaluating the Accuracy of Spatial Fluid Volume Estimation in Veterinary Students: A Comparison of First- and Third-Year Students Predictions of Fluid Volumes on Simulated Floor Tiles

Macy A Riedemann[1], Rodney S Bagley[2]* and Darlene J Greathouse[3]

[1]Veterinary Student, College of Veterinary Medicine, 1800 Christensen Drive, Iowa State University, Ames, Iowa 50011, USA

[2]Department of Veterinary Clinical Sciences, College of Veterinary Medicine, 1809 S Riverside Dr, Iowa State University, Ames, Iowa 50011, USA

[3]Marketing Department, Business Analytics, School of Business, 4800 Lumpkin Hall, Eastern Illinois University Charleston, IL 61920, USA

Corresponding author: Rodney S Bagley, DVM, DACVIM (Neurology and Internal Medicine), CCRP, CVA, Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Iowa State University, Ames IA, 50011, USA

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Abstract

Background: Estimating unknown volumes of fluid is an important clinical skill in veterinary medicine when gauging fluid loss from patients. This study evaluates the volume estimation accuracy of first-year and third-year veterinary students at a single US veterinary college.

Methods: First- and third-year veterinary students estimated a fluid volume in millimeters placed on different surface tile colors of simulated hospital flooring and of three separate fluid volumes. Estimations were compiled for analysis to identify general volume estimation accuracy of three separate volumes of fluid on both white-tile and brown-tile surfaces. Statistical comparisons between accuracy of estimates for each volume and tile color were performed using the standard statistical methodology.

Results: Estimations were generally inaccurate for all volumes and tile color combinations. Within these inaccuracies, surface color did affect estimation accuracy. There was a general pattern wherein most students underestimated the volume, with smaller percentages of students accurately estimating or overestimating the fluid volume. Additionally, estimation accuracy differed slightly between first- and third-year veterinary students.

Conclusions: These results identify a gap in student ability to predict certain fluid volumes on floor surfaces like a hospital environment. Therefore, education, training, and deliberate practice to improve the accuracy of these types of estimations is likely necessary as volume estimations appear not as an inherent skill set.

Keywords: *Comparison, Estimation, Flooring, Fluid Volume, Veterinary Students, Skill gap*

Introduction

There are numerous clinical competencies within the veterinary profession that have been discussed in multiple contexts [1-7]. Accurate estimation of fluid volumes in various conditions is one such skill in veterinary medicine that contributes to effective patient assessment and treatment. Proper estimation of fluid volumes aids in assessing hydration status, organ function, and overall patient health as well as ensuring appropriate medical intervention when necessary [8]. This skill is most obvious for tangible fluid losses from the body. For example, bladder management is particularly important for patients with neurological disease affecting their ability to voluntarily urinate [9-11]. These patients require manual bladder expression to prevent complications from over-distension and bladder damage. Establishing the volume of urine manually expressed by the care giver aids in determining appropriate bladder decompression to avoid detrusor atopy or bladder wall damage. Volume estimation is equally important in surgical and traumatic injury settings [12]. Another example is when a patient is actively hemorrhaging, blood loss may accumulate on an operating room or examination room floor, requiring accurate estimation to ensure proper identification of significant fluid loss and subsequent fluid replacement. Similarly, critical patients presenting with vomiting, external effusions, epistaxis, or exudating from deep wounds need precise fluid loss assessments to guide resuscitation efforts [13-32]. These situations highlight the critical importance of accurately estimating fluid volumes in a spatial environment as these estimates may be directly linked to patient health decisions and associated outcomes.

Unfortunately, individuals estimating fluid volumes in several contexts within a medical setting demonstrate significant variability and inaccuracy in those estimates [13-32]. This includes estimating blood loss, urine volumes, and other body fluid determinations. There is both a tendency to both underestimate and overestimate under various conditions, making these assessments unreliable. Incorrect estimations can lead to incorrect fluid replacement calculations, potentially affecting patient outcomes. Therefore, accuracy estimating

tangible fluid losses from a patient is a reasonable direct skill assessment for veterinary professionals.

As the first phase in understanding the inherent skill level of veterinary students in these estimations, we quantified the level of predication accuracy related to spatial fluid volumes in a hospital environment. The specific aim was to assess the accuracy of veterinary students' ability to estimate the volume of fluid on a flat surface simulating a hospital floor environment. We were also interested if floor color and level of veterinary experience would influence these estimates.

In this study, three hypotheses were tested.

Hypothesis 1) Students will estimate the volume of a urine-substitute fluid on a flat surface (i.e., floor) within 5% of the actual fluid volume present.

Hypothesis 2) Students will estimate the volume of a urine-substitute fluid on a flat surface (i.e., floor) within 5% of the actual fluid volume present independent of the surface color.

Hypothesis 3) Third-year veterinary students will have the same degree of accuracy in comparison to first-year veterinary students.

