Internet Journal of Allied Health Sciences and Practice

Volume 18 | Number 3 Article 14

June 2020

The Use of Tinkertoys® for Teaching Hip Anatomy and Alignment

Deborah M. Wendland
Mercer University College of Health Professions Department of Physical Therapy,
wendland_dm@mercer.edu

The Use of Tinkertoys® for Teaching Hip Anatomy and Alignment

Abstract

Background: Health education can require an emphasis on potentially difficult concepts in anatomy and alignment. **Purpose**: The purpose of this study is to describe the effect of active use of Tinkertoys® to promote understanding of alignment and to report its effectiveness for knowledge acquisition among students according to spatial ability. **Methods**: Two cohorts of physical therapy (PT) students (n=70) participated in this project over two years. Thirty-four students (second cohort) rated their math and spatial abilities on a survey. Following a traditional lecture on femoral torsion and angle of inclination, all participants took a pre-test. Then, a Tinkertoys® model of the lower limb was used along with a pelvic bone to simulate the hip anatomy and alignment. Only students in the second cohort received the opportunity to simultaneously manipulate similar models at their desks. At the end of the class period, a post-test was given. Four days later, a similar quiz was given. Descriptive statistics and repeated measures with pairwise comparisons were used to analyze the data. **Results**: Quiz means improved from pre-test (32.1%) to post-test (74.6%, p=0.023). Differences were not evident between people who self-reported stronger versus weaker spatial abilities (p=0.186). **Conclusions**: Tinkertoys® model use, with or without simultaneous model manipulation, facilitated learning, regardless of self-reported spatial ability.

Author Bio(s)

Deborah M. Wendland, PT, DPT, PhD, is an Associate Professor of Physical Therapy in the College of Health Professions at Mercer University in Atlanta, GA. She is also a licensed physical therapist in the state of Georgia and a certified pedorthist.

Acknowledgements

Acknowledgements: This work was supported by the Mercer University College of Health Profession for their Scholarship of Teaching and Learning grant.

The Internet Journal of Allied Health Sciences and Practice
Dedicated to allied health professional practice and education
Vol. 18 No.3 ISSN 1540-580X

The Use of Tinkertoys® for Teaching Hip Anatomy and Alignment

Deborah M. Wendland

Mercer University

United States

ABSTRACT
Background: Health education can require an emphasis on potentially difficult concepts in anatomy and alignment. **Purpose**: The purpose of this study is to describe the effect of active use of Tinkertoys® to promote understanding of alignment and to report its effectiveness for knowledge acquisition among students according to spatial ability. **Methods**: Two cohorts of physical therapy (PT) students (n=70) participated in this project over two years. Thirty-four students (second cohort) rated their math and spatial abilities on a survey. Following a traditional lecture on femoral torsion and angle of inclination, all participants took a pre-test. Then, a Tinkertoys® model of the lower limb was used along with a pelvic bone to simulate the hip anatomy and alignment. Only students in the second cohort received the opportunity to simultaneously manipulate similar models at their desks. At the end of the class period, a post-test was given. Four days later, a similar quiz was given. Descriptive statistics and repeated measures with pairwise comparisons were used to analyze the data. **Results**: Quiz means improved from pre-test (32.1%) to post-test (74.6%, p=0.023). Differences were not evident between people who self-reported stronger versus weaker spatial abilities (p=0.186). **Conclusions**: Tinkertoys® model use, with or without simultaneous model manipulation, facilitated learning, regardless of self-reported spatial ability.

Keywords: 3-D model, teaching strategies, spatial ability

INTRODUCTION

Physical therapy (PT) and other health-related education relies heavily on gross anatomy and developing a clinician's ability to accurately describe and visualize potential effects of anatomical variations. The literature has consistently reported that those with better spatial abilities perform better with anatomical material.[1–3] Thus, a conceptual awareness of anatomy, alignment, and joint movement, can be especially challenging for some students. While challenging, it has been reported that a student's ability to control orientation when learning anatomy may facilitate spatial learning.[2] Currently, cadavers and anatomical models are used in PT curricula to facilitate the learning of anatomy, alignment, and joint movement. Unfortunately, these methods can be cost prohibitive and may only allow limited student manipulation of models to better understand existing spatial relationships.

