RESEARCH REPORT

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Another Nail in the Coffin for Learning Styles? Disparities among Undergraduate Anatomy Students' Study Strategies, Class Performance, and Reported VARK Learning Styles

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The concept and existence of learning styles has been fraught with controversy, and recent studies have thrown their existence into doubt. Yet, many students still hold to the conventional wisdom that learning styles are legitimate, and may adapt their outside of class study strategies to match these learning styles. Thus, this study aims to assess if undergraduate anatomy students are more likely to utilize study strategies that align with their hypothetical learning styles (using the VARK analysis from Fleming and Mills, 1992, Improve Acad. 11:137–155) and, if so, does this alignment correlate with their outcome in an anatomy course. Relatedly, this study examines whether students' VARK learning styles are correlated with course outcomes regardless of the students' study strategies, and whether any study strategies are correlated with course outcomes, regardless of student-specific VARK results. A total of 426 anatomy students from the 2015 and 2016 Fall semesters completed a study strategies survey and an online VARK questionnaire. Results demonstrated that most students did not report study strategies that correlated with their VARK assessment, and that student performance in anatomy was not correlated with their score in any VARK categories. Rather, some specific study strategies (irrespective of VARK results), such as use of the virtual microscope, were found to be positively correlated with final class grade. However, the alignment of these study strategies with VARK results had no correlation with anatomy course outcomes. Thus, this research provides further evidence that the conventional wisdom about learning styles should be rejected by educators and students alike. Anat Sci Educ 00: 000–000. © 2018 American Association of Anatomists.

Key words: virtual microscopy; flashcards; desirable difficulty; active learning; retrieval; learning preference; learning styles; VARK; study strategies

INTRODUCTION

The concept and existence of student "learning styles" has been a subject of great discussion and debate in educational research (Coffield et al., 2004; Hawk and Shah, 2007). Popularized in the 1970s and 1980s, a *learning style* is defined as "a student's consistent way of responding and using stimuli in the context of learning" (Claxton and Ralston, 1978). Since its popularization, many articles have been written to describe hypothetical ways that students should learn best according to a particular learning style (Fleming and Mills, 1992; Fleming, 1995; Marcy, 2001; Drago and Wagner, 2004; Murphy et al., 2004; Tanner and Allen, 2004; Fleming and Baume, 2006; Lujan and DiCarlo, 2006; Baykan and Naçar, 2007; Slater et al., 2007; Breckler et al., 2009; Dobson, 2009; Fleming, 2012a,b; Kim et al., 2015; Davidson and Ritchie, 2016; Höffler et al., 2017) and led to a call that instructors should design their lessons so as to address multiple learning styles (Marcy, 2001; Wehrwein et al., 2007; Alkhasawneh, 2013, Bhutkar and Bhutkar, 2016). However, in their seminal meta-analysis of past studies that examined learning styles, Pashler et al. (2009) showed that few of these studies held up to rigorous control, and those that did meet rigorous methodology standards failed to justify conventional wisdom about the concept of learning styles.

A great deal of research has shown that changing presentation or teaching strategies to align with student learning

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styles does not improve outcomes enough to justify the financial or temporal costs involved (Coffield et al., 2004; Pashler et al., 2009; Reiner and Willingham, 2010, Papanagnou et al., 2016). In addition, previous research has also shown that whether or not study materials are provided in line with the student's learning style does not improve learning outcomes (Kollöffel, 2012). Thus, these studies suggest that a rigid interpretation of a learning style is inappropriate; that while a student may have a *preference* for learning material in a particular format, presentation of the material in different formats does not impair learning.

Another explanation for the lack of correlation among teaching methods, learning styles, and student outcomes is the fact that *teaching* and *learning* are not the same concepts. Most learning occurs outside of the classroom, when students study the material on their own or in small groups (McKee, 2002; Aquino, 2011; Bulent et al., 2015). This outside study time is when a student's perceived learning style or preference may be incorporated through the use of specific study strategies, at no costs to instructors or administrations. In fact, Kraemer et al. (2014) has suggested that whether the presentation of the information is in line with the student's learning preferences may not affect outcomes because the students will convert the information into alignment with their learning preferences during outside study time. If Kraemer et al. (2014) are correct, then the concept of learning styles becomes most relevant when a student is utilizing his/her own study strategies outside of class to learn the material. Further, if learning styles are a truly valid concept, then students who utilize study strategies that match their learning style should outperform students whose study strategies and learning styles do not match.

Thus, the first aim of the present research assesses if undergraduate anatomy students are more likely to develop and utilize study strategies that align with their hypothetical learning styles. The second aim addresses if students do align their study strategies with their hypothetical learning style, does this alignment correlate with their outcome in the course. By addressing these research questions, the authors will provide a rigorous assessment (called for by Pashler et al., 2009) of the validity of learning styles as a concept.

VARK Learning Styles

While many researchers have proposed different types of learning styles (Coffield et al., 2004; Hawk and Shah, 2007), the authors chose to utilize the visual, auditory, reading/writing, and kinesthetic (VARK) model developed by Fleming and Mills (1992) due to its accessibility, conciseness, and widespread recognition among our students. The VARK questionnaire is freely available online (VARK, 2017) and consists of only 16 questions, making it more likely for a student to complete the test than a longer learning style survey. In addition, many undergraduates are already familiar with this model from previous classes or instruction (Reiner and Willingham, 2010).

The VARK model categorizes students based on the sensory modality in which they prefer to have information presented to them (Fleming and Mills, 1992). The individual categories are:

- **Visual (V)**: Individuals are categorized as visual (V) learners if they prefer to view information as drawings, diagrams, or flowcharts. It is recommended that they study by looking at pictures, graphs, and flowcharts.
- **Auditory (A)**: People are classified as auditory (A) learners if they prefer to hear information being presented to them. It is recommended that they study by attending classes, discussing the material with others, and reading notes or text out loud into a tape recorder.
- **Reading/Writing (R)**: Reading/writing (R) learners prefer to see new information in writing via text or tables. It is suggested that they study by writing out notes in their own words or organizing lists and tables of information.
- **Kinesthetic (K)**: Finally, students are classified as kinesthetic (K) learners if they prefer new information to be clearly relevant to the real world or something that they can manipulate with their hands. It is recommended that they study using hands-on approaches, application of the materials, and real-life examples.

