



Spatial Skills and Demographic
Factors in CS1



Six Studies of Spatial Skills
Training in Intro CS Courses

Spatial Skills in STEM with a focus on Computing and Diversity

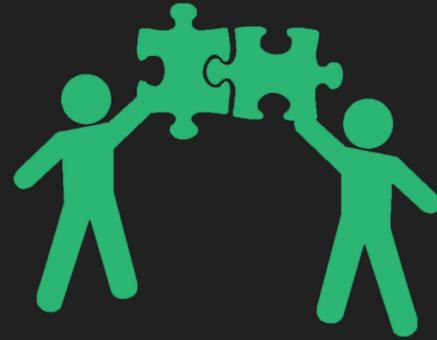
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Collaborative Effort!



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Spatial Skills and
Demographic
Factors in CS1



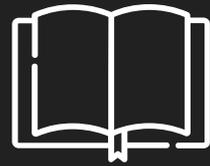
Six Studies of Spatial
Skills Training in
Intro CS Courses

UNIVERSITY OF
Nebraska
Lincoln

Sheryl Sorby

Today's Focus

- Spatial skills training was conducted with CS1 students across a semester
- Several factors relating to CS and spatial skills were measured
- These measures were examined in relation to each other to determine interactions
- What next-steps have been taken and what is being done now

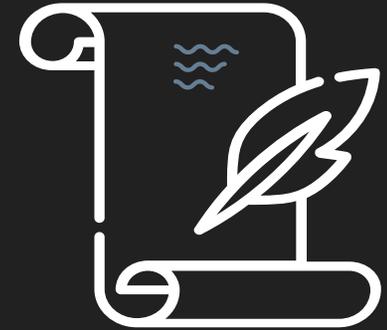


Background

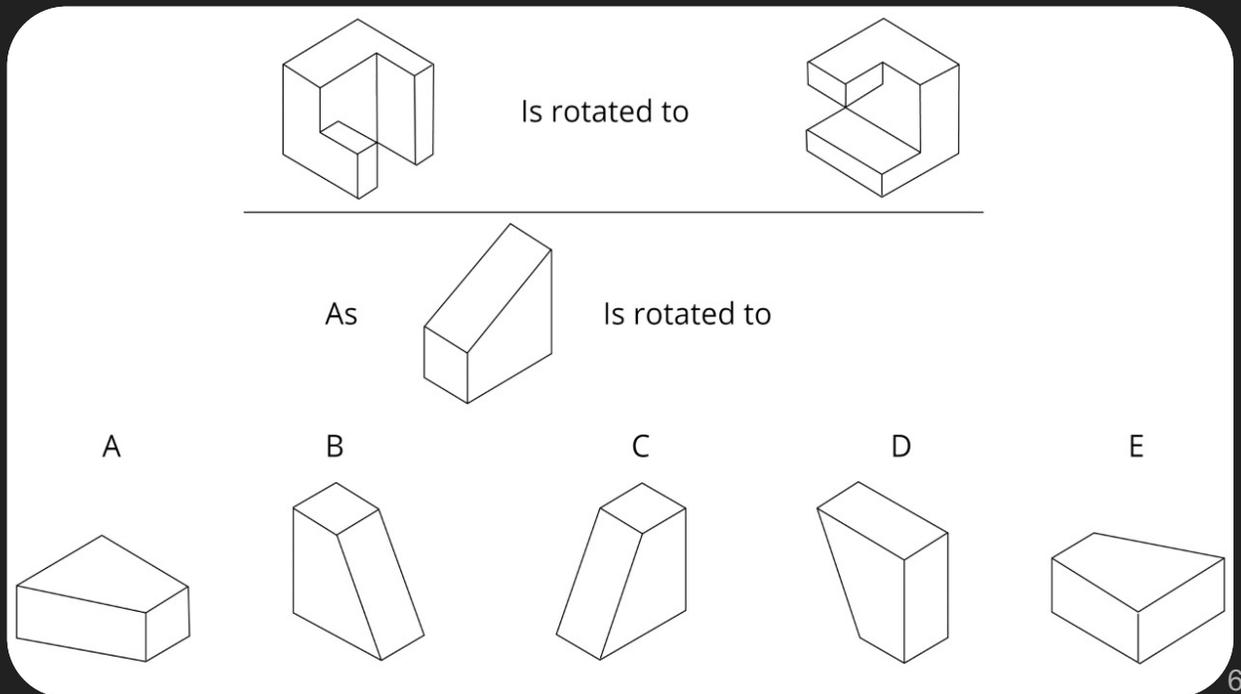
Have you heard of spatial skills?