The importance of and challenge related to facilitating spatial understanding have been considered in several studies. Chatterjee reported that individuals with low spatial ability depended on two-dimensional pictures and thinking to learn anatomy while those with high spatial ability were able to think in three dimensions and integrate different types of images.[4] In a meta-analysis, spatial abilities were modifiable with even small amounts of training.[5] In fact, those with lower abilities could see larger changes.[5,6] Using visualizations, teachers can help students improve their ability to learn information requiring spatial conceptions.[7] With training, Wright et al found that gains made with practice were able to be transferred to new tasks as well as other spatial tasks that differed from those practiced.[8]

With evidence supporting the modifiability of spatial ability, it is important to consider teaching strategies that support the development of spatial ability when it is required. Multi-modal instruction is potentially advantageous for learning if the components are actively integrated.[9] Active participation of students when using multiple tools for instruction is critical.[10]

There has been evidence that certain experiences support development of spatial abilities including the use of construction toys.[11] Other toys, such as play dough and Operation®, have proven effective to facilitate visualization as well as psychomotor skill development.[12,13] The use of these interactive toys facilitates multiple approaches for instruction and learning.

To date, available studies suggesting models to facilitate hip anatomy and alignment knowledge acquisition, along with their effectiveness, are limited. The initial trial using Tinkertoys® to visually demonstrate the effect of the femur structure (femoral torsion and angle of inclination) on the alignment at the hip and the lower limb was performed by this investigator.[14]

Patented in 1914, the original Tinkertoys® set included wooden spools with superficial holes drilled every 45 degrees around the perimeter and one hole through the center of the spool.[15] Different colored sticks corresponded to different lengths and allowed for manipulation, visualization, and discussion of lever arms, mechanical advantage, and stress. The utilization of Tinkertoys® for hip anatomy and alignment instruction resulted in a significant improvement in the understanding of these typically difficult concepts.[14] While the use of the Tinkertoys® was helpful, it must be noted that the students had limited access to the Tinkertoys® model provided by the faculty member so a need for a second cohort with slight study modifications was identified.

Given the literature supporting the trainability of spatial cognition, the usefulness of multi-modal instruction, the importance of active control to manipulate models, and the need for active participation in learning, the purpose of this project was to describe a novel technique (active use of Tinkertoys®) to promote spatial understanding of hip anatomy and alignment among PT students within an applied anatomy course through active learning and exploration. A secondary purpose was to determine the usefulness of this model for knowledge acquisition and its relationship to self-reported spatial ability.

METHODS

The Mercer University IRB approved this study (H1411301) which was conducted with students in two consecutive years of an applied anatomy course within the Doctor of Physical Therapy (DPT) curriculum at Mercer University. To assist with considering and clarifying any effect on self-reported spatial ability found in the initial trial, the second cohort was asked to complete a survey prior to engaging in the class period utilizing the Tinkertoy® model. The survey was created for this study and asked students to rate their math and spatial abilities on a scale of 1-10. A lower score represented a lower self-assessment of spatial ability whereas a higher score represented a self-assessment that the individual's spatial abilities were better.

Each cohort of students received a lecture addressing femoral torsion and hip angle of inclination within their gross anatomy course in Mercer's DPT curriculum prior to (within 1-2 weeks) the presentation of the Tinkertoys® model. On the day the Tinkertoys® model was to be introduced, students were asked to participate in this study. Following informed consent, the students were asked to take a quiz (pre-model test) on this information. After the pre-model test, a demonstration of the hip structure and alignment, including femoral anteversion, retroversion, and angle of inclination, was given using the Tinkertoys® model. With the first cohort of students, the instructor demonstrated the hip structure and alignment using the Tinkertoys® with the students observing only.

To further support acquisition of knowledge, the second cohort of students was provided with Tinkertoys® to allow simultaneous manipulation of the models along with the instructor. Both cohorts of students had access to the toys for practice outside of the classroom. Additionally, a video of the same demonstration was posted to the class web page for both cohorts.