Methods and Methods

This study was IRB approved (24-329, 25-186). Study participants included first-year (VM1) and third year (VM3) veterinary students from the College of Veterinary Medicine at Iowa State University. Participants were invited to participate through direct communication with each of the student classes. The study was conducted with the two separate VM1 and VM3 classes during two consecutive years (2024 and 2025) to increase participant enrollment and enhance the sample size. Participants scheduled a 10-minute time slot to complete their observations. Before participation, all participants signed a consent form explaining the study and their role. Answers were provided anonymously and no student identification information was collected other than year within the curriculum. The study team was present to oversee and ensure experimental control.

Research Design

Pre-Experiment Setup

A commercially obtained fluid (Lemon-Lime Gatorade Sports Drink®) was used as a urine substitute for this study due to its similar color and viscosity to normal urine. The urine substitute had a specific gravity of 1.020, was watery in consistency, and light yellow in color. Additionally, six simulated tile surfaces were prepared using non-absorbing materials: three white tiles and three brown tiles, each measuring two feet by two feet. These tiles were placed on individual cubicles labeled Stations 1 through 6 in a temperature/humidity-controlled environment within the Clinical Skills Lab at Iowa State University (Figures 1 and 2). The cubicle tiles alternated white-brown-white-brown-white-brown. Each tile received a pre-measured volume of urine substitute of either 15, 30, or 60 ml dispensed from a syringe onto the tile surface for visual fluid volume estimation. The fluid was placed in the center of the tile to form a relatively circular geometric shape.

Study Activities

Prior to enrolling in the study, participants were given a verbal overview of their role and instructions for completing the study. Participants had 10 seconds at each station to view the volume and to



Figure 2: Student viewing and estimating the associated fluid volume.



Figure 1: Examples of two viewing stations used for estimating fluid volumes. Brown tile (left) and White Tile (right).

record their answers on a sheet of paper provided prior to entering the study area. Participants entered the study area and moved from station to station until they had completed all six stations and recorded their predictions. Participants could not view the fluid volume until standing directly in front of the station so that there was a standardized angle (Figure 2). A finite viewing time was used for each station. A timer indicated when it was time to move to the next station.

The sequence of the fluid volumes was randomly selected and placed at each station prior to the study initiation (example – Station A – 30 ml, Station B – 60 ml, station C – 15 ml). Participants were instructed to estimate the fluid volumes in whole numbers and in milliliters (ml). Each participant estimated three different volumes of fluid on white floor tiles and brown floor tiles. When the participant left the study area, a research assistant collected the participants' written answers for statistical analysis.

Statistical Analysis

The participant's written answers were manually entered into an Excel spreadsheet for analysis, organized by participant classification, VM1 and VM3. Descriptive, nonparametric, and mixed-effects analysis were conducted to evaluate the accuracy of veterinary students' estimates of fluid volume and to determine whether estimation accuracy differed by fluid volume, surface color, and veterinary student classification. Because the estimation data were non-normally distributed, medians and absolute percent error (APE) were emphasized in the descriptive analysis, and nonparametric tests were used for group comparisons. Mixed-effects analysis was conducted to account for the repeated volume estimates provided by each student. Analysis was conducted using Excel and IBM SPSS (Version 30.0.0.0 (172)) with a significance value of 5%.

Absolute percent error (APE) was used to evaluate estimation accuracy by surface color, with lower APE values indicating greater accuracy. A Wilcoxon signed-rank test was performed to determine whether estimation accuracy differed between the paired brown- and white-surface conditions with a statistically significant difference set at $p < .05$. A Mann–Whitney U test was used to evaluate for a statistically significant difference in estimation accuracy between VM1 and VM3 ($p < .05$). For the mixed-effects linear test, data from the 2024 and 2025 groups were combined resulting in 180 VM1 and VM3 students and 1,080 total estimates. The analysis examined whether estimation accuracy differed by student classification (VM1 vs. VM3), station color (white vs. brown), and actual fluid volume (15, 30, and 60 mL).

Table 1: Combinations of tile color and actual fluid volumes for estimation.

Estimate Combination	Tile Color	Actual Volume (ml)
1	Brown	15
2	Brown	30
3	Brown	60
4	White	15
5	White	30
6	White	60

Results

Fluid-Volume Estimation Accuracy

A total of 118 VM1 students (VM1 Cohort 1 (2024), N= 54; VM 1 Cohort 2 (2025), N=64) and 62 VM 3 students (VM3 Cohort 1 (2024), N=19; VM3 Cohort 2 (2025), N=43) participated in this study (Tables 1-5). Each of the participants recorded 6 estimates, one for each tile color/volume combination (Brown tile – 15 ml; Brown tile – 30 ml; Brown tile – 60 ml; White tile – 15 ml; White tile – 30 ml; White tile – 60 ml). This equated to a total of 708 and 372 independent observations for VM 1 and VM 3 students, respectively.

Table 2: The percentage of students that accurately estimated the actual volume in each cohort and for each tile color/actual volume combination.