In the VARK model, if a person has a preference for one of these categories, the learner is said to be unimodal. Sometimes, individuals may have preferences for more than one of these categories. If an individual has relatively equally strong preferences in two of the four categories (e.g., shows a preference for both Visual and Auditory), the learner is categorized as *bimodal*. If an individual has preferences for three of the four categories, the learner is categorized as *trimodal*. If a learner shows preferences among all four categories, the individual is categorized as *quadrimodal*. A majority of individuals fall into one of these multimodal categories.

History, Research, and Controversy with VARK

As previously mentioned, the VARK model has been extensively studied and is perhaps the most widely known theory about learning styles. Unfortunately, as the VARK model gained publicity and traction in mainstream education, controversy developed about the model. The VARK model was originally developed as a tool to promote discussion and reflection on learning strategies (Fleming and Mills, 1992) though that message has largely gotten lost, causing Fleming to keenly remind readers that the VARK analysis was never meant to be a diagnostic tool (Fleming, 1995; Fleming and Baume, 2006). Pashler et al.'s (2009) report about the lack of evidence for demonstrable learning styles using rigorous methods, and other similar studies at the time (e.g., Scott, 2010), lead Fleming back to defending his model (Fleming, 2012a,b) though these defenses have had little to no citations to support them. Nonetheless, the present authors have extensive anecdotal evidence of how many students continue to use VARK learning styles as a "crutch" for why they may not learn something well (e.g., "I'm just not a visual learner."). Furthermore, some teachers and instructors were erroneously taught that including all learning styles in your instruction was essential and thus they perpetuated the myth themselves (Dekker et al., 2012). Pashler et al. (2009) also noted the public appeal of learning styles as playing in to the uniqueness of the individual and possibly the self-esteem movement that has continued since the 1970s as an additional factor in the continued use of the VARK model.

The VARK model has also been criticized for its lack of demonstrated validity measures (Hawk and Shah, 2007; Wehrwein et al., 2007), which has been difficult to show since the questions do not restrict participants to a single answer. Leite et al. (2010) did find some preliminary evidence of reliability and validity to the internal structure of the survey using confirmatory factor analysis, but they recommended only using the VARK model for low stakes assessments and not for research since the validity of the content, response process, relationships between variables, and consequences of testing have not yet been assessed. Fitkov-Norris and Yeghiazarian (2015) also found some validity to the VARK model as they report that the Rasch model (a form of internal construct validity analysis that checks the fit of binary or more than two ordinal responses to a formal scale model) generally fits the VARK questionnaire for all but one question. Unfortunately, the sample size of the Fitkov-Norris and Yeghiazarian study was not especially large (107 business students in England) once the sample was separated into multiple different categories. Further, the Fitkov-Norris and Yeghiazarian sample likely is too small to be representative, given the number of people that have taken the VARK questionnaire (see below). As such, how well their validity report represents all of the individuals around the world who have taken the VARK questionnaire is still up for debate.

Despite these controversies, VARK has remained a heavily utilized resource with over 15,000 students from the US taking the survey online in a single month (January 2007), and that number only includes those US students that were taking the survey for the first time (Leite et al., 2010). The online VARK Questionnaire (VARK 2017) claims over 250,000 people responded in October of 2014 alone, and this number does not include anyone that took it on paper during that time. Thus, this continues to be a very popular resource.

VARK has been studied extensively, and an overview of some of the major studies with undergraduate students in anatomy and physiology disciplines from the past decade is presented here. (Additional discussion of studies relevant to this research continues in the discussion.) Wehrwein et al. (2007) administered the VARK questionnaire to 134 undergraduates in physiology and found that males were more likely to be multimodal, especially quadrimodal. They recommended that teachers should vary their instruction methods widely to maintain a broader interest in science. However, they also recommended that students should be aware of their preferences and adjust their own study strategies to match their VARK assessment results even if the instruction style of the course does not match. Interestingly, Breckler et al. (2009), in his study of physiology undergraduates, found that only 15% of students could accurately predict their VARK results, suggesting that how a student *thinks* they best learn typically does not match well with how the VARK *predicts* they should learn. In another analysis of physiology undergraduates at the University of Florida, Dobson (2009) reported associations between VARK learning preferences with gender and with physiology grades. However, Dobson did not use the whole VARK questionnaire, but instead chose only three questions that loosely corresponded to VARK categories and then asked the students to self-assess which category (V, A, R, or K) described them best [which Breckler et al. (2009) had shown that most students could not do accurately]. Alkhasawneh and colleagues surveyed Jordanian nursing students and found evidence that VARK learning preferences can change based on educational experiences (Alkhasawneh et al., 2008; Alkhasawneh, 2013). In 2008, Alkhasawneh et al. found increases in the scores of all VARK categories following the implementation of problem-based learning in a maternal-family health course. In 2013, Alkhasawneh surveyed first-, second-, and third-year nursing students and found that the third-year students preferred more kinesthetic activities while second-year students preferred read/write, and first-year students preferred visual. However, this was a cross-sectional, and not a longitudinal, study so the individual preferences of each cohort may have simply been different. Finally, Farkas et al. (2015) surveyed 492 undergraduates in a 200-level combined anatomy and physiology course. They report no significant differences in learning preferences between genders or between academic years.

Thus, research on VARK in anatomy and physiology education has had conflicting results. In addition, most of these studies have been performed in physiology (and not anatomy classes). Research about VARK in single anatomy classes (and not combined anatomy and physiology or across entire programs, such as nursing, medicine, etc.) has been sparsely reported. Finally, these studies did not evaluate and compare VARK and study strategies using a validated survey to document these strategies (Husmann et al., 2016).

Research Aims

Given all of the above, this manuscript addresses two major research aims and two corollaries:

1. Do students who take the VARK questionnaire align their study strategies with the VARK category that has their highest score?
2. Do students whose study strategies align with the VARK category of their highest score do significantly better (or worse) in an undergraduate anatomy class (A215) than students who do not follow their VARK recommendations?

   a. Do students who are dominant in any particular VARK category do better (or worse) in A215 regardless of their study strategies?
   b. Do students who use any particular study strategies do better (or worse) in A215 regardless of the category of their highest VARK score?

MATERIALS AND METHODS

The following study was deemed exempt by the Indiana University Institutional Review Board (Protocol #1509015906). Data for this study was examined after the end of the semester and after final grades were submitted, per IRB guidelines. Methods are outlined below.