Post-Model Evaluation

To evaluate the effectiveness of this teaching model, students were given two additional quizzes over time. At the end of the same class period in which the model was introduced, the students were given the same quiz as was given prior to this teaching model (immediate post-model test). This quiz was given approximately ninety minutes after introduction of the model and after other unrelated class material had been covered. A third quiz (4-day post-model test) was given the next time the class met (three days in between). There was no additional instruction provided on the hip content, and the students were not made aware that there would be a quiz to minimize additional studying. The 4-day post-model test asked similar, but not the same, questions as the previous quizzes. Similar questions that tested the same concepts were used to avoid a repeated testing bias.

Tinkertoys® Model Description

To describe the concept of femoral anteversion and retroversion as well as angle of inclination, Tinkertoys® were used to allow for visualization of these concepts. The Tinkertoys® were used to mimic the lower limb such that circular pieces were used as the ankle, knee, hip, and head of the femur. Colored "dowels" represented the femoral neck, femoral shaft, the tibia, and the foot, connecting the large circular pieces. Together this model, mimicking the lower limb, was established and used along with a pelvic bone to describe the relationships that occur at the hip joint.

Anteversion and Retroversion

For anteversion and retroversion, a typical amount of femoral torsion was demonstrated in the model such that when the model was connected to the pelvic bone by seating the "head of the femur" into the acetabulum, the result was a typical alignment and anteriorly-facing lower limb (Figure 1b). In contrast, an increased angle of torsion (anteversion) was shown by rotating the femoral neck dowel anterior of the "normal" position and again the "head of the femur" was seated into the acetabulum. With this second seating, the position of the lower limb could easily be seen with the knee facing medially, appearing as if in a toe-in position (Figure 1a). Finally, a decreased angle of torsion (retroversion) was shown by repositioning the femoral neck dowel posterior to the "normal" position and seating it into the acetabulum. The lower limb subsequently displayed a laterally rotated position, appearing as if in a toe out position (Figure 1c).

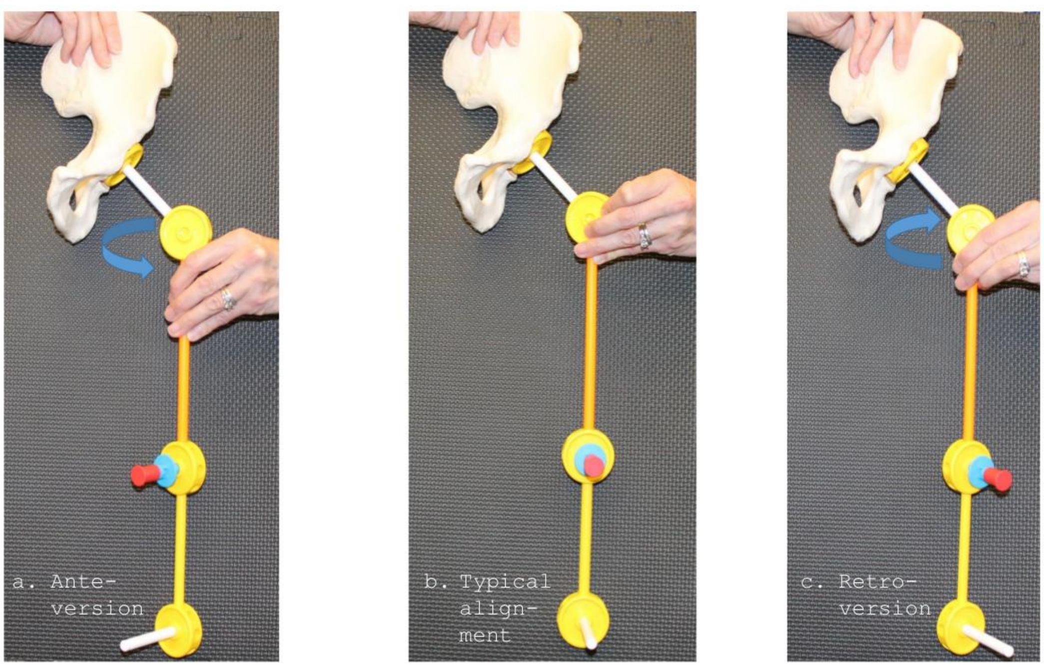

Figure 1. Femoral torsion. *a. anteversion; arrow denotes rotation of the femoral neck to a position anterior of the "normal" position b. typical alignment c. retroversion; arrow denotes rotation of the femoral neck to a position posterior of the "normal" position*