Tile Color/Actual Fluid Volume	Percentage of Students Making an Accurate Estimation/Cohort			
	VM 1 - Cohort 1 (N=54)	VM 1 - Cohort 2 (N=64)	VM 3 - Cohort 1 (N=19)	VM 3 - Cohort 2 (N=43)
Brown Tile - 15 ml	2%	5%	0%	2%
Brown Tile - 30 ml	4%	5%	0%	5%
Brown Tile - 60 ml	6%	0%	0%	2%
White Tile - 15 ml	2%	2%	0%	0%
White Tile - 30 ml	2%	2%	0%	0%
White Tile - 60 ml	0%	2%	0%	0%

Table 3: The percentage of students that underestimated the actual volume in each cohort and for each tile color/actual volume combination.

Tile Color/Actual Fluid Volume	Percentage of Students Underestimating the Actual Volume (Total)/Cohort			
	VM 1 - Cohort 1 (N=54)	VM 1 - Cohort 2 (N=64)	VM 3 - Cohort 1 (N=19)	VM 3 - Cohort 2 (N=43)
Brown Tile - 15 ml	98%	86%	100%	86%
Brown Tile - 30 ml	91%	89%	100%	86%
Brown Tile - 60 ml	93%	89%	100%	91%
White Tile - 15 ml	98%	95%	100%	91%
White Tile - 30 ml	98%	94%	100%	91%
White Tile - 60 ml	100%	95%	100%	93%

Table 4: The percentage of students that underestimated the actual volume by greater than 50% in each cohort and for each tile color/actual volume combination.

Tile Color/Actual Fluid Volume	Percentage of Students Underestimating the Actual Volume by greater than 50%/Cohort			
	VM 1 - Cohort 1 (N=54)	VM 1 - Cohort 2 (N=64)	VM 3 - Cohort 1 (N=19)	VM 3 - Cohort 2 (N=43)
Brown Tile - 15 ml	80%	64%	89%	70%
Brown Tile - 30 ml	69%	67%	100%	72%
Brown Tile - 60 ml	87%	67%	100%	67%
White Tile - 15 ml	83%	72%	100%	84%
White Tile - 30 ml	89%	64%	100%	74%
White Tile - 60 ml	91%	75%	95%	77%

Table 5: The percentage of students that overestimated the actual volume in each cohort and for each tile color/actual volume combination.

Tile Color/Actual Fluid Volume	Percentage of Students Overestimating the Actual Volume/Cohort			
	VM 1 - Cohort 1 (N=54)	VM 1 - Cohort 2 (N=64)	VM 3 - Cohort 1 (N=19)	VM 3 - Cohort 2 (N=43)
Brown Tile - 15 ml	0%	9%	0%	12%
Brown Tile - 30 ml	6%	6%	0%	9%
Brown Tile - 60 ml	2%	11%	0%	7%
White Tile - 15 ml	0%	3%	0%	9%
White Tile - 30 ml	0%	5%	0%	9%
White Tile - 60 ml	0%	3%	0%	7%

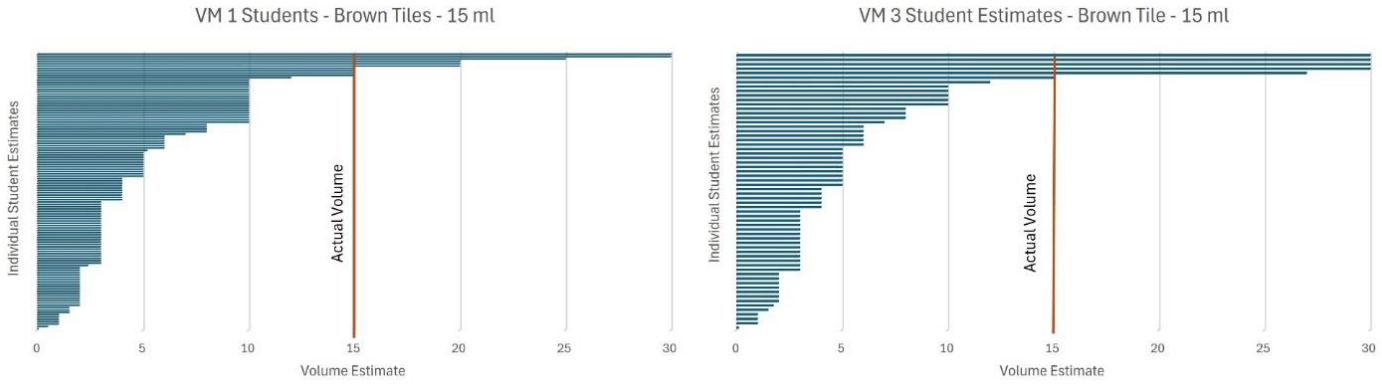


Figure 3: Distribution of estimates from grouped VM1 students (left) and VM3 students (right) for Brown Tile with 15 ml of actual fluid. The vertical line designates the true fluid volume present.