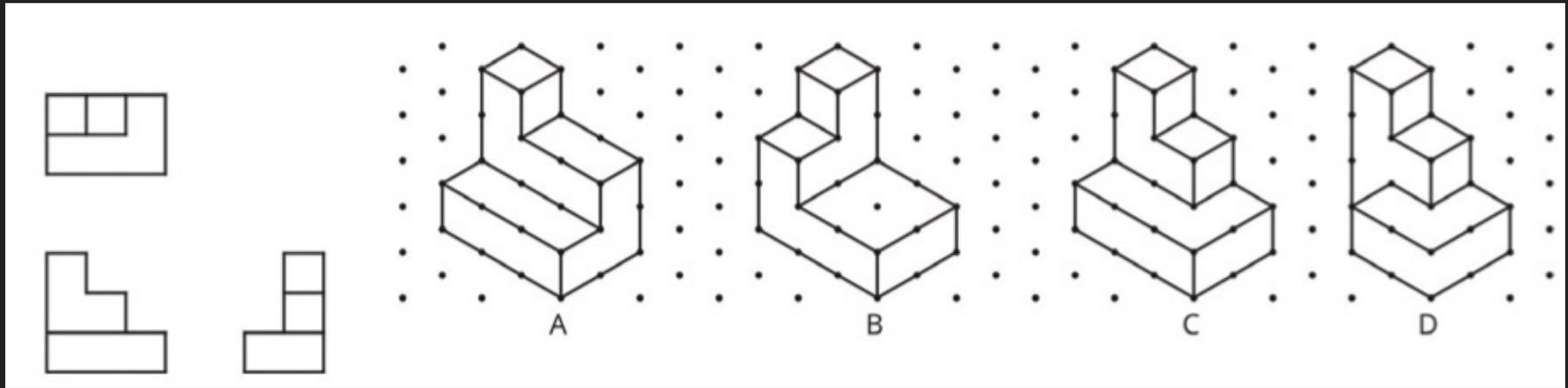
Background: What Are Spatial Skills?



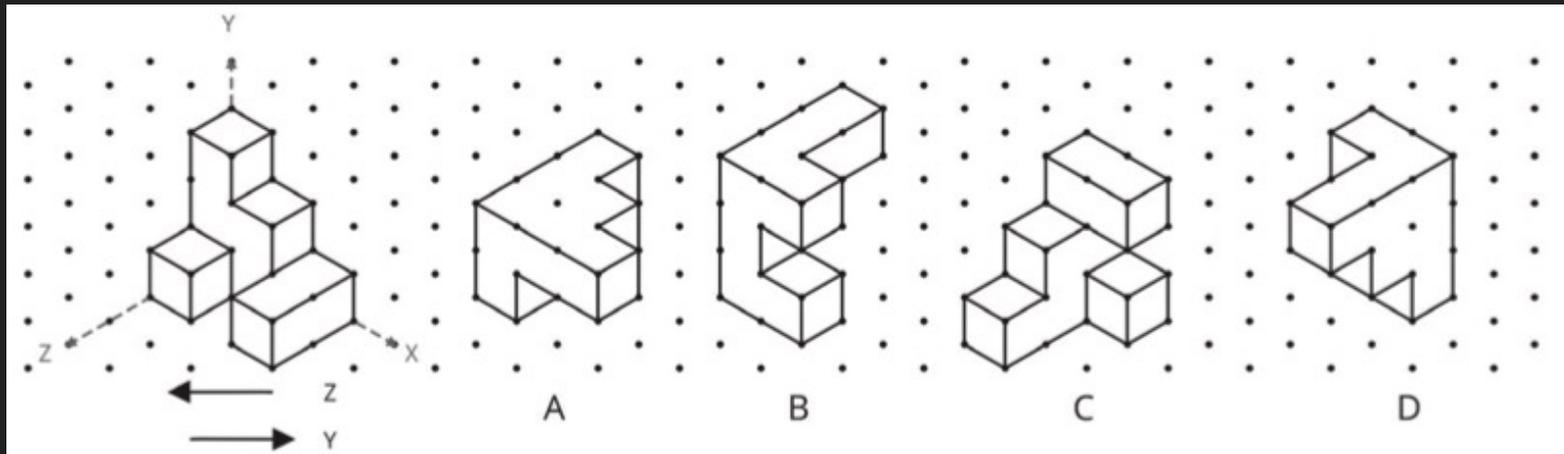
- Cognitive abilities:
 - Internal rotation
 - Paper folding
 - Constructing flat patterns
 - Revolution of solids