Angle of Inclination
To demonstrate the angle of inclination, again the lower limb Tinkertoys® model was utilized along with a bone model of a pelvic bone (Figure 2b). The Tinkertoys® model adjustment to show a changing angle at the femoral neck/shaft of the femur was accomplished by modifying the hole in which the femoral neck dowel was placed. For an increased angle of inclination, the Tinkertoys® femoral neck dowel was placed at the top of the circular piece. Because of the increased angle, when the model was seated into the acetabulum, a coxa valgum position could easily be noted (Figure 2a). Finally, after review of the change in hip position, the subsequent response at the knee was explicitly demonstrated by shifting the location of the "tibia" to allow the "foot" to meet the floor, resulting in the concomitant genu varum positioning.

For a decreased angle of inclination, the Tinkertoys® femoral neck dowel was placed into a lower hole of the circular piece representing the junction of the femoral shaft and neck. Again the revised model was placed so that the "head of the femur" was well-seated into the acetabulum resulting in a visible representation of a coxa varum position that occurs with this change in the angle of inclination (Figure 2c). Finally, after review of the change in hip position, the subsequent response at the knee was explicitly demonstrated by shifting the location of the "tibia" to allow the "foot" to again meet the floor, resulting in the concomitant genu valgum positioning.

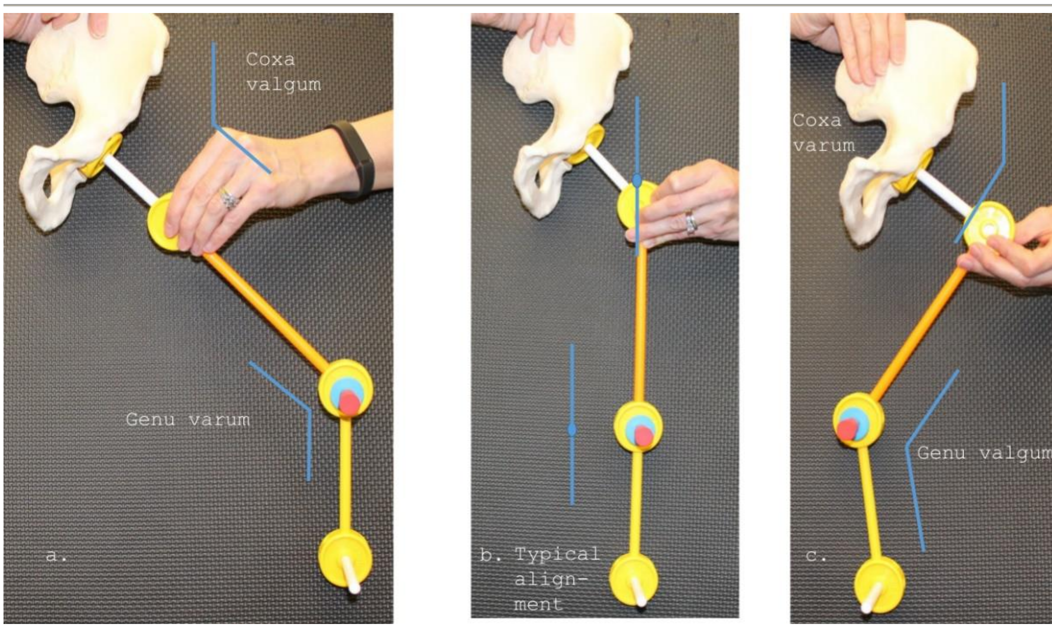

Figure 2. Femoral angle of inclination. *a. Increased angle of inclination resulting in coxa valgum and genu varum. b. Typical angle of inclination resulting in neutral lower extremity alignment c. Decreased angle of inclination resulting in coxa varum and genu valgum*

Data Analysis
Descriptive statistics and repeated measures with pairwise comparisons were used to analyze the test scores across time. Spearman's correlation was used to assess the relationship between reported visual spatial ability and quiz change scores. IBM SPSS Statistics version 23 (Armonk, NY: IBM Corp.) was used to perform all statistical analyses.