For most participants from both VM1 and VM3 years, fluid volumes were consistently underestimated regardless of actual fluid amounts (Table 3). For the 15-mL volume, the median estimate was 3 ml, representing an absolute difference of 12 ml and an 80.0% error relative to the actual volume. For the 30-ml volume, the median estimate was 7 ml, corresponding to a 23 ml difference and a 76.7% error. At the 60 ml volume, the median estimate was 13 ml, representing a 47 ml difference and a 78.3% error. For all students, all volumes, and both tile colors, there was a similar pattern among responses with a majority underestimating the actual volume (Figures 3-8).

The accuracy rate was <5% in the grouped responses. When the accuracy parameters were expanded to an estimate with 25% of the actual volume, students' estimates remained inaccurate ranging from 0 to 14% (median 5%) for all tile color/volume combinations (Table 6). Finally, there was a small number of students that overestimated the volume in each of the assessments.

As estimates at all three fluid volumes differed substantially from the actual volumes, hypothesis 1 was rejected. Overall, student participants consistently underestimated the amount of fluid present, with the typical estimate representing only approximately one-fifth to one-quarter of the actual fluid volume.

Effect of Surface Color on Estimation Accuracy

Absolute percent error (APE) was used to evaluate estimation accuracy by surface color, with lower APE values indicating greater accuracy. The mean APE was 72.45% for white surfaces and 70.44% for brown surfaces. The median APE was 80.00% for white surfaces compared with 73.33% for brown surfaces.

A Wilcoxon signed-rank test was performed to determine whether estimation accuracy differed between the brown- and white-surface conditions. The analysis indicated a statistically significant difference in APE between surface colors ($p < .05$). The lower median and mean APE observed for brown surfaces indicate that participants estimated fluid volumes more accurately on brown surfaces than on white surfaces. Therefore, hypothesis 2 was rejected. These findings suggest that surface color influenced participants' ability to visually estimate fluid volume, although estimation error remained substantial on both surface colors.

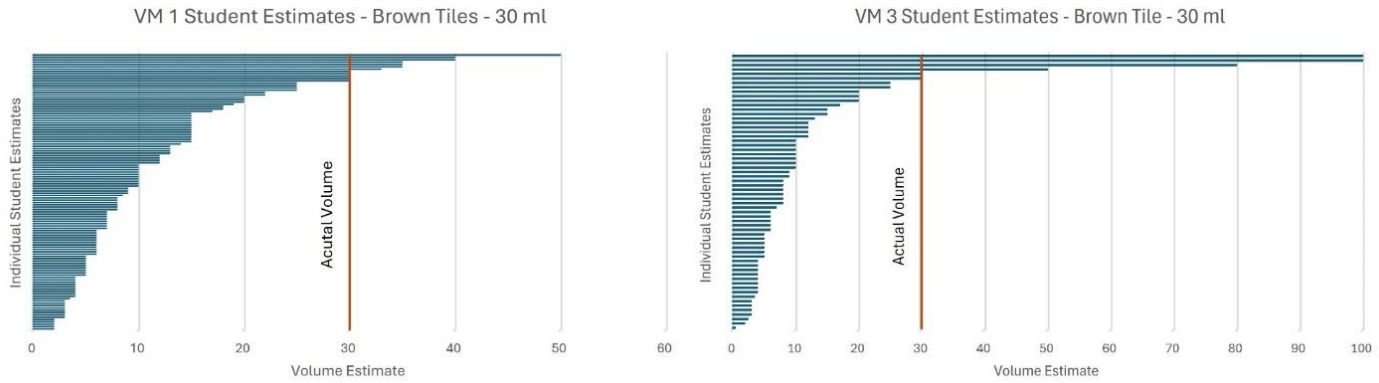


Figure 4: Distribution of estimates from grouped VM1 students (left) and VM3 students (right) for Brown Tile with 30 ml of actual fluid. The vertical line designates the true fluid volume present. Note that the estimate scale is different between groups as there were larger estimates from the VM4 students.