The Course: Anatomy A215

Anatomy A215 (Basic Human Anatomy) is a one-semester, five credit hour undergraduate systems-based anatomy course taught at Indiana University. The course is comprised of one large lecture (400+ students at the beginning of each semester) that meets for 50 minutes a day three times weekly and twelve smaller laboratory sections (approximately 36 students each) that meet for 1.75 hours two times weekly. Two faculty members teach the lecture component of the course, while the laboratory component is taught by two graduate teaching assistants (TAs) and an undergraduate teaching assistant (UTA). A215 is required and/or recommended for multiple health science curricula including pre-nursing, kinesiology, nutrition, exercise science, pre-optometry, pre-dental, and pre-allied health (e.g., athletic training, physical therapy, occupational therapy). The majority of students are freshmen and sophomores, although limited numbers of juniors and seniors are also enrolled.

The gross anatomy and histology of all body systems are presented in both the lab and lecture parts of the course. The lecturers discuss the material using PowerPoint slides and provide the students with abbreviated lecture notes that they must fill in during class. The lecturers utilize a variety of classroom assessment techniques (Angelo and Cross, 1993), such as memory matrices, to incorporate active learning throughout lecture. Lecture material is assessed by four multiple choice examinations (worth 360 points total) and eight online quizzes (worth 40 points total).

During the laboratory sessions, TAs provide a 15–20 minute introduction to the day's content, and then the laboratory is run as student-regulated learning time with bones, three-dimensional models and virtual microscopy slides available to help learn the material. (The virtual microscopy component of the class has been discussed in detail in Husmann et al., 2009.) The TAs also demonstrate gross anatomical structures on two prosected cadavers (donors) housed in the room. The four short-answer laboratory examinations (100 points each) then assess students' knowledge of anatomic features on these same bones, models, virtual microscopy slides, and the cadavers that are available to study. These four laboratory examinations total four hundred points (400), resulting in a maximum of eight hundred (800) points (spread equally between lab and lecture) that may be earned in the course.

Students from the Fall 2015 and Fall 2016 semesters were invited to participate in this research. Of the 390 students from the Fall 2015 semester and the 377 students from the Fall 2016 semester that completed the course, a total of 244 and 182 students, respectively, participated in the study. Thus, the total sample size for both semesters was 426 students. However, some students did not answer every question on the survey and some did not turn in all components of the VARK assessment. These missed responses then resulted in slightly lower sample sizes for some analyses (e.g., Tables 3, 5, and 6).

VARK Survey

During the first week of the semester, all Anatomy A215 students were informed about the VARK website (VARK, 2017) and encouraged to complete the VARK questionnaire to determine the VARK category (or categories) that fit them best. Students were given one point extra credit if they completed the VARK questionnaire and reported their results in the course's online management learning system. Students were encouraged by the instructors to read through the suggested study strategies for each VARK category, and consider incorporating some of the study strategies into their study regimen, if they felt they would be useful.

After the end of the semester and final grades were submitted, the VARK results were compared to their study strategy survey responses (to address aim 1) and the agreement (or lack thereof) was then compared to the total points earned in the class (to address aim 2).

Study Strategy Survey

The study strategy survey used here was developed by J. Bradley Barger following the methods of Fowler (1995) and piloted with a small group of undergraduate students before final revisions (Barger, 2012). The survey was also evaluated by a sample of Indiana University anatomy faculty and graduate students involved in the A215 course. Over several semesters, both medical and undergraduate students took the survey and a Cronbach's alpha coefficient was calculated to assess reliability or internal consistency of the survey questions on this combined (medical and undergraduate) population. Cronbach's alpha is measured on a scale of 0 to 1, with values of 0.7 or greater considered to be good measures of reliability (Field, 2009). The survey attained a Cronbach's alpha of 0.767, indicating good reliability (Husmann et al., 2016).

The survey included twenty-six Likert scale questions about study strategies, attendance, and attitudes. A sample of these questions has previously been published by Husmann et al. (2016). The final section of the survey included additional categorical questions on basic demographics, such as age, gender, ethnicity, and academic standing.

The study strategy survey questions were then coded by both investigators based on the VARK category that best aligned with the question. For example, "Reading the text or tables from the textbook" was categorized as R (reading/writing) while "reviewing figures from the textbook" was categorized as V (visual). These categories were also discussed with anatomy faculty and graduate students serving as teaching assistants in the course for further confirmation. This survey was administered via Qualtrics (Qualtrics, Provo, UT) and set-up behind a Central Authentication System (CAS) log-in so that a Family Educational Rights and Privacy Act (FERPA, 2017) release could be included in the informed consent form and grades could be matched to the individual's survey.

VARK and Survey Administration

Anatomy A215 students were invited to complete the VARK questionnaire during the first two weeks of class (VARK, 2017). The link for the questionnaire was posted on their assignments page and on the calendar for the class. Announcements were also made during the lecture sessions. Upon completion, students were asked to post a screen capture of their VARK results onto the course management page for one extra credit point (see Fig. 1). These results included a numerical score for each of the categories (visual, auditory, reading/writing, and kinesthetic) and what the program calculated to be that individual's preference. The results also included links to study strategies that are believed to correlate with each VARK category.

Due to the large number of students assessed by the program as multimodal (285 of 417, including 170 assessed as quadrimodal), one of the authors (PH) further categorized students by their highest scoring VARK category. This highest scoring category was then referred to as their VARK dominant category. If multiple categories had the exact same highest score, then all categories with that highest score were included as the VARK dominant categories.

A link to the study strategies survey was also posted on the learning management system and up to two extra credit points were included as an incentive. (These same extra credit points could also be awarded for completing an online homework module, so that no coercion for taking the survey was involved.) Again, reminder announcements about the study