RESULTS
Thirty-six students (27 female, 9 male) participated in the first cohort, and 34 students (21 female, 13 male) participated in the second cohort. While quiz scores were different between cohorts (p=0.012), the quiz change scores over time were not different between cohorts (pre- to immediate post-model test: p=0.641; immediate post- to 4-day post-model test: p=0.812). The overall pre-model test average score, with both groups combined, was 32.1±25.9% (Cohort 1: 27.8±28.5% vs. Cohort 2: 36.8±22.4%) while the overall immediate post-model test average score was 74.6±26.8% (Cohort 1: 68.8±29.5% vs. Cohort 2: 80.9±22.5%) (Figure 3). The combined cohort quiz scores (pre-model versus immediate post-model) were significantly different ($p<0.001$). Pre- to immediate post-model test change scores ranged from 0 to 100% with a mean change score of 41.0±30.0% in Cohort 1 and 44.1±26.0% in Cohort 2. No students scored more poorly on the immediate post-model test than the pre-model test.

On the 4-day post-model test, the overall average was 82.9±18.8% (Cohort 1: 77.8±21.3% vs. Cohort 2: 88.213.1%). The combined cohort 4-day post-model tests were also significantly different from their pre-model test scores ($p<0.001$). Immediate post-model test and 4-day post-model test (combined cohort) were also significantly different from each other ($p<0.023$). In the first cohort, from immediate post-model test to the 4-day post-model test, six people had scores that did not change (all were 100%), twelve had scores that dropped (six from 100%), and eighteen had scores that continued to rise. Similarly, in the second cohort, from immediate post-model test to the 4-day post-model test, fifteen people had scores that did not change (11 were 100%), six had scores that dropped (all from 100%), and 13 had scores that continued to rise.

Spatial abilities were reported in the second cohort only. In this cohort, no relationship was evident between test performance and self-reported spatial ability. Visual spatial rating was not correlated with change scores from pre-model to immediate post model (correlation coefficient, r = -0.102, p = 0.566) or with change scores from immediate post model to 4-day post model (correlation coefficient, r = 0.164, p = 0.353) (Figure 4).

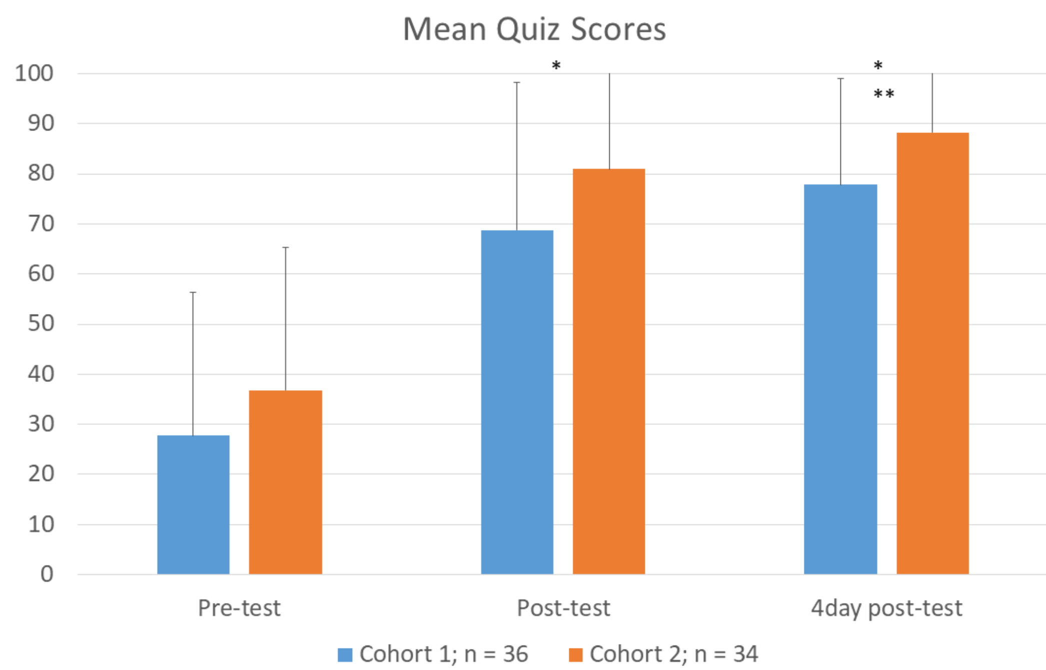

Figure 3. Mean quiz scores across cohorts. (Cohort 1: n = 36; Cohort 2: n = 34) * denotes significant difference of combined scores from combined Pre-test scores. **denotes significant difference of combined scores from combined Post-test scores.