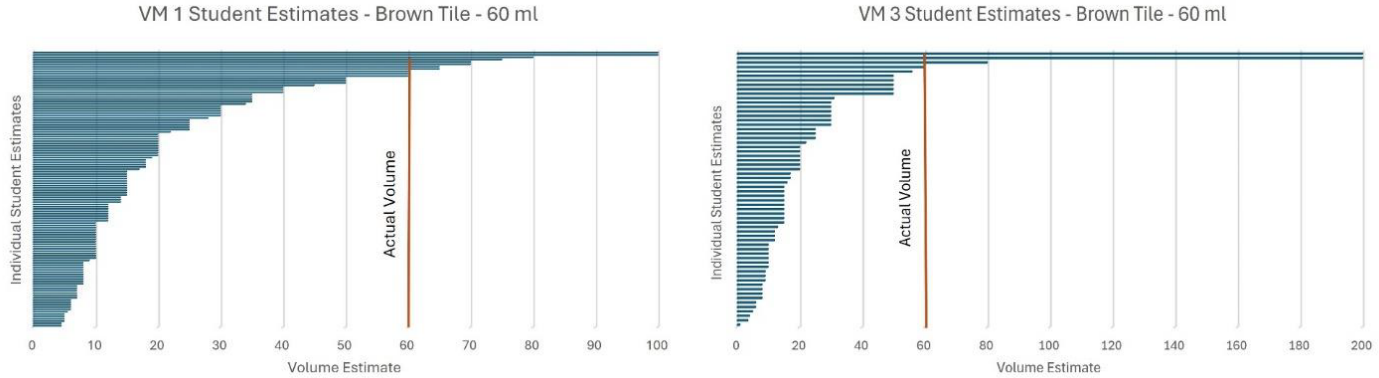


Figure 5: Distribution of estimates from grouped VM1 students (left) and VM3 students (right) for Brown Tile with 60 ml of actual fluid. The vertical line designates the true fluid volume present. Note that the estimate scale is different between groups as there were larger estimates from the VM4 students.

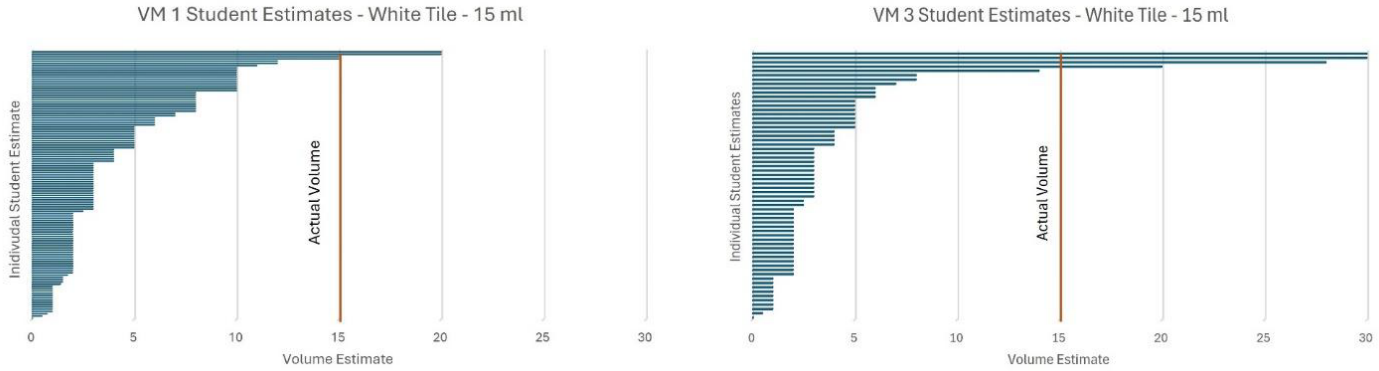


Figure 6: Distribution of estimates from grouped VM1 students (left) and VM3 students (right) for White Tile with 15 ml of actual fluid. The vertical line designates the true fluid volume present.

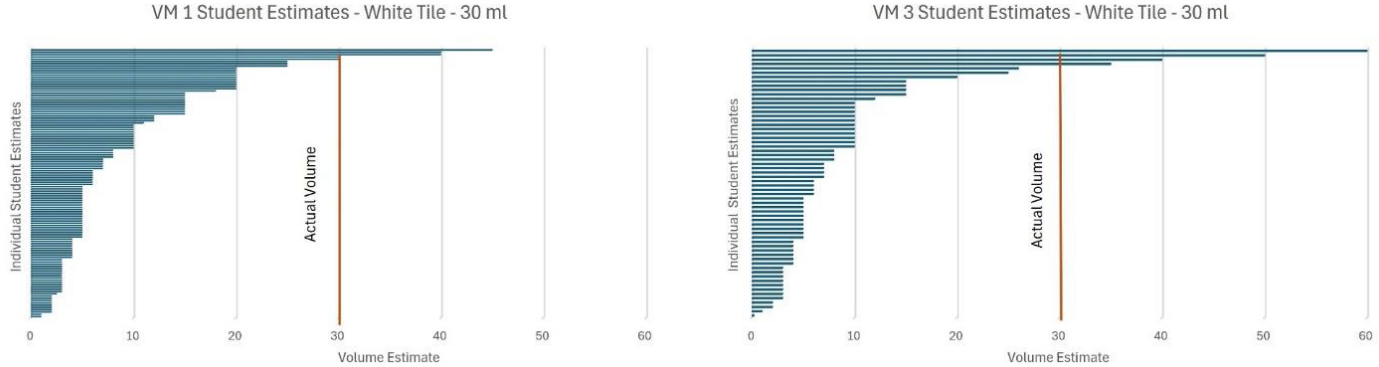


Figure 7: Distribution of estimates from grouped VM1 students (left) and VM3 students (right) for White Tile with 30 ml of actual fluid. The vertical line designates the true fluid volume present.