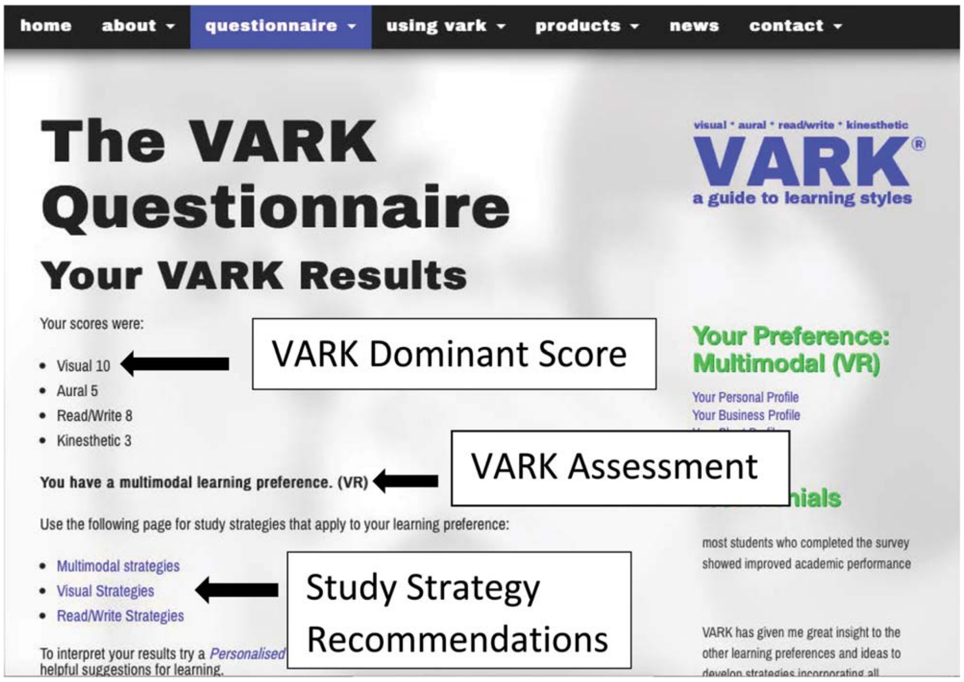

Figure 1.

Screen Capture of Student Submission from VARK Questionnaire (VARK. 2017).

strategies survey were also made during the lecture sessions. The survey was available for two weeks and closed the day after the last examination. Study strategies scores were then combined to generate a total score for study strategies that were classified as visual (V), a total score for study strategies that were classified as auditory (A), a total score for study strategies that were classified as reading/writing (R), and a total score for study strategies that were classified as kinesthetic (K). These scores were then divided by the number of study strategies on the survey that fell into that category to create a ratio since not all four categories had equal numbers of study strategies that were included on the study strategy survey. Thus, each student was given a combined numerical ratio for visual study strategies, one for auditory study strategies, one for reading/writing study strategies, and one for kinesthetic study strategies.

Statistical Analysis

Data was evaluated for normal distributions and equality of variance. Equality of variance was confirmed. However, while normal distributions were confirmed based on a visual analysis of the histograms, the Kolmogorov-Smirnov analysis was found to be statistically significant at $P < 0.0001$. Since a statistically significant Kolmogorov-Smirnov test puts the presence of a normal distribution in question, all results include both parametric and non-parametric tests. All statistics were calculated using SPSS statistical package, version 24.0 (IBM Corp., Armonk, NY) with a cutoff of $P = 0.05$ as the threshold for statistical significance.

Initially, final mean point totals between the samples for each semester and the mean of the total class (including those that did not participate in the study) were compared using single sample t-tests and Wilcoxon signed rank tests to determine if the participants were representative of the entire class. These single sample tests were necessary since the individual scores of those that did not participate could not be used (i.e., only the average of the entire class could be compared since the non-participating students did not consent for the researchers to use their individual grade data in this project). The final point totals across the two semesters evaluated were also compared using independent sample t-tests and Kruskal-Wallis tests to determine whether or not grade differences between the two semesters were statistically significantly different. Basic demographics between semesters were also compared to determine if the demographic makeup of the class was consistent (see Table 1).

Next, relative frequencies of the number of categories preferred in the VARK computer-generated assessment and males' and females' scores in each VARK category were compared using independent samples *t*-tests and Mann-Whitney U tests to determine if this sample of VARK results were consistent with those previously published in the literature. Pearson's and Spearman's rho correlations were then calculated among VARK numerical scores and final point totals, as well as independent samples t-tests and Mann-Whitney U tests between VARK assessment binaries (e.g., was V (visual) part of their original, computer-generated VARK assessment either individually or as part of a multimodal assessment – yes or no) for laboratory and lecture scores separately, to determine if any VARK categories were innately beneficial in the class regardless of study strategies employed (aim 2a). Pearson's and Spearman's rho correlations were then calculated among study strategies and final point totals in anatomy to

Table 1.

Basic Human Anatomy (A215) Course Demographics and Average Performance

Demographics	Fall 2015 Class Composition (%) (N = 244)	Fall 2016 Class Composition (%) (N = 179)	Average Final Class Performance	
			Total point[a] (±SD)	% (±SD)
Sex				
Male	20.5	22.5	679.2 (±76.9)	84.9 (±9.6)
Female	79.1	75.8	671.5 (±87.4)	83.9 (±10.9)
Age				
<18	0.4	0	629.6 (N/A)	78.7 (NA)
18–19	29.9	31.9	665.3 (±88.2)	83.2 (±11.0)
20–21	58.2	54.9	677.9 (±81.1)	84.7 (±10.1)
22–23	11.1	8.8	665.4 (±97.7)	83.2 (±12.2)
24+	0.4	2.7	728.7 (±79.5)	91.1 (±9.9)
Ethnicity				
African-American	7	8.8	612.0 (±77.3)	76.5 (±9.7)
American Indian	0.8	1.6	640.7 (±70.2)	80.0 (±8.8)
Asian-American	9	4.4	699.5 (±79.3)	87.5 (±9.9)
Hispanic	1.6	2.7	584.7 (±90.6)	73.1 (±11.3)
White	77.9	78	680.5 (±83.8)	85.1 (±10.5)
Academic standing				
Freshman	9.4	8.8	689.6 (±84.6)	86.2 (±10.6)
Sophomore	32.4	35.2	658.9 (±89.5)	82.3 (±11.2)
Junior	37.7	34.6	675.5 (±83.0)	84.4 (±10.4)
Senior	18.9	18.1	687.8 (±74.5)	86.0 (±9.3)
Hours reported studying in the week preceding the examination				
0–2	1.75	2.75	611.5 (±106.8)	76.4 (±13.4)
3–5	18.2	20.3	656.8 (±94.2)	82.1 (±11.8)
6–8	34.7	31.3	672.6 (±88.6)	84.1 (±11.1)
9–11	21.4	21.4	684.2 (±76.9)	85.5 (±9.6)
More than 11	23.8	24.2	682.9 (±74.6)	85.4 (±9.3)

[a]Maximum total available points to be earned = 800. N/A = not available.

determine if any study strategies were particularly helpful for class performance, regardless of the VARK results (aim 2b).