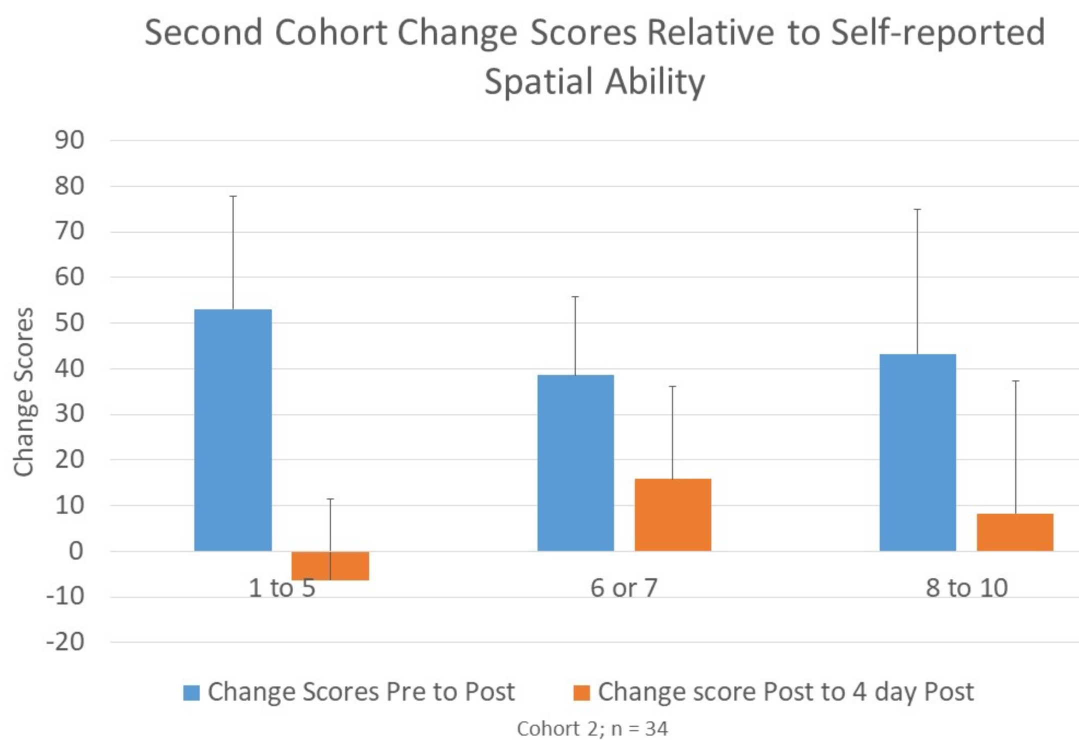

Figure 4. Mean Change Scores Relative to Self-reported Spatial Ability. (Cohort 2: n = 34)

DISCUSSION:

The primary purpose of this project was to describe the use of a novel technique (active use of Tinkertoys®) to promote understanding of hip anatomy and alignment among PT students within an applied anatomy course through active learning and exploration. The use of the Tinkertoys® model resulted in significantly improved performance on post-model tests compared to the pre-model test performance across two cohorts of students. With further assessment regarding student spatial ability in the second cohort, the changes remained, regardless of self-reported spatial ability. Overall, the two cohorts had similar results. Both groups started with scores that would be considered "failing" in most classrooms after receiving a lecture on hip anatomy and alignment in the gross anatomy class. With the simple addition of the Tinkertoys® model with or without the simultaneous active use of the model, scores improved to an overall "passing" score. In the group who had the ability to actively and simultaneously manipulate the Tinkertoys® model during the class presentation, half as many had scores that dropped from the immediate post-model test to the 4-day post-model test (six vs. twelve). This absolute improved retention difference may or may not have been impacted by the ability of the students to manipulate their own models along with the instructor. The effective use of physical models to improve knowledge acquisition and retention is consistent with the literature.[16,17]