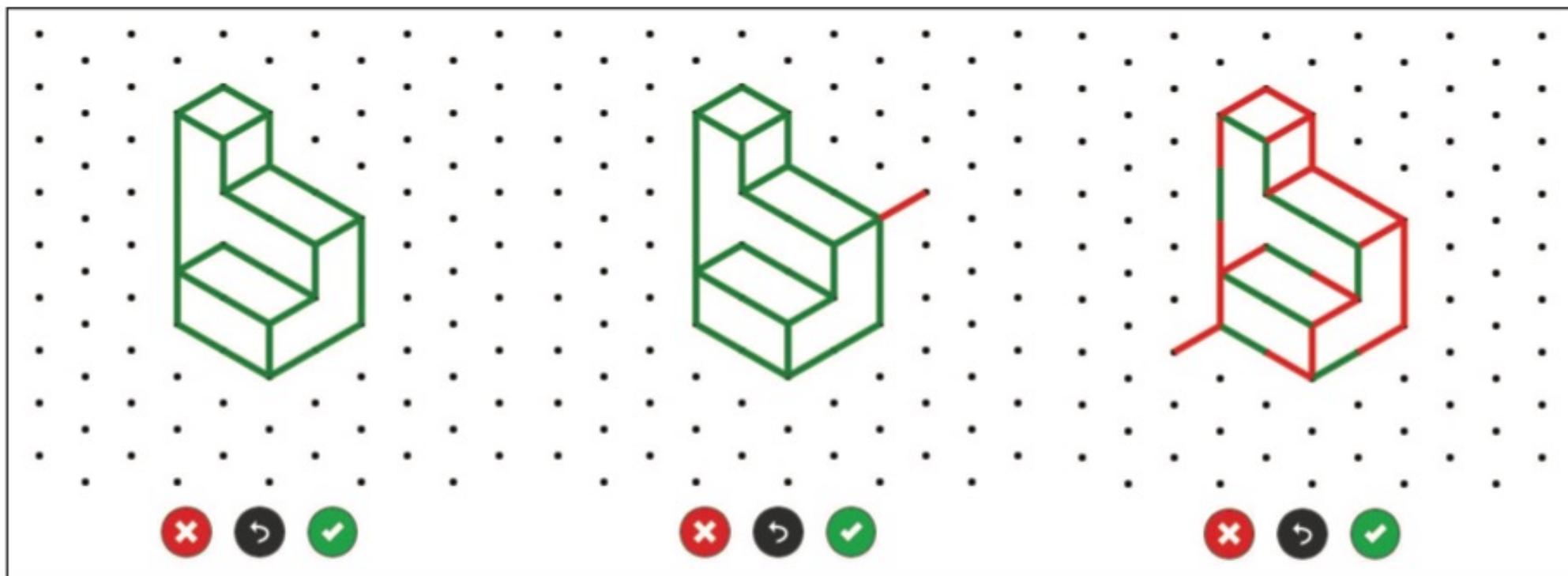
For the object shown in the orthogonal view on the left, select the correct corresponding isometric view.



Select the corresponding view on the right that shows the result of rotating the object on the left by the indicated amount.



