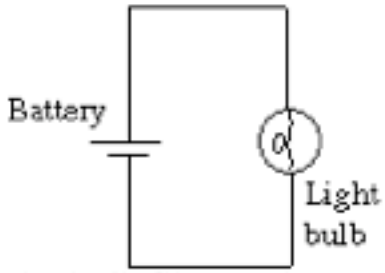
Teaching Experiments in Physics and Astronomy at the ANU

Paul Francis, Craig Savage and Cristina Figl

Two parts

1. Data mining the student records. Lots of interesting stuff is coming up and I'm not sure what to make of it.
2. Teaching innovations we've made over the last ten years.

12.



Which of the following statements is true about the electric field inside the bulb filament?

○ The field must be zero because the filament is made of metal.
0.571% 1

○ The field must be zero because a current is flowing.
5.14% 9

○ The field must be zero because any excess charges are on the surface of the filament.
3.43% 6

○ The field must be non-zero because the flowing current produces an electric field.
65.1% 114

○ The field must be non-zero because no current will flow without an applied field.
14.9% 26

○ The field must be zero for reasons not given above.
6.86% 12

○ The field must be non-zero for reasons not given above.

4.00% 7

Number responding: 175

Data Mining

Location of high school	Pre-test score
ACT	17.2
NSW	20.4
Victoria	25.2
Tasmania	18.6
South Australia	17.7
West Australia	22.5
China	21.8
Singapore	14.8
Malaysia	17.9

Paid work

- Students doing lots of paid work have low pre-test scores.
- But over the semester they catch up, finishing off with post-test scores statistically indistinguishable from everyone else.

No correlations

- With gender
- With english language ability
- With degree program (engineers vs science students).
- and almost no correlation between how well the students rated their physics ability and how well they did.

Natural language procesing

- Students were asked to descrbe their own personality.
- Median description had 5-6 words, each averaging 5 letters.
- I pulled out all the words used by a decent number of students but not too common…
- Correlated use of words with performance (threshold of 99% confidence).

- Friend(ly)
- Quiet
- Outgoing
- Hard (working)
- Work
- Introvert(ed)
- People
- Shy
- Willing
- Happy
- Think

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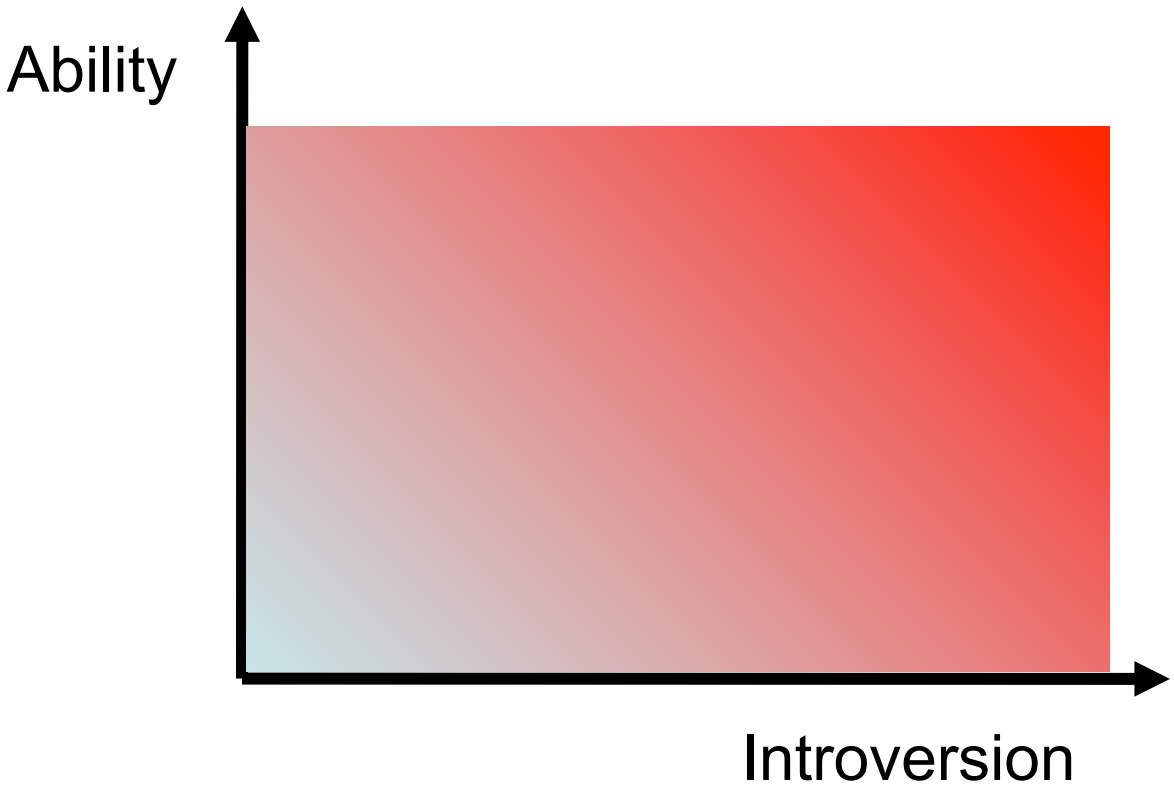
It’s a strong effect