The secondary purpose was to determine if one's self-reported spatial ability was linked with the effectiveness of the use of the Tinkertoys® model for learning hip anatomy and alignment. Regardless of reported spatial ability in the second cohort, the groups were indistinguishable regarding their acquisition of knowledge as demonstrated by the test scores. What can be said is that compared to didactic lecture of the hip anatomy and alignment alone, using the Tinkertoys® model seemed to yield a more favorable outcome in quiz scores. Improvement in learning from the original lectured information to the instruction using the Tinkertoys® model is consistent with what was reported in a meta-analysis assessing the effectiveness of physical models in teaching and by Garg et al.[1,2] regarding student self-rotation of models.[5] Garg et al.[1,2] found that, when students could control the manipulation of models, there was a facilitation of spatial learning whereas when the images were programmed to rotate to different views, learning was not more facilitated with the multiple viewpoints.[1,2] They showed that the difference between models that the student could or could not manipulate was more critical for the students with lower spatial ability.[1,2] Thus, allowing for student control of the Tinkertoys® was consistent with effective facilitation of spatial learning. In our study, all students benefited from the use of the Tinkertoys® model.

While the use of standardized testing to establish spatial ability may be considered ideal, in this group, it should be considered that the individuals were people studying an area of science and likely had adequate spatial abilities for the subject area. In fact, people admitted to a graduate school for physical therapy tend to be high achievers in school, particularly the sciences. With such a tendency, an assumption was made that these individuals would be fairly accurate in their ability to determine their own spatial ability. One supporting study reported that when intellectually competent people were compared to intellectually incompetent people, the more competent could more accurately assess their own skill.[18] For students that rated themselves lower, it seemed that their spatial ability was still sufficient because there was no difference noted between groups when assessing learning using the Tinkertoys® model.

Overwhelmingly, most students benefited from this teaching technique; however, not all students were equally responsive. Responsiveness or lack of responsiveness to this educational technique is a good example of how, for some people, visual aids are not more valuable than the written or spoken word or another format for learning.[19] Not all people learn in the same way. Because people learn differently, it is still important to address new knowledge in various ways to best facilitate the teaching of a whole class.

There are several reasons, consistent with the literature, which may contribute to the effectiveness of this teaching model and strategy. It has long been shown that teaching requires different techniques and strategies to facilitate learning in students with differing learning styles. Specifically, using visual aids to guide processing of the information is one available strategy that may be effective to assist learning.[19] Yammine and Violato report that physical models are helpful tools for teaching anatomy.[17] The Tinkertoys® model provided a mechanism where students could visualize changes that may occur at the bone along with subsequent responses of the skeletal system. Additionally, this model was designed so that while studying, students could continue to manipulate the Tinkertoys® to mimic different clinical scenarios. The act of being able to self-manipulate the model to facilitate spatial learning is consistent with the literature.[2]

Beyond being effective, a model must be feasible for use in the classroom. This model is feasible with limited requirements of time or resources. Taking less than 10 minutes of classroom time, the time required is minimal. The cost is also low. A single Tinkertoys® set is sufficient to use as an example model and costs around $25. While not required for a positive outcome, more sets could be purchased as a one-time expenditure to facilitate more student/model interaction. The sets are reusable and, with minimal out of pocket expense and time required, the use of this model is feasible in most gross or applied anatomy courses.

Limitations

This study had several limitations. The cohorts were relatively small, but similar results between the two groups as well as combining the groups strengthen the results. The initial lecture introducing femoral torsion occurred in the same course, but with different instructors. Given that this study looked at change within an individual, the initial instruction was unlikely to affect the change score. There was also not an explicit control group that was tested further. Time or other instruction since the initial introduction of this material could have resulted in learning as well. For the immediate post-test score change, it is unlikely that other instruction or time was influential in the change because testing occurred within the same class period as was the Tinkertoys® model instruction.

The survey to determine spatial ability was simply a self-report without reliability and validation testing. The use of a psychometric test to assess spatial ability rather than self-report could have provided a more accurate insight into the spatial ability of each subject. Even with psychometric tests, the ability of such tests of cognitive ability to predict performance in academic settings is limited.[20] Similar comparisons have not been made with self-reported ability assessments. As such, it is possible that an individual's self-concept which would inform his or her self-report may influence effort and performance.[20,21]

Also, as the current study showed, students, on average and regardless of learning style or spatial ability, improved understanding when measured by performance on a test following the use of the Tinkertoys® model. While comparing cohorts and the effect of being able to manipulate models in real time may be interesting, this was not the intent of the study. Rather, the effectiveness of the model itself was what was being considered. It was for this reason that the cohorts were combined.