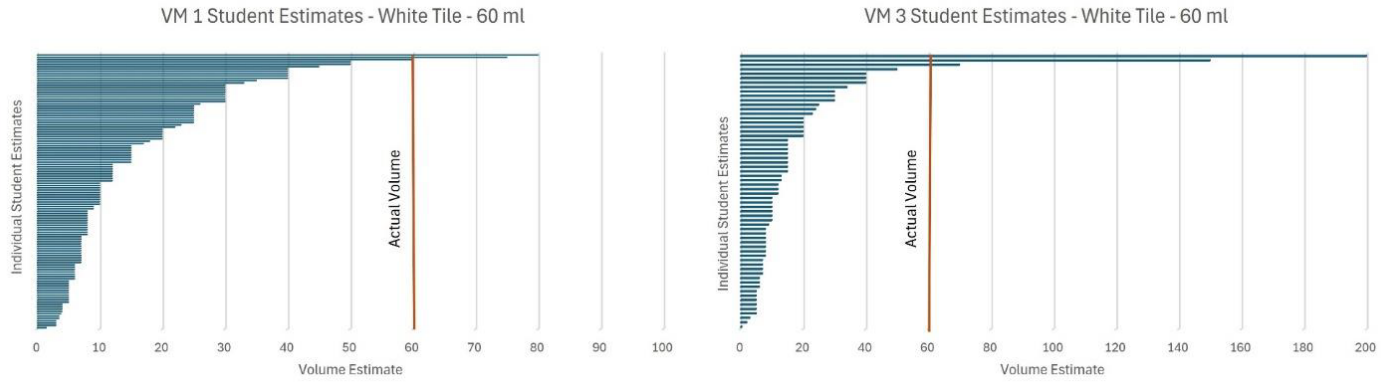


Figure 8: Distribution of estimates from grouped VM1 students (left) and VM3 students (right) for White Tile with 60 ml of actual fluid. The vertical line designates the true fluid volume present. Note that the estimate scale is different between groups as there were larger estimates from the VM4 students.

Table 6: The percentage of students estimating within 25% (rounded to the nearest whole number), either under or overestimating, of the actual volume in each cohort and for each tile color/actual volume combination.

Tile Color/Actual Fluid Volume	Percentage of Students Overestimating the Actual Volume/Cohort			
	VM 1 - Cohort 1 (N=54)	VM 1 - Cohort 2 (N=64)	VM 3 - Cohort 1 (N=19)	VM 3 - Cohort 2 (N=43)
Brown Tile - 15 ml	0%	6%	0%	5%
Brown Tile - 30 ml	11%	14%	5%	7%
Brown Tile - 60 ml	7%	13%	5%	14%
White Tile - 15 ml	4%	5%	0%	2%
White Tile - 30 ml	2%	6%	0%	7%
White Tile - 60 ml	2%	6%	5%	5%

Comparison of VM1 and VM3 Estimation Accuracy

Estimation accuracy was also compared between VM1 and VM3 veterinary students. There were differences in the total number of participants in each cohort with more VM1 student participants (N=118) compared to VM3 participants (N=62). First year student observations had a mean APE of 68.66%, whereas VM3 observations had a mean APE of 77.06%. The median APE was 80.00% for both groups. Variability was greater among VM3 observations, with a standard deviation of 39.90 compared with 23.51 for VM1 observations.

A Mann–Whitney U test indicated a statistically significant difference in estimation accuracy between VM1 and VM3 ($p < .05$). Although the groups had identical median APE values, VM1 demonstrated a lower mean APE, indicating lower overall estimation error than VM3. Therefore, the results did not support the hypothesis 3 that VM1 and VM3 students would demonstrate the same degree of estimation accuracy and hypothesis 3 was also rejected. The findings did not provide evidence that additional veterinary education time and educational experiences from the VM1 to VM3 year resulted in improved visual fluid-volume estimation. In this study, however, there was a trend for VM1 participants demonstrating lower median estimation error compared with VM3 participants.

Mixed-Effects Results

Overall, there was no statistically significant difference in estimation accuracy between VM1 and VM3 students ($p=.089$). Estimation accuracy differed significantly by station color ($p<.001$). Students were more accurate at the brown stations, with an average absolute error of 24.07 mL compared with 26.08 mL at the white stations.

Estimation accuracy also differed significantly based on the actual amount of fluid ($p<.001$) (Figure 9). The average error increased as the amount of fluid increased. Students were off by an average of 10.86 mL when estimating 15 mL, 20.99 mL when estimating 30 mL, and 43.38 mL when estimating 60 mL.

The effect of station color also varied depending on the amount of fluid being estimated ($p=.003$). The difference in accuracy between the brown and white stations became larger as the actual fluid amount increased, however, this pattern did not differ significantly between VM1and VM3 students. Overall, the findings indicate that station color and the amount of fluid being estimated were related to estimation accuracy while student classification was not.