- Someone who uses the word ‘quiet’ does as well at the start of the course as everyone else does at the end…

Geeks like physics?

- I don’t think this really explains it…



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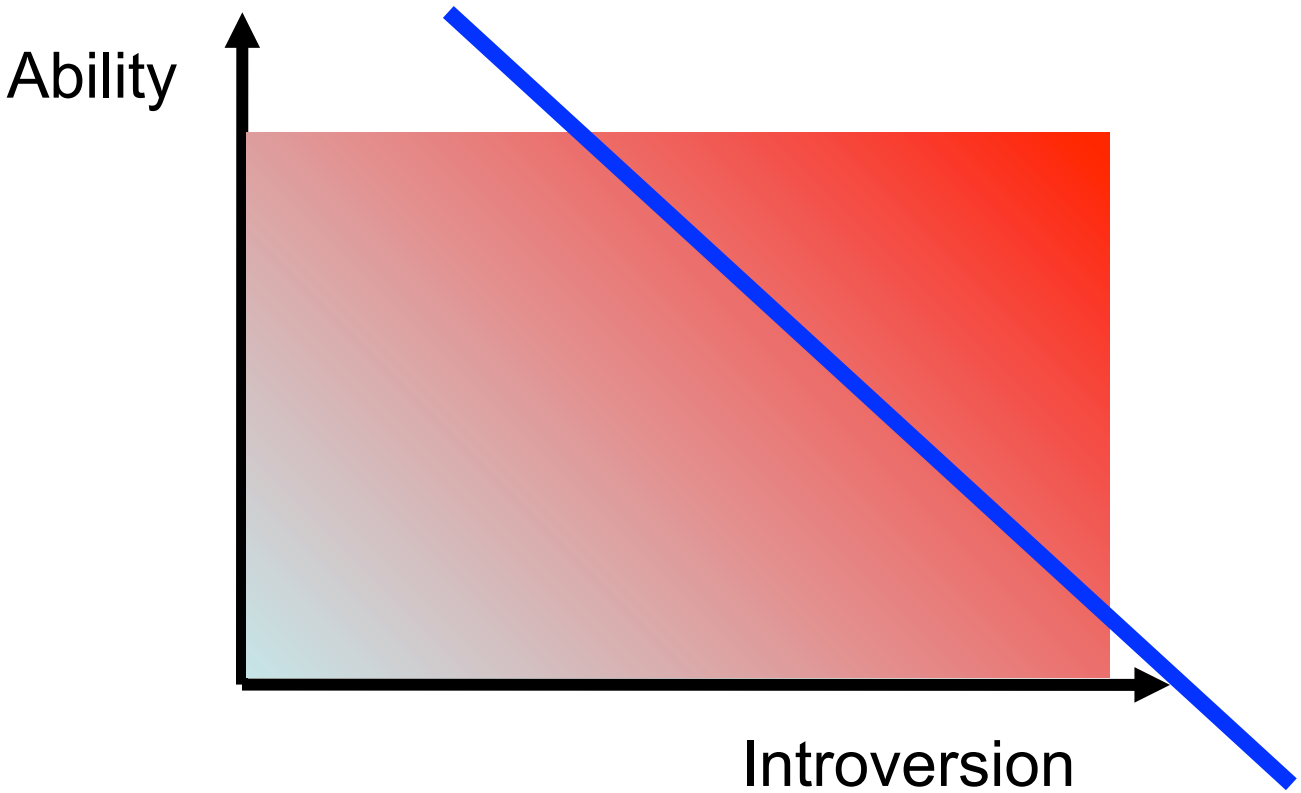