Online Module Example

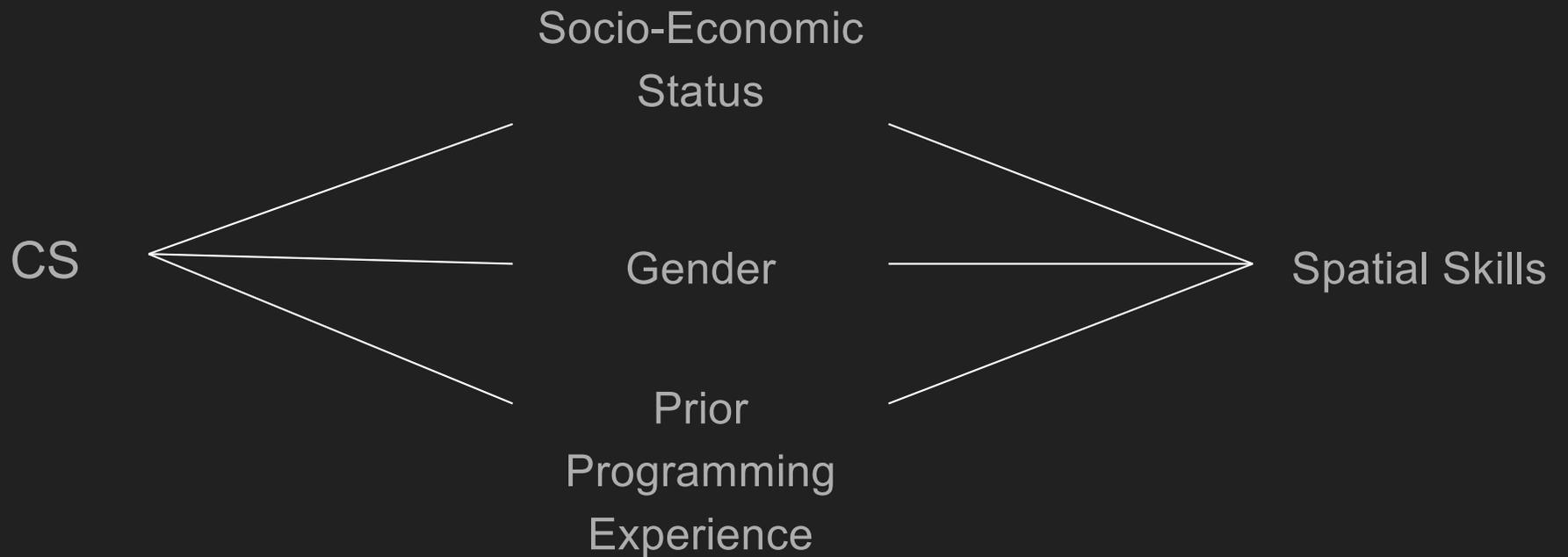


Background: Spatial Skills and CS



- Spatial Skills and success in computing have been linked
- Spatial skills correlate with:
 - CS module grades (*Jones & Burnett, 2008; Bockmon et al., 2019; Endres et al., 2021*)
 - source code navigation efficiency (*Jones & Burnett, 2007*)
 - computational thinking activities at a primary level (*Moschella & Basso, 2020*)
 - low-level expression evaluation (*Parkinson et al., 2020*)
 - socio-economic status (*Parker et al., 2018*)
- Spatial skills training also improves CS outcomes (*Cooper et al., 2015; Bockmon et al., 2020; Parkinson & Cutts, 2020*)
- Spatial skills are believed to be associated with mental model building and memory encoding (*Parkinson & Cutts, 2018; Margulieux, 2019*)

Background: Factors between Spatial Skills and CS



U of T Mississauga CS Program

- First year students in mathematical and computational sciences program are in a general first year and must specialize in 2nd year
- Students are required to take CS1 (introduction to programming in python)
 - Interdisciplinary – students in other streams may also enroll in the course
- Data was gathered from students enrolled during the Fall 2020 semester (September 2020 - December 2020)
- Course entirely online



Background: Spatial Skills Training



- Original course developed by Sheryl Sorby for use in engineering
- Comprised of drilling exercises:
 - Rotating 3D shapes
 - Flat patterns, folding into 3D shapes
 - 2D shapes revolved into 3D solids
 - Reflection
 - Intersections of solids
- The same course has been used to train CS students, with positive results
- Online version developed at University of Glasgow
 - Contains all the same questions, but online



Research Questions

Research Questions

RQ1: Is online spatial skills training effective?

RQ2: Do men and women both benefit from spatial skills training?

RQ3: Are spatial skills related to other factors associated with differences in academic performance in computing?





Procedure



Procedure: Participants & Course Structure

- 778 students were enrolled in total
- 670 students completed the course
- 78% of students participated for their survey data/results to be used for research purposes
- Spatial skills training and tests were mandatory for course marks (5% of their final grade)
- Demographic survey responses not required. Only approximately 230 completed responses



Procedure: Measures & Instruments

Spatial Skills



PSVT:R - the Purdue Spatial Visualisation Test of Rotations developed by Guay and Yoon

Prior Programming Experience



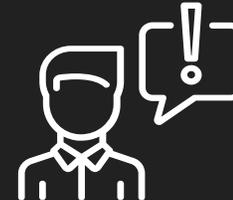
SCS1 - a CS1 knowledge assessment developed by Parker et al.

Demographic Data



A survey on socio-economic status measures (family income, parental education, etc) and gender

Self Efficacy



Self efficacy instrument developed by Steinhorst et al.

CS1 Assessment



Final CS1 grade for the semester from summative assessment

Background: SCS1 Assessment



What is SCS1?

- A test (in pseudo code) that assesses a student's ability in programming.
- We deployed the SCS1 in the beginning to get an idea of a student's prior programming experience, if they had any.
- The questions were all multiple choice.
- This provides a more objective measure as opposed to asking, "how much programming have you done before?"

Background: Self Efficacy



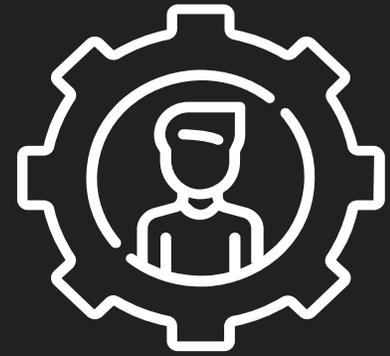
What is Self Efficacy Score?

- We also tried asking students how comfortable they are with various topics related to computer science. There were 25 statements in total.
- They are provided with statements, and the options range from “strongly disagree” to “strongly agree”.
- These include:
 - I can trace the execution of a program.
 - I can explain the difference between built-in and user-defined types.
- We then placed a score (where “strongly disagree” stands for 1, “strongly agree” stands for 7), and took the average of their responses to all questions as their score.