Summary Analysis

The results demonstrate substantial inaccuracy in visually estimating fluid volumes across all conditions examined. Estimates were markedly below the actual fluid amounts, and estimation errors greatly exceeded the proposed 5% accuracy criterion. Surface color significantly affected estimation accuracy, with brown surfaces producing more accurate estimates than white surfaces. Estimation accuracy also differed significantly by veterinary student classification, with VM1 observations demonstrating lower median error than VM3 observations.

Discussion

The primary findings of this study demonstrate that veterinary students were unable to accurately estimate fluid volumes presented on a flat surface, with estimations significantly underestimating the actual volume. These results identify a gap in student's inherent ability to accurately predict fluid volumes in a simulated hospital floor

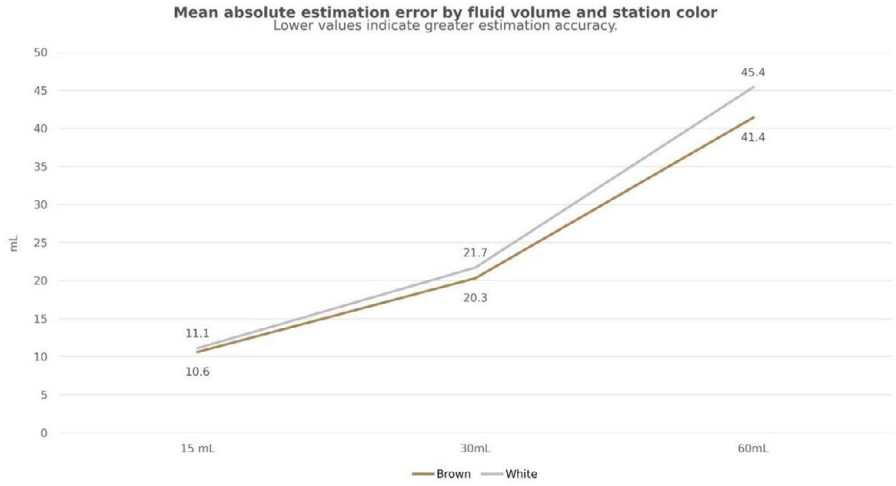


Figure 9: Mean absolute estimation error by actual fluid volume and station color for combined VM1 and VM3 students. Lower values indicate greater estimation accuracy. Absolute estimation error increased with fluid volume and was lower for brown than white stations.

environment which has previously not been documented. This pattern was observed across both surface colors and levels of veterinary educations, suggesting that visual estimation of fluid volume on a flat surface may be challenging for veterinary students regardless of their stage in the curriculum. Estimation accuracy was also influenced by surface color, with these students providing slightly more accurate estimations when fluid was presented on the darker surface compared with the white surface. Additionally, VM3 students provided slightly more accurate volume estimations than VM1 students, however, both groups were inaccurate in their estimations. Together, these findings demonstrate that both the visual characteristics of the surface and level of veterinary education may influence the accuracy of fluid volume estimation.

This inability of participants to consistently estimate volumes within 5% of the actual volume further demonstrates the difficulty of accurately assessing fluid volumes based only on visual assessment [13-32]. The tendency for underestimation observed in this study was consistent among participants regardless of the conditions. Although the amount of underestimation observed in this study may differ from what occurs in a clinical setting, being aware of this limitation may encourage students and clinicians to be more cautious when estimating fluid volumes in a similar hospital environment. These findings were consistent with the information of accuracy of precision of volume estimations which find significant variation in the fluid volume assessments in medical environments [13-32].

As we did not ask participants to record their reasoning for their estimates, we are unable to provide cognitive perspectives on this result. One explanation for the degree of underestimation observed is that participants may not have been highly motivated to achieve an accuracy estimate because there was no incentive associated with being within 5% of the actual volume. Participants knew their estimates were being recorded, but there was no consequence or reward associated with the accuracy of their estimations. Therefore, motivation in a low-stakes environment may have contributed to the variability of degree of error observed. Because this factor was not directly assessed, however, its influence on the results cannot be determined. This study also used relatively small volumes of fluid which could influence the estimations. These volumes were chosen, however, to simulate amounts of urine that might be expressed from the bladder of a small dog with manual bladder expression.

Surface color was also associated with estimation accuracy, with participants providing slightly more accurate estimations on the darker surface compared with the white surface. This was an interesting and unanticipated outcome of this study given the intuitive contrast between white tile and the yellow color of the study fluid. One possible explanation is that the fluid may have been more difficult to visually interpret on the darker surface, causing participants to pay closer attention when making their estimations. While multiple unidentified factors may have contributed to the observed difference, the results suggest that surface characteristics can influence visual fluid volume estimation.