Finally, each student's VARK dominant category was compared with their highest study strategy ratio to see if students were aligning their study strategies with their VARK results (aim 1). If these two variables agreed (e.g., auditory [A] was the category of their highest VARK score and they had the highest ratio for auditory study strategies), then they were categorized as 'agree'. If the two variables were different (e.g., kinesthetic was the category of their highest VARK score, but they had the highest ratio for reading/writing study strategies), then they were categorized as "disagree." Independent samples *t*-tests and Mann-Whitney U tests were then calculated between the "agree" and "disagree" groups to determine if students who utilized study strategies that aligned with their VARK dominant category had statistically significantly different final point totals in the course than those students whose study strategies and VARK dominant category did not align (aim 2). These comparisons were also calculated for each individual VARK dominant category with the multimodal individuals removed, so as to reduce the influence of those students who had multiple dominant categories (which would increase the likelihood of agreement).

RESULTS

During the Fall 2015 semester, 244 out of 390 students completed both the VARK questionnaire and the study strategy survey. During the Fall 2016 semester, 182 out of 377 students completed both the VARK questionnaire and the study strategy survey. The total sample size for both semesters was 426, though some questions were left blank or VARK assessments were incomplete, resulting in slight smaller sample sizes for some analyses.

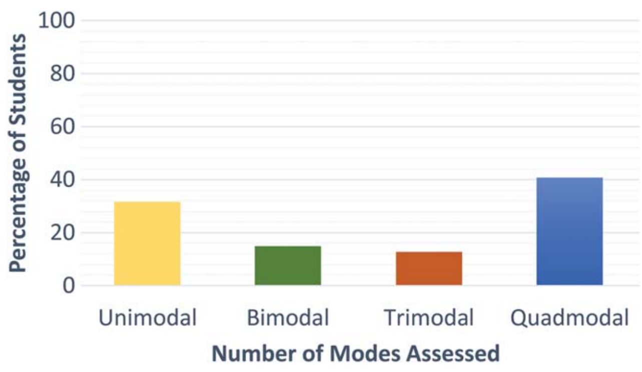

Figure 2.

Number of VARK Preferences Assessed by the Questionnaire.

For the Fall 2015 class, the course mean was an 80.3% with a median of 83.12%, while the mean for our sample from that semester was 84.04% with a median of 86.15%. For the Fall 2016 class, the course average was 80% with a median of 84.22%, while the average for our sample from that semester was 84.28% with a median of 86.69%. Single sample t-tests revealed a statistically significant difference between the final average percentage for the sample and the class in general ($P < 0.0001$) for each semester while Wilcoxon signed rank tests also found a statistically significant difference for the Fall 2015 semester ($P = 0.012$) and a slight, but statistically non-significant difference for the Fall 2016 semester ($P = 0.300$). These results suggest that the students who participated in this project did at least generally better than the average student in the course for both semesters. However, independent samples t-tests and Kruskal-Wallis tests were calculated on our sample to check for statistically significant differences in mean total points earned between the two semesters. Since no statistically significant differences were found ($P = 0.818$ parametric, $P = 0.690$ non-parametric), all further analyses were calculated with the data from both semesters combined.

Figure 2 shows relative frequencies for the number of categories preferred in the VARK assessment. In particular, it illustrates that over 40% of students were assessed as quadrimodal, or strong in all four VARK categories. Figure 3 shows the distribution of VARK dominant categories in the A215 students. Those students whose dominant scores tied are included in the counts for all categories that had this highest score. Given that previous studies by Wehrwein et al. (2007), Dobson (2009), and Farkas et al. (2015) had found gender differences in VARK results, parametric and non-parametric comparisons were calculated for males' and females' numerical scores in each VARK category (Table 2). While females were found to have higher numerical scores in all four VARK categories, these differences were only statistically significant in the R (reading/writing) category.

Parametric and non-parametric correlations among VARK numerical scores and final grades (Table 3) show that VARK scores all have positive correlations with each other except between the R and K categories, but no correlations with total points earned in the anatomy class. No statistically significant correlations were found between VARK numerical scores and lecture or laboratory point totals. Based on the correlations between V, A, R, and K scores, it was hypothesized that some ambitious students may simply be using more approaches in all of the categories to try to improve their grades. However, no statistically significant correlations were found between average ratios across all VARK study strategy categories and final point totals in the class (Pearsons = −0.041, $P = 0.403$, Spearmans = −0.060, $P = 0.219$). These results suggest that students who are utilizing more study strategies across VARK categories do not have higher final point totals in the class than their peers.

Comparisons of final grades between VARK assessment binaries (yes/no, including when the category is part of bimodal, trimodal, etc.) were also run and yielded no statistically significant results (Table 4). Thus, being categorized (or not being categorized) as any particular VARK category, such as V (visual), also does not correlate with higher or lower grades in anatomy. Comparisons between VARK assessment binaries were also calculated for laboratory and lecture examination scores separately to determine if any one VARK category is associated with higher or lower scores in lecture or laboratory separately, but no statistically significant results were found. These results indicate that whether a student was assessed by the VARK model as "strong" in each of the categories (either as an individual dominant score or as part of a multimodal dominant score) was not associated with a statistically higher or lower point total in the class as a whole or in lecture or laboratory separately.

Parametric and non-parametric correlations were also calculated between study strategies and final point total in anatomy (Table 5). These correlations showed statistically significant negative correlations with use of practice questions, coloring books, flashcards, other textbooks, and other websites, which suggests that increased use of these resources was more common in students with lower point totals in the class. Statistically significant positive correlations were found between the final point total and use of the virtual microscope and the notes, suggesting that increased use of these

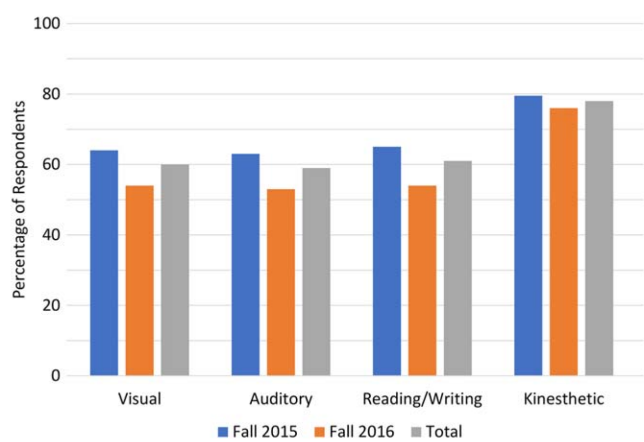

Figure 3.

Relative Frequencies of VARK Categories. Each category includes all individuals assessed with that preference as unimodal or as part of a multimodal assessment (e.g., bimodal, trimodal).

Table 2.