Background: Demographic Data

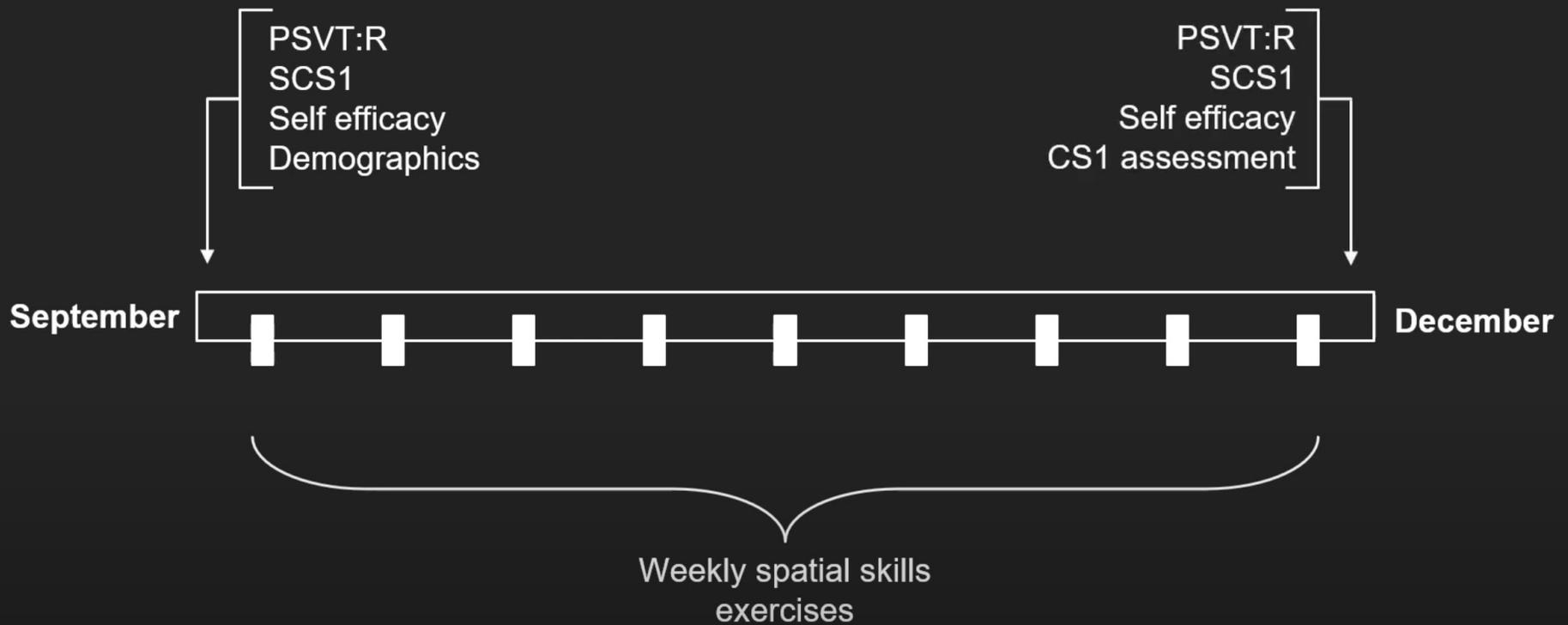
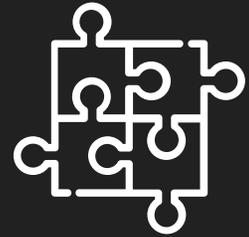
What types of demographic data were asked of students?

- Distance from campus
- Living with family
- Receiving grants or financial assistance
- Annual household income
- Parental Education
- How many hours they work a week
- Gender - scores between men and women