The difference in estimation accuracy between VM1 and VM3 students is an additional finding of interest. Third year students had slightly more accurate estimates than VM1 students which may indicate that additional time in veterinary education or greater exposure to clinical environments is associated with improved ability to estimate fluid volumes. However, the reason for this difference cannot also be determined from the current study. It is also important to note that even though VM3 students were more accurate in their estimations compared to VM1 students, overall VM students were equally inaccurate compared to actual fluid volumes assessed. Given the over inaccuracy regardless of year in the veterinary curriculum, it does not appear that additional time in the curriculum per se improves estimating ability in this context. Third year students may have had greater clinical exposure, however, there is no formal educational experience estimating fluid volumes on similar surfaces in the current veterinary curriculum. Therefore, an explicit educational experience was not the reason for slightly better accuracy for fluid volume estimations in VM3 students. Other differences between the two groups, including differences in prior education, individual experience, or familiarity with estimating fluid volumes, could also have contributed to the observed difference. Third year students are

exposed to aligned volume-related educational activities such as drawing volumes of fluid in to syringes with known volume indicators when administering drugs to patients in teaching laboratories.

Given the study design and physically performed in a controlled, non-clinical low-stakes environment, several study variables should be considered when interpreting these results. First, there was a difference in total participants between VM1 and VM3 students. While this was accounted for in the statistical analysis, it is possible that this created an inherent self-selection bias that favored or disfavored the overall results from each cohort. As the general trends from each combined cohort were similar, the overall conclusions from the results, however, seem reasonable. Equally, given the variability in estimates in each cohort, the generalized conclusions likely will not hold true for any unique individual as each individual's skill in this estimation process may be different. Second, as the estimates were made sequentially, we could did not control for an acquired bias as the participants moved through the first to last station. For example, it is possible with each successive observation that the students learned and adapted, which influenced their subsequent decision-making. It is unknown if this adaptive process occurred or what influence early estimates had on those estimations performed subsequently. The accuracy rates, however, for each tile color/volume tended to be similar which suggests that there was little adaption in estimation while progressing through the six stations. Third, the fluid on the flat surface may have occasionally changed shape over time. Because participants may have viewed the fluid at slightly different stages geometric shaping, the changes in fluid distribution could have influenced estimation accuracy. Fourth, the two surfaces may have differed in characteristics beyond color. For example, the surface characteristics of the tile may have affected cohesion and surface tension which may have affected geometric shaping or minor fluid absorption into the tile and therefore influenced participants' visual estimations. Fifth, the lighting of the environment, color contrasting between the fluid and the tile surface, and viewing angle may be additional variables influencing estimates. Finally, this study only included veterinary students from one institution, so the results may not be applicable to all students at other veterinary colleges or for veterinarians or veterinary support staff.

As a direct educational outcome, future studies might investigate whether direct visual learning improves fluid volume estimation accuracy [33-39]. One potential approach would be to have participants view actual volumes in an educational laboratory, then repeat the volume estimation task. Comparing estimation accuracy before and after this learning intervention could help determine whether visual exposure to known fluid volumes improves subsequent estimation. Future studies could also control more closely for surface characteristics, evaluate additional surface colors or materials, and investigate whether providing an incentive for accuracy for accuracy affects participant performance.

Finally, these results may have implications for estimating fluid volumes such as voided urine in an actual clinical setting. Based on the results of this study and translatable to a teaching hospital environment, if an accurate measurement of voided urine or other fluids in the environment is important for patient assessment, it would be necessary to collect that urine in a suitable container so that an accurate measurement could be performed. If actual measurement is not possible, then the general recommendation from our results would be to consider that any assessed volume within the ranges of this study (that is, 15 to 60 ml) is likely an underestimate of the actual volume present. Median results from this study would suggest that any estimate should be at least doubled within these volume ranges. Given that a smaller percentage of students were actually accurate, and a similar smaller percentage overestimated the volumes present, this conclusion is not generalizable for all potential students asked to evaluate fluid volumes in a similar manner. Overall, these study findings highlight the potential limitations of visual fluid volume estimation and support the importance of recognizing the potential for underestimation when visually assessing fluid losses in the clinical setting [13-32].

Conclusion

In conclusion, this study found that veterinary students without previous training tended to significantly underestimate fluid volumes presented on a flat surface and were unable to consistently estimate volumes within 5% of the actual volume. Estimation accuracy was also influenced by surface color, with students providing more accurate estimations on the darker surface, and VM3 students providing more accurate estimates than VM1 students. These findings suggest that accurate visual fluid volume estimation can be difficult for veterinary students and that factors such as surface characteristics and level of veterinary education may influence estimation accuracy. Recognizing this potential for underestimation may help students and clinicians be more aware of the limitations of visually estimating fluid losses in a clinical setting. Future studies should investigate whether teaching students to visualize known fluid volumes can improve their estimation accuracy.

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Ethics Statement

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to and the appropriate ethical review committee approval has been received.

Iowa State University Institutional Review Board 24-329 and 25-186 (Documentation available upon request).

Informed consent was obtained from all subjects involved in this study.

Data Availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Conflict of Interest

The authors declare no conflicts of interest.

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