VARK Category Differences between Males (M) and Females (F).[a]

	Mean VARK score	*t*-score	*P*-value	Mann-Whitney U	*P*-value
Visual	M: 5.85 F: 6.53	−1.814	0.070	12159.5	0.088
Auditory	M: 6.44 F: 6.53	−0.259	0.796	13604.5	0.830
Reading/ Writing	M: 5.54 F: 6.57	−2.642	0.009[a]	11141	0.006[a]
Kinesthetic	M: 8.07 F: 8.06	0.025	0.980	13520	0.762

This table illustrates the equivalent or higher scores of females in each category. These differences are statistically non-significant in all categories, except for the reading/writing preference.
[a]Significance cut-off of $P = 0.05$.

resources was more common in students with higher point totals in the class.

Additional interesting findings were found when comparing students' VARK dominant categories and their highest study strategy ratio. Only 32.85% of the students had dominant study strategies that agreed with their VARK dominant category. The remaining 67.15% of students were found to be preferentially utilizing study strategies that did not fit with their VARK dominant category.

Comparisons between those whose highest study strategies ratio & dominant VARK category agree versus those whose study strategies and dominant VARK category do not agree

Table 3.

Correlations of VARK Category Scores and Final Grades

VARK category	Statistical tests and sample sizes	Anatomy total points	Laboratory points	Lecture points	Visual	Auditory	Reading/ Writing
Visual							
	Correlation (P/S)[b]	0.075/0.089	0.085/0.086	0.060/0.072	XXXXXX[c]		
	Significance (*P*)[a]	0.126/0.070	0.085/0.080	0.224/0.142			
	N	414	414	414			
Auditory							
	Correlation (P/S)	0.068/0.074	0.073/0.093	0.056/0.056	**0.226/0.209d**	XXXXXX	
	Significance (*P*)	0.170/0.134	0.138/0.059	0.253/0.254	**<0.0001/<0.0001**		
	N	414	414	414	**414**		
Reading/Writing							
	Correlation (P/S)	0.030/0.050	0.008/0.040	0.045/0.055	**0.147/0.150**	**0.203/0.232**	XXXXXX
	Significance (*P*)	0.538/0.307	0.863/0.417	0.358/0.268	**0.003/0.002**	**<0.0001/<0.0001**	
	N	414	414	414	**414**	**414**	
Kinesthetic							
	Correlation (P/S)	0.008/0.016	0.046/0.046	−0.024/−0.009	**0.353/0.344**	**0.372/0.359**	0.076/0.075
	Significance (*P*)	0.875/0.748	0.354/0.350	0.622/0.859	**<0.0001/<0.0001**	**<0.0001/<0.0001**	0.121/0.127
	N	414	414	414	**414**	**414**	414

[a]This table illustrates the correlations between many of the VARK categories, but the lack of correlates between VARK Categories and grades in the course. Statistical significance cut-off at $P = 0.05$. Statistically significant correlations are shown in bold; [b](P/S) = Pearson correlation/Spearman correlation. Both parametric (Pearson) and nonparametric (Spearman) correlation test were run for each category to account for potential skewedness in the sample. They are reported with the Pearson correlation and significance on the left and the Spearman correlation and significance on the right; [c]XXXXXX indicates where the correlations shown in the table become redundant.

Table 4.

Comparisons of Final Grades between Those Who were and were Not Classified into each of the VARK Categories

VARK Category and points earned in A215	Average point total for those included in this category (±SD)	Average point total for those not included (±SD)	*t*-scores	*P*-value	Mann-Whitney U	*P*-value
Visual						
Total	677.4 (±83.9)	670.6 (±84.2)	−0.697	0.486	18898.0	0.361
Laboratory	342.2 (±39.8)	336.8 (±40.7)	−1.330	0.184	18342.5	0.165
Lecture	335.1 (±48.8)	333.8 (±48.9)	−0.272	0.786	19606.0	0.759
Auditory						
Total	673.6 (±84.5)	676.3 (±83.6)	0.446	0.655	19766.0	0.756
Laboratory	340.0 (±41.1)	340.2 (±38.8)	0.053	0.958	19900.0	0.845
Lecture	333.6 (±48.1)	336.1 (±49.9)	0.505	0.614	19410.0	0.539
Reading/writing						
Total	673.2 (±86.1)	677.1 (±80.8)	0.442	0.659	19522.5	0.792
Laboratory	338.7 (±41.9)	342.4 (±37.3)	0.908	0.365	19094.0	0.528
Lecture	334.6 (±49.1)	334.7 (±48.6)	0.025	0.980	19812.5	0.989
Kinesthetic						
Total	674.7 (±84.0)	674.7 (±84.5)	0.139	0.889	13636.5	0.989
Laboratory	340.2 (±40.1)	339.6 (±40.5)	−0.133	0.894	13578.0	0.941
Lecture	334.5 (±48.8)	335.6 (±49.4)	0.112	0.911	13575.0	0.919

This table demonstrates that there were no statistically significant differences in anatomy grade based on inclusion in the visual (V), auditory (A), reading/writing (R), or kinesthetic (K) categories (significance cut-off of $P = 0.05$). Both parametric (independent samples t-tests) and nonparametric (Mann-Whitney U tests) were calculated to account for potential skewedness in the sample. Numbers include all individuals that were categories as Visual, Auditory, Reading/Writing, or Kinesthetic as unimodal or as part of a multimodal (e.g., bimodal, trimodal) assessment.

Table 5.

Correlations between Study Strategy and Final Grade

Study strategy utilized, per survey response	Pearson's correlation with Final Point Total (r)	*P*-value	Spearman's Rho correlation with Final Point Total	*P*-value
Use of Practice Questions	**–0.155**	**0.001**	**–0.105**	**0.003**
Use of Virtual Microscope	0.127	0.009	0.090	0.017
Use of Lecture Notes	0.122	0.012	0.126	0.001
Use of Coloring Book	–0.236	0.000	–1.71	<0.0001
Use of Flashcards	–0.114	0.019	–0.096	0.007
Use of Other Textbook	–0.124	0.010	–0.114	0.003
Use of Outside Websites	–0.363	0.000	–0.273	<0.0001
Making Your Own Flashcards	–0.148	0.002	–0.111	0.002

This table shows the study strategies that correlated with final point totals in the course. Both parametric (Pearson) and nonparametric (Spearman) correlations were calculated to account for potential skewedness in the sample; number of participants (N = 424).

Table 6.