CONCLUSION:

The Tinkertoys® model is a simple, effective way to support and facilitate the acquisition of hip anatomical and alignment knowledge within an applied anatomy course.

REFERENCES

1. Garg A, Norman G, Spero L, Maheshwari P. Do virtual computer models hinder anatomy learning? *Acad Med*. 1999;74(10):S87-S89.
2. Garg AX, Norman G, Sperotable L. How medical students learn spatial anatomy. *The Lancet*. 2001;357:363-364.
3. Guillot A, Champely S, Batier C, Thiriet P, Collet C, . Relationship between spatial abilities, mental rotation and functional anatomy learning. *Adv Health Scienes Educ*. 2007;12(4):491-507.
4. Chatterjee AK. The Importance of Spatial Ability and Mental Models in Learning Anatomy (Doctoral dissertation, Purdue University, 2011). *Retrieved Ann Arbor, MI: ProQuest LLC. Retrieved from http://www. purdue. edu/policies/pages/teach_res_outrea ch/c_22. html.* 2011.
5. Uttal D, Meadown N, Tipton E, Hand L, Alden A. The malleability of spatial skills: a meta-analysis of training studies. *Psychol Bull*. 2013;139(2):352-402.
6. Whitlock L, McLaughlin A, Allaire J. Individual differences in response to cognitive training: using a multi-modal, attentionally demanding game-based intervention for older adults. *Comput Hum Behav*. 2012;28:1091-1096.
7. Newcombe N. Seeing relationships using spatial thinking to teach science, mathematics, and social studies. *Am Educ*. 2013;Spring:26-40.
8. Wright R, Thompson W, Ganis G, Newcombe N, Kosslyn S. Training generalized spatial skills. *Psychon Bull Rev*. 2008;15(4):763-771.
9. Roy M, Chi M. The self-explanation principle. In: Mayer R, ed. *Cambridge Handbook of Multimedia Learning*. ; 2005:271-286.
10. Se A, Passos R, Ono A, Hermes-Lima M. The use of multiple tools for teaching medical biochemistry. *Adv Physiol Educ*. 2008;32:38-46.
11. Sorby S, Drummer T, Kedmon H, Charlesworth P. Developing 2-D spatial visualization skills for non-engineering students. Presented at the: Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition; 2005.
12. Eftekhar B, Ghodsi M, Ketabchi E, Ghazvini A. Play dough as an educational tool for visualization of complicated cerebral aneurysm anatomy. *BMC Med Educ*. 2005;5:15.
13. Falcone J. Don't touch the sides: a fun and novel system for using Operation® for practicing open and robotic surgical skills. *Am Surg*. 2013;79(5):547-549.
14. Wendland D. The use of a 3-D toy model for teaching anatomical and biomechanical concepts of the hip. Poster presented at the: APTA Combined Sections Meeting; February 4, 2015; Indianapolis, IN.
15. Pajeau CH. Toy Construction-Blocks. US1113371A. October 13, 1914.
16. Losco CD, Grant WD, Armson A, Meyer AJ, Walker BF. Effective methods of teaching and learning in anatomy as a basic science: A BEME systematic review: BEME guide no. 44. *Med Teach*. 2017;39(3):234-243.
17. Yammine K, Violato C. The effectiveness of physical models in teaching anatomy: a meta-analysis of comparative studies. *Adv Health Sci Educ*. 2016;21(4):883-895. doi:10.1007/s10459-015-9644-7
18. Kruger J, Dunning D. Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *J Soc Psychol*. 1999;77(6):1121-1134.
19. Carifio J, Perla R. A critique of the theoretical and empirical literature of the use of diagrams, graphs, and other visual aids in the learning of scientific-technical content from expository texts and instruction. *Interchange*. 2009;40(4):403-436.
20. Freund PA, Kasten N. How smart do you think you are? A meta-analysis on the validity of self-estimates of cognitive ability. *Psychol Bull*. 2012;138(2):296-321. doi:10.1037/a0026556
21. Furnham A. Gender and personality differences in self- and other ratings of business intelligence. *Br J Manag*. 2005;16:91-103. doi:10.1111/j.1467-8551.2005.00434.x