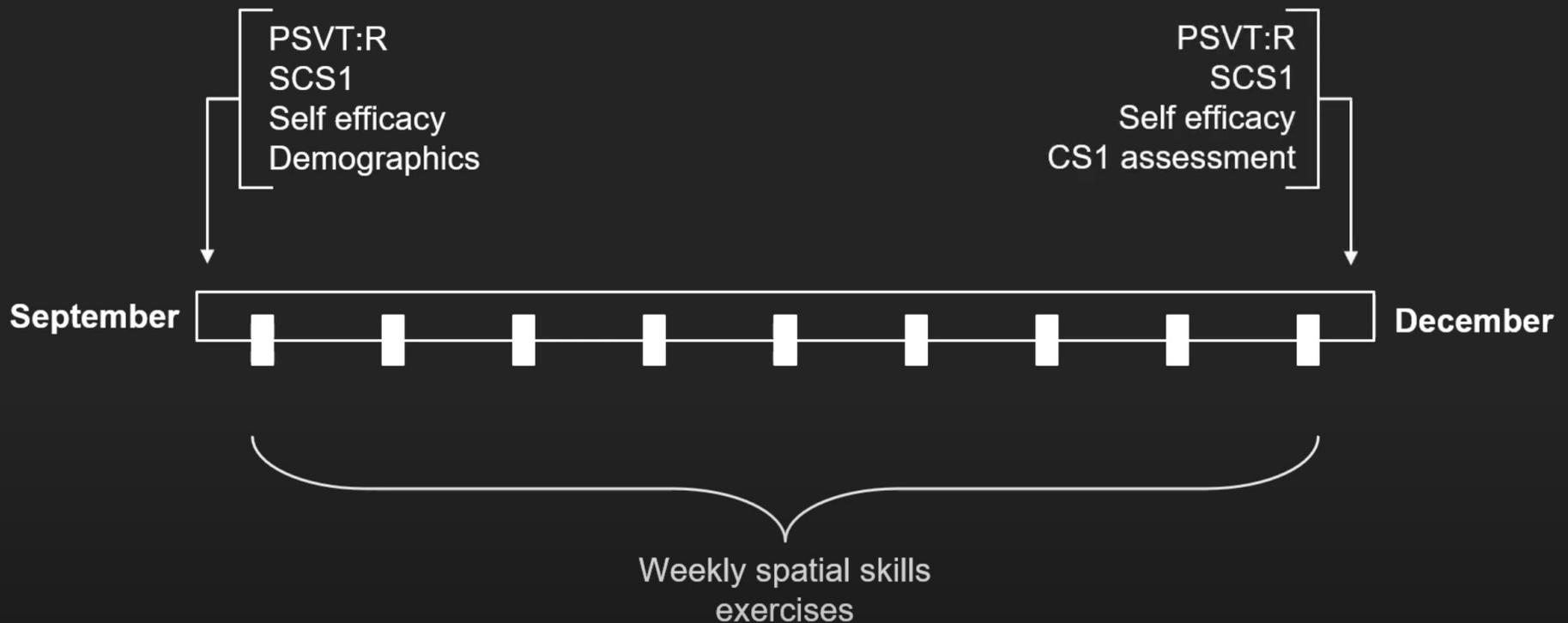


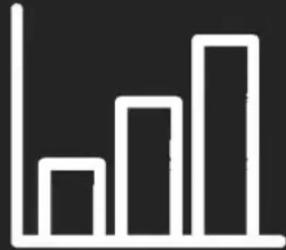
Note that due to the low participation rate, we were unable to find any noteworthy conclusions.

Procedure: Course Structure



Procedure: Data Collection and Cleaning





Results

Results: RQ1 - Is online spatial skills training effective?

Gains observed in the pre- and post-PSVT:R

Mean gain for all students

1.81

Mean gain for students initially <21

2.53

Mean gain for students initially <21 who completed training

4.34

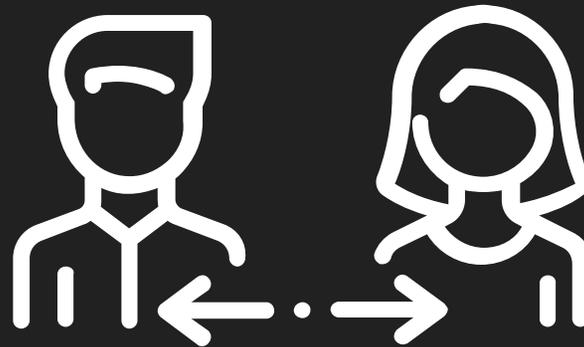
Results: RQ1 - Is online spatial skills training effective?

- Students did not enjoy the training
- It was a main feature of complaint in the weekly feedback on the program
 - “The Professors ... put up with my rudeness in regards to my view on the spatial skills exercises lol”
 - "Aside from the spatial skills my experience in this course was great”
- Students also didn't really know why they were doing it



Results: RQ2 - Do men and women both benefit from spatial skills training?

- Both men and women saw almost equal improvements in spatial skills on average
 - But women improved slightly more than men
- However, men initially had a higher average spatial skill score to begin with.
 - Women improved to be roughly on par with mens' original scores



Results: RQ2 - Do men and women both benefit from spatial skills training?

Pre-test Scores:

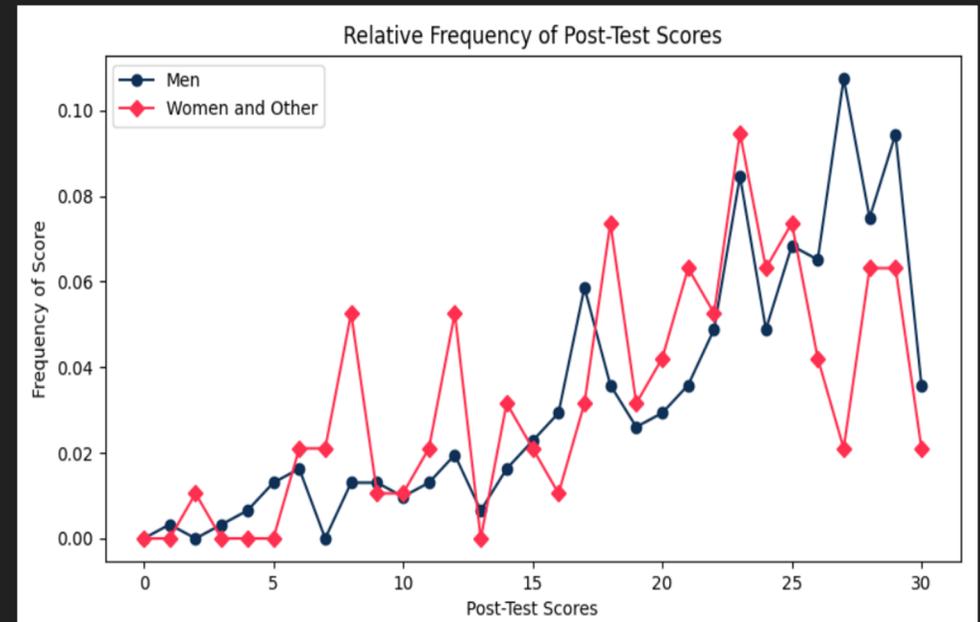
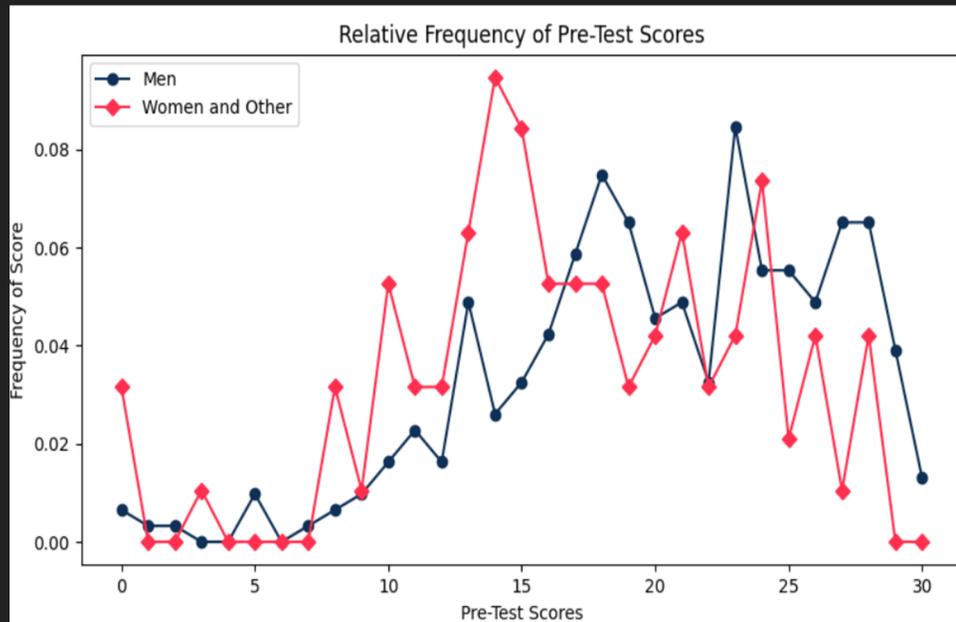
Gender	Mean Score	Standard Deviation	Median	IQR
Men (n = 307)	20.27	6.07	21	8
Women (n = 95)	17.01	6.32	17	9

Results: RQ2 - Do men and women both benefit from spatial skills training?

Post-test Scores:

Gender	Mean Score	Standard Deviation	Median	IQR
Men (n = 307)	21.91	6.54	23	9
Women (n = 95)	19.93	6.84	21	9.5

Results: RQ2 - Do men and women both benefit from spatial skills training?



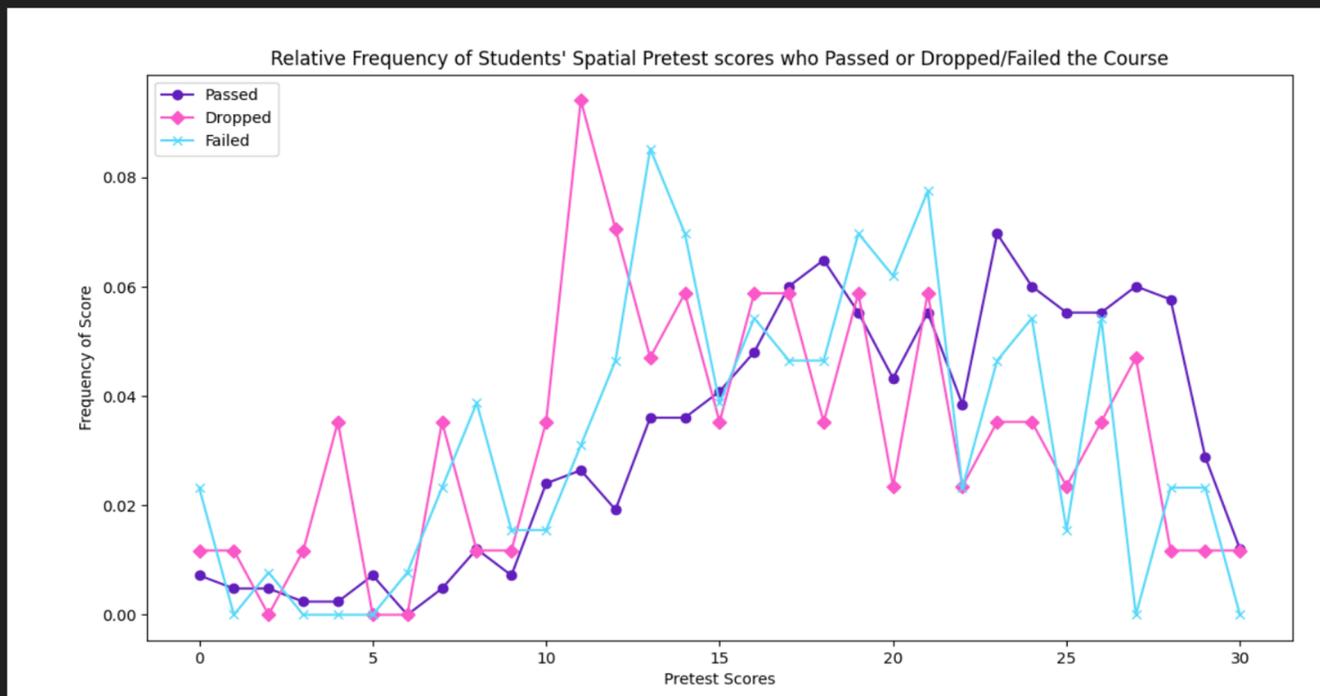
Results: RQ3 - Are spatial skills related to other factors associated with differences in academic performance in computing?

Is spatial skills related to...

- **Social economic status?**
 - We were unable to see any significant or notable correlations (r values were < 0.2).
- **Self-efficacy?**
 - We were unable to see any significant or notable correlations (r values were < 0.2).
- **Prior programming experience?**
 - There's a very weak, linear relationship between spatial skills test scores and SCS1 scores.
 - ($r \approx 0.25$, $p < 0.001$)
- **Final grades?**
 - There's a very weak, linear relationship between spatial skills test scores and SCS1 scores.
 - ($r \approx 0.26$, $p < 0.001$)

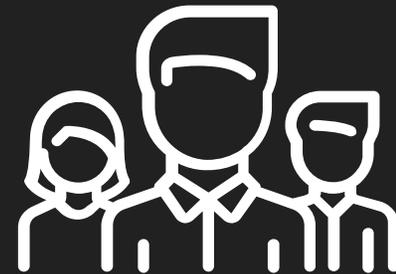
Results: RQ3 - Are spatial skills related to other factors associated with differences in academic performance in computing?

- We also noticed that:
 - Students with lower spatial skills are more likely to drop/fail the course.
 - No real difference between domestic and international students.



Results: Limitations and Caveats

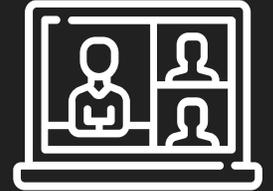
- Spatial skills are developed on the online course, but not by as much as in paper-based formats
- Women develop spatial skills at a slightly faster rate than men, but still end up slightly lower than where men started
- Overall, we see a small effect with previous programming experience and grades but...
 - Correlations are still quite low.
 - There could be confounding variables that influenced the correlations, as opposed to the tests themselves.
- A naturalistic study, fraught with difficulty!





Summary

Summary



- Online spatial skills training develops spatial skills
- Spatial skills training raises the spatial skills of both men and women
 - There is a slightly higher spatial skills gain from women between the pre- and post-tests, although their pre-test scores were low to begin with
- There's a weak linear relationship between spatial test scores against SCS1 scores and final grades
 - But this could be due to confounding variables as opposed to causation



Recommendations

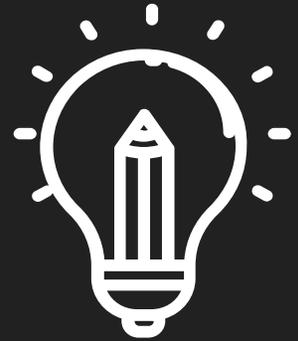
- The sooner the intervention begins, the better.
- Only provide training to those who need it.
- In-person vs. online spatial skills training
 - In-person: more enjoyable. Trade-off: more work to mark.
 - Online: less enjoyable. Benefit: rapid feedback.
- Engagement is greater when the course formally recognizes training
- Intrinsic motivation should be developed by presenting prior research.
- The PSVT:R test is best conducted on paper in exam conditions.



Next Steps & Future Work



Currently Employed Next Steps



- Lead a development team to roll the problems into a more usable application and to better integrate them in our LMS
- Consider: “how to best normalize the gender gap?”
- Summer training for CS1 students prior to starting the course
 - Bonus marks
 - Sell them on the importance

Possible Future Work



- Creation of a better method for collecting SES data.
- Continued improvement and refinement of spatial skills tools and systems.
- Investigation of spatial skills impact in other disciplines.
- Creating a spatial skills problem bank.

ANY
QUESTIONS?