Comparison of Final Grades between Students Whose Study Strategies Agree with their VARK Assessment and Students Whose Study Strategies do Not Agree with their VARK Assessment

VARK category	Does dominant VARK category agree or disagree with study strategy?	Mean final grades (%)	*t*-scores	*P*-value	Mann-Whitney U	*P*-value
Visual	Agrees (n=14)	88.88	−1.252	0.216	254	0.277
	Disagrees (n=45)	85.50				
Auditory	Agrees (n=22)	85.46	−0.503	0.617	482	0.753
	Disagrees (n=46)	84.20				
Reading/writing	Agrees (n=36)	80.46	1.641	0.105	660	0.202
	Disagrees (n=44)	85.16				
Kinesthetic	Agrees (n=30)	83.37	0.095	0.924	1614	0.742
	Disagrees (n=112)	83.59				
All categories	Agrees (n=136)	83.94	0.470	0.639	18779.5	0.927
	Disagrees (n=278)	84.45				

This table shows no statistically significant differences in final grades between students whose study strategies agreed with their VARK preferences and those whose did not (statistical significance cut-off of $P = 0.05$).

revealed no statistically significant difference in final anatomy grades (Table 6). Independent samples *t*-tests were also run between "agree" and "disagree" individuals for each VARK dominant category with the multimodal individuals removed to reduce the influence of those students who had multiple dominant categories (which increased the chances of agreement), but there were still no statistically significant differences. These results indicate that whether or not students utilized study strategies that were consistent with their VARK dominant categories was not associated with statistically significantly higher or lower point totals in the class.

DISCUSSION

The results detailed above demonstrate that an overwhelming majority (67%) of students used study strategies that were inconsistent with their highest scoring VARK category (aim 1). In addition, those students who utilized study strategies consistent with their highest scoring VARK category did not perform significantly differently in the class from those students that did not use their VARK recommended study strategies (aim 2). Furthermore, no specific VARK categories were associated with improved outcomes in A215: Basic Human Anatomy (aim 2a). Instead, specific study strategies such as use of outside websites or flashcards were found to have a significant negative correlation with final point totals, while use of the provided notes and virtual microscope were found to have positive relationships with final grades (aim 2b).

Previous research using the VARK learning style questionnaire found that kinesthetic was the most common learning style category for undergraduates in health sciences (Alkhasawneh et al., 2008; Breckler et al., 2009; James et al., 2011). The present study also found kinesthetic to be the most popular category with the Anatomy A215 students. One study that contradicted this trend is the research by Dobson (2009), which found that the kinesthetic learning style was reported least in his first and second year undergraduates. However, the fact that he used only three questions from the VARK questionnaire and then had students self-identify their VARK category preference (which Breckler et al. 2009 had shown most students could not accurately do) may have skewed his results.

When looking at the number of VARK categories preferred by students, previous research had shown the following ranges: 13.8–69.9% unimodal, 11.7–72% bimodal, 10.8–42.5% trimodal, and 0–56.3% quadrimodal with a combined 30.1–86.8% considered multimodal (Drago and Wagner, 2004; Murphy et al., 2004; Lujan and DiCarlo, 2006; Baykan and Naçar, 2007; Wehrwein et al., 2007; Breckler et al., 2009; Leite et al., 2010; Nuzhat et al., 2011; Alkhasawneh, 2013; Samarakoon et al., 2013; Peyman et al., 2014; Prithishkumar and Michael, 2014; Urval et al., 2014; Farkas et al., 2015; Meyer et al., 2015; Balasubramaniam and Indhu, 2016; O'Mahony et al., 2016). The present research also fits nicely into these ranges with 31.65% unimodal, 14.87% bimodal, 12.71% trimodal, and 40.77% quadrimodal (with a standard error of mean of 0.064) for a combined 68.35% multimodal. As such, this research and the student sample may be considered a fairly typical representation of an undergraduate VARK population, and comparisons of this research's results with other VARK research is appropriate.

Aim 2a: Correlations among Course Performance and VARK Categories

None of the VARK categories were found to correlate with final grades in anatomy, which is consistent with previous research in first-year medical students' anatomy courses (Urval et al., 2014; O'Mahony et al., 2016). However, others have disagreed with this finding. Dobson (2009) did find that learning styles correlated with final physiology grades, but again, he used only a small part of the VARK questionnaire. Kim and colleagues also found that VARK category preferences were associated with differences on a surgical residency examination

(Kim et al., 2015) and with surgical resident interviewees on their Step 1 scores (Kim et al., 2016), though his samples sizes were sometimes not very robust and it must be admitted that residents are a substantially different population from a 200-level anatomy course. Being at least five to ten years ahead in their studies (and having been successful enough to gain admission and graduate from medical school), residents are more likely to have already capitalized on their study strategy strengths than undergraduates in a 200-level anatomy course.

In the present study, nearly all of the VARK category scores correlated with each other. This finding is similar to the study of Drago and Wagner (2004), which found that visual, auditory, and kinesthetic categories were all linked. Based on this evidence, it was hypothesized that some students, particularly females since they had higher numerical responses in all four VARK categories, may simply be using more approaches to studying in attempts to improve their grades. However, no strong correlations were found between combined study strategy scores across all VARK categories and final grades, which would have indicated that using more study strategies across all VARK categories was a successful method for improving course performance. Thus, while VARK categories do correlate with each other, these findings demonstrate no relationships between final grades and preferring one VARK category over another.

Aim 2b: Correlations among Course Performance and Study Strategies

The study strategies commonly reported by undergraduate anatomy students in the present study were also consistent with those in previously published literature. The use of outside resources (e.g., other texts, websites, etc.) was also discussed by Gallard-Echenique et al. (2016), who found that students in nursing prerequisite classes were more likely to attempt to look information up online or figure it out themselves than they were to ask a professor or tutor. Unfortunately, this previously reported use of outside resources does not seem to be particularly effective in the present study, given the negative correlations with final anatomy grades.

Negative correlations were also seen with the use of flashcards and practice questions versus anatomy final grade. These findings were surprising, given the extensive research by Karpicke (Roediger and Karpicke, 2006; Karpicke and Bauernschmidt, 2011; Karpicke and Blunt, 2011) and Dobson (Dobson and Linderholm, 2015; Dobson et al., 2017) on the benefits of self-testing for information retention. However, our findings agree with the work of Felicilda-Reynaldo et al. (2017), who found that anatomy was one of the nursing prerequisite courses most commonly associated with rote memorization and that flashcards were the most common strategy for that memorization. Furthermore, Ye et al. (2016) demonstrated with undergraduates in chemistry that this rote memorization was associated with lower final grades, lower metacognitive skills, and poorer affective traits (e.g., self-efficacy). Hartwig and Dunlosky (2012) in their survey of introductory psychology students also found a distinction in student reports of self-testing versus flashcard use. They suggest that students may not be using flashcards to self-quiz (e.g., students may just be reading them) or the flashcards may only include very basic information, thus not achieving the greater connections and deeper understanding necessary for the examinations. Consequently, the use of flashcards may indicate rote memorization strategies that are not compatible with the connections between information and the ability to apply what has been learned.