I did the same analysis to student responses to the questions: what do you like (and dislike) about physics.

- "Like" term correlating with performance

  Understand(ing)

- "Unlike" term (anti) correlating with performance

  Calculations

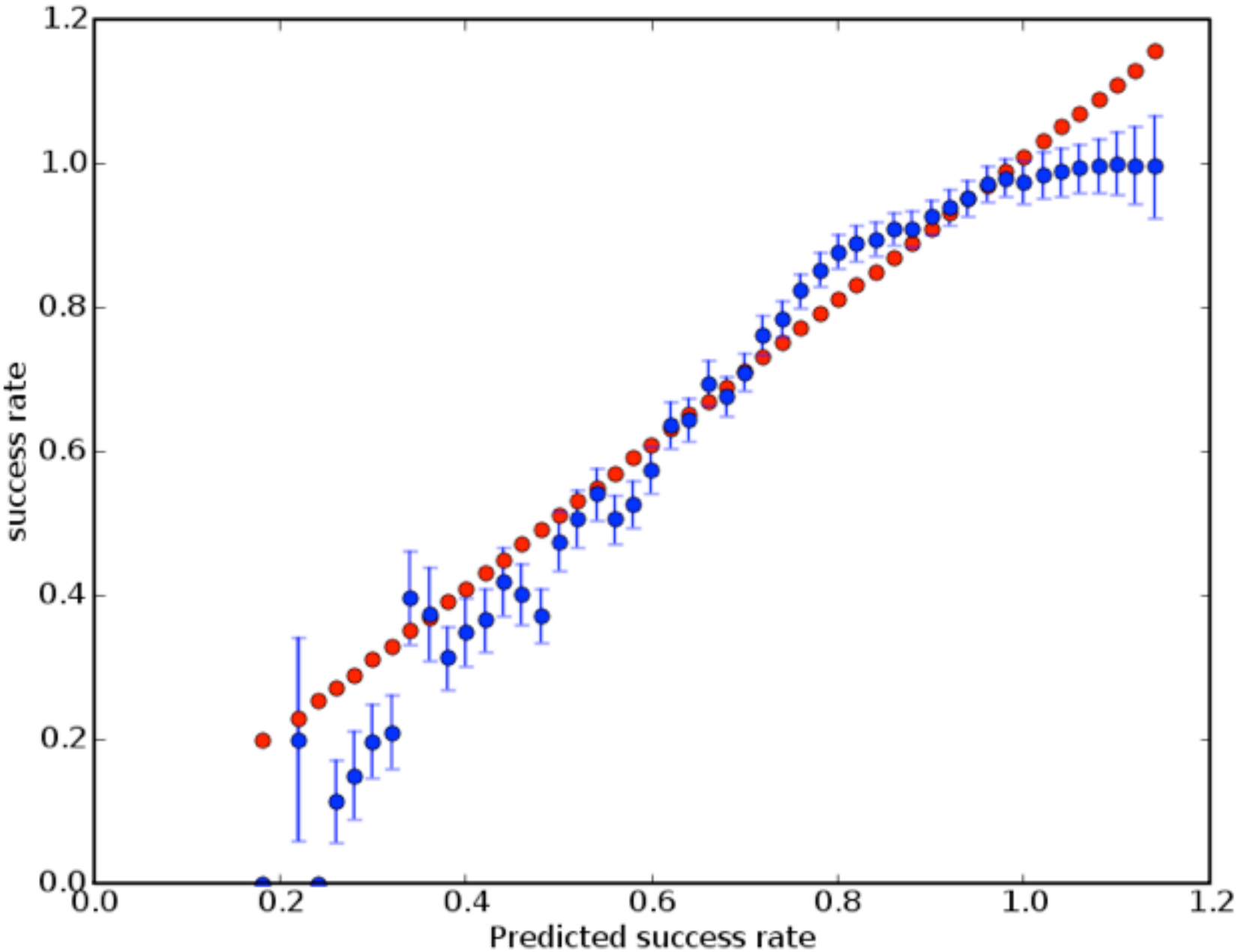
Model of performance

- Construct a matrix of scores: student against question.
- Model one - give every student an ability rating *a* (on a scale of 0-1) and every question an easyness rating *e* (also on a scale of 0-1).
- Probability of a given student getting a given question correct - I guessed:

$$p = \sqrt{ea}$$

Iterate

- Generate new matrix using the model.
- Compare success rates (for both questions and students) against model, tweak *e* and *a* values as necessary.
- It converges pretty fast.
- Then test against data - bin all question/ student combinations by predicted probability of getting the right answer and compare with observed value.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success rate
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0.2
0.4
0.6
0.8
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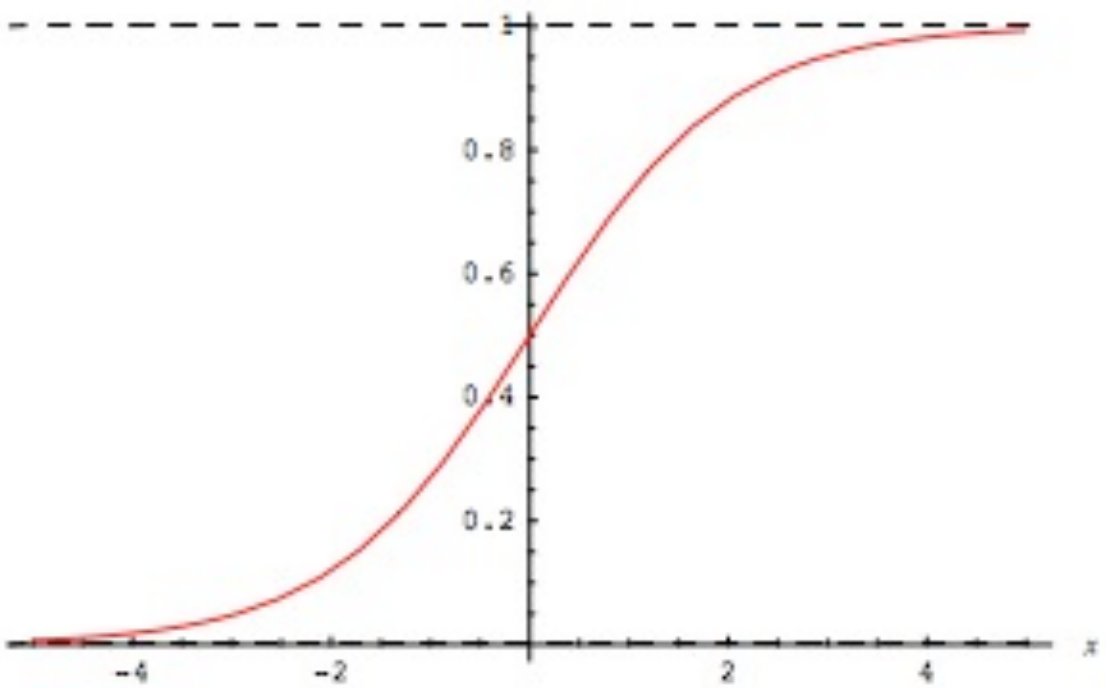
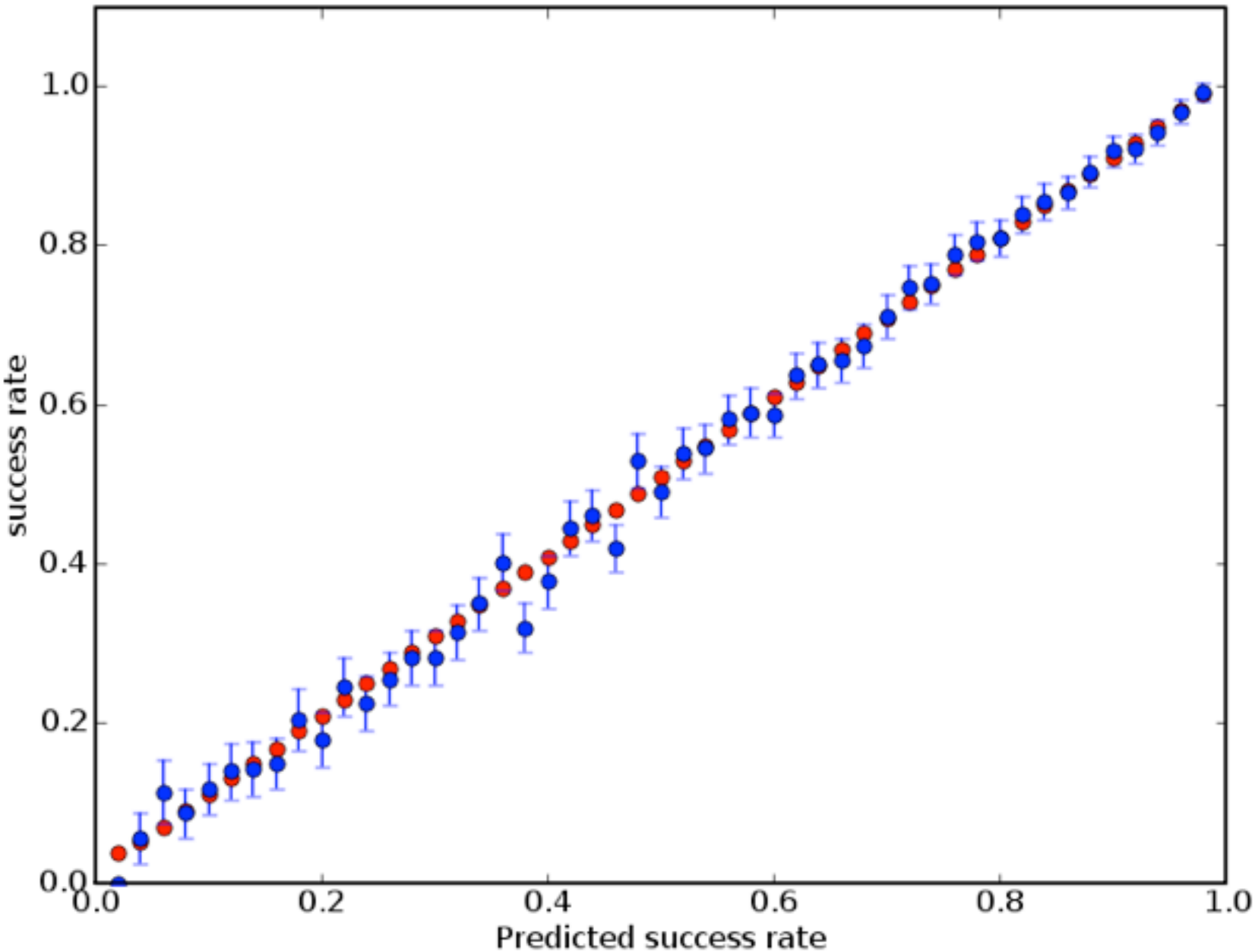
1.2
Predicted success rate

Revised model

- Use e and a again, but probability of success is now given by a sigmoid function:

$$p = \frac{1}{1 + e^{-x}}$$

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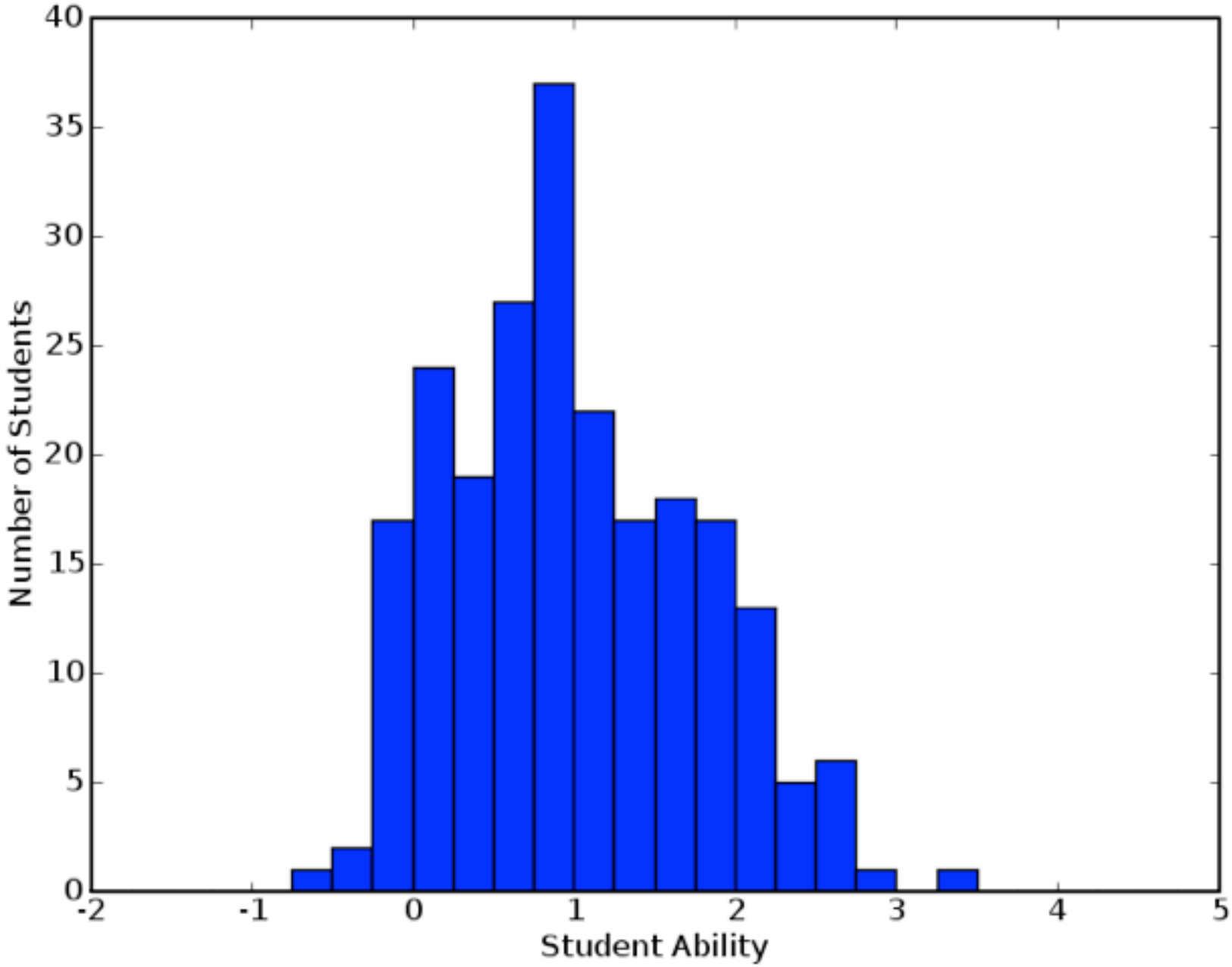
40
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Number of Students
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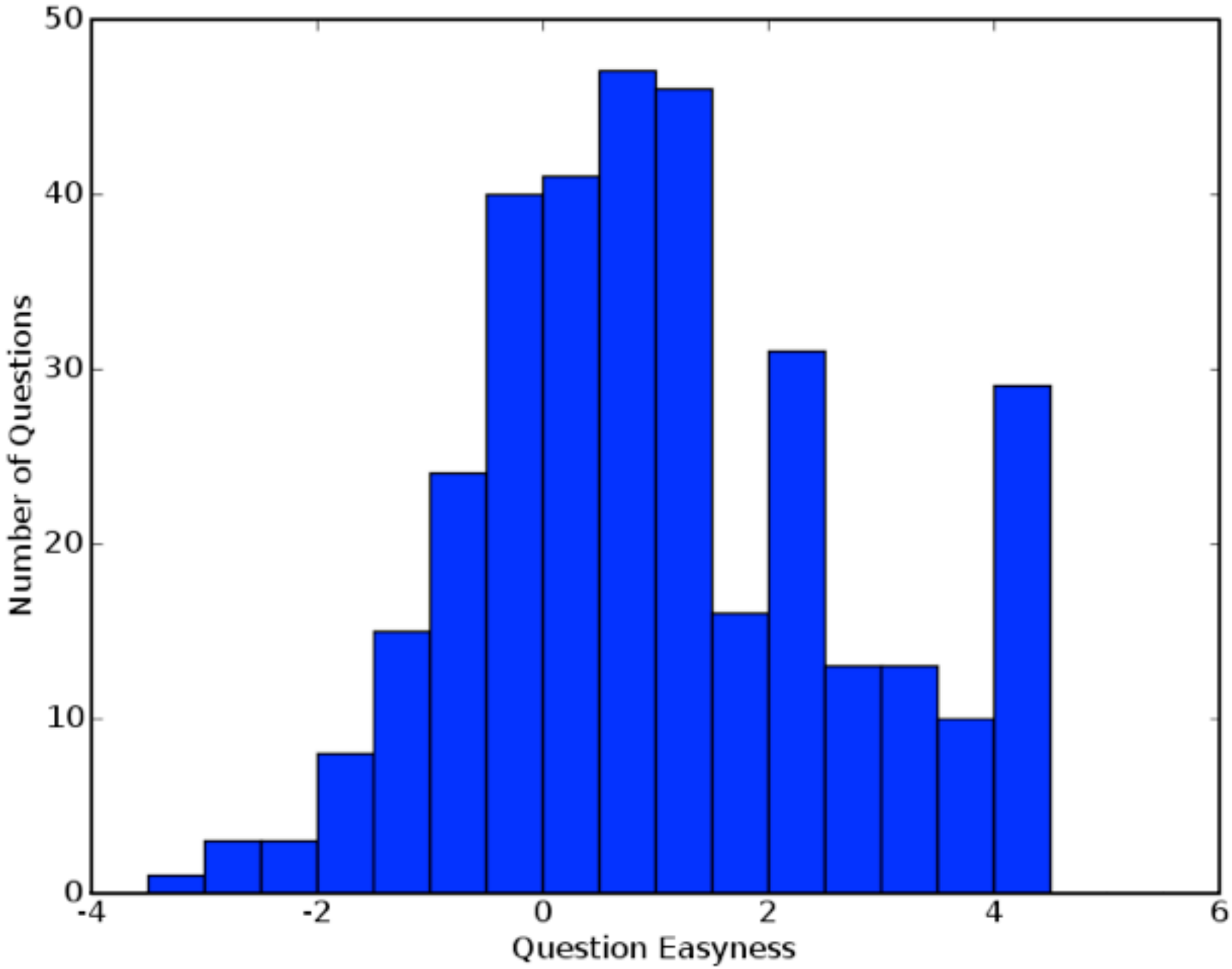