The negative association between the use of practice questions and final anatomy grade was also surprising, but these results may be related to the students using practice questions that are not indicative of the level or content of the examination. For example, the textbook that is required for this class includes practice questions, some of which are not the type of questions seen on the examinations and/or cover content that is not required for this course (e.g., embryology). If these questions are the ones being used by the students, the lack of alignment with course examination questions could be contributing to this negative correlation.

Positive correlations between study strategies and final grades included the use of lecture notes and the use of the virtual microscope. Similar results for presentation or lecture notes have been found previously as long as the student is able to concentrate on the notes and additional notes are taken frequently (Nonis and Hudson, 2010; Advokat et al., 2011; Felicilda-Reynaldo et al., 2017). The positive association with use of the virtual microscope is also not surprising, given the amount of histology (up to 25% per each laboratory examination) that students are required to know for both the lecture and laboratory examinations. Previous research has also indicated that one of the benefits that students like most about the virtual microscope is the ability to use it from home or other locations (Husmann et al., 2009) as opposed to the models or prosected cadavers associated with the anatomy laboratory, which cannot leave the laboratory. One possible explanation for the present result is that the positive correlation between virtual microscope use and final point totals may also relate to students who spend more time with the material outside of class (possibly using the virtual microscope) being more successful than those students who do not.

Overall, many of the study strategies with which the Anatomy A215 students may be the most comfortable (e.g., flashcards, websites, etc.) were found to have negative correlations with final point totals, while use of lecture notes and virtual microscopy were found to have positive correlations. One explanation of these results may be Bjork and Bjork's (2014) premise of "desirable difficulty" for a given task. This premise states that tasks that have some degree of difficulty associated with them will be more useful for learning than those tasks that are not difficult. Thus, 'desirably difficult' tasks (such as working through a complex problem or finding cell types using the virtual microscope) will help students learn better than passive tasks like using a web search engine to find answers or reading over flashcards. An alternative, or perhaps supplemental, explanation for students' use of less effective study strategies may relate to the neurofeedback loops that develop around studying. Fitkov-Norris and Yeghiazarian (2013) found that study strategies that are used frequently can become true study habits via neurofeedback loops. As these feedback loops develop over time, it may be increasingly difficult for students to change the study strategies that they are using.

Aims 1 and 2: Alignment between VARK Categories and Study Strategies

When comparing the VARK categories with the study strategies reportedly used by the students (aim 1), two-thirds of students did not report using study strategies that aligned with their VARK dominant category. Yet, Fleming advocates that "Adopting learning behaviors that are aligned with your preferences is more likely to lead to positive learning outcomes than adopting alternative strategies that are the opposite of your preferences" (Fleming, 2012a). Unfortunately, even when the study strategies were aligned with the recommended behaviors in this study, no benefits were seen to the final anatomy grade (aim 2) and Fleming provides no citations to support his claim. Thus, providing students with their VARK category preferences may not actually be beneficial to the students since most of the students don't change their study strategies and, even if they do, there do not appear to be any appreciable effects on course performance.

Limitations

There are some limitations to this study. The participation rate for this study is a bit lower than expected (55.5%) and there is some selection bias present, possibly produced by the use of extra credit (albeit <1% of the final grade) as an incentive for participation. It is possible that more motivated students were inclined to participate for the extra credit points, even though these points were negligible toward the final anatomy grade. However, even if all the students who did not participate had studied in accordance with their VARK category preferences, these students still generally performed more poorly in the course than those students who did participate, and thus it is unlikely that our overall conclusions would be different. It should also be noted that our analyses did have variable numbers of students assessed in various categories (e.g., Table 6). This has the potential to increase the likelihood of the type 2 error. In addition, all study strategies discussed here were self-reported. As such, it is possible that students were not accurately reporting how they prepared for the examinations. There was also some disagreement on the alignment between some study strategies and their associated VARK category. For example, the use of lecture notes was generally considered an R (reading/writing) strategy but it could also be considered a V (visual) strategy if pictures were also included. (Pictures were not included in the lecture notes for the present study.) However, if the faculty and TAs that determined which study strategies fit with which VARK category could not come to a general consensus, then the study strategy/question was not used so as not to skew the results. This research was also unable to control for other background variables that may be impacting student performance such as base test-taking ability as may be indirectly indicated by Scholastic Assessment Test/American College Testing (SAT/ACT) scores, overall grade point averages, additional work or home responsibilities during the semester, whether a student was first-generation college-bound, and so on. Thus, there may be additional factors that have impacted student performance, irrespective of a student's VARK category preference and study strategies. Finally, it is possible that this particular undergraduate anatomy class may not be entirely representative of other undergraduate anatomy classes; further research with other anatomy classes is needed to see if the research findings apply to other student populations.

CONCLUSIONS

The VARK learning styles inventory (Fleming and Mills, 1992) has the potential for individuals to reflect on how they learn, and encourage students to adopt study strategies that may work better for them than their existing strategies. The aims of the present study were to assess if undergraduate anatomy students develop and use study strategies consistent with their hypothetical learning styles and if so, does this alignment correlate with outcomes in the course. Unfortunately, while many students find the VARK test interesting, the undergraduate anatomy students in this research did not utilize the results from VARK to make changes to their study strategies. Students may be resistant to venture from study strategies that they have used in the past and that are comfortable and easy (Bjork and Bjork, 2014) or have become true habits (Fitkov-Norris and Yeghiazarian 2013), but instead may cling to their misconceptions about how they think they learn best or are expected to learn. However, there still is some hope for helping these students. Explicit instruction in evidence-based study strategies may help students to better develop study strategies that are truly beneficial (McCabe, 2011). Thus, future research should focus on continuing to define these evidence-based study strategies.

This present research also demonstrates that even those students who did utilize study strategies consistent with their VARK dominant category had no greater success in the course. These present findings, along with extensive prior studies about the myths of learning styles (e.g., Pashler et al., 2009) provide strong evidence that instructors and students should not be promoting the concept of learning styles for studying and/or for teaching interventions. Thus, the adage of 'I can't learn subject X because I am a visual learner' should be put to rest once and for all.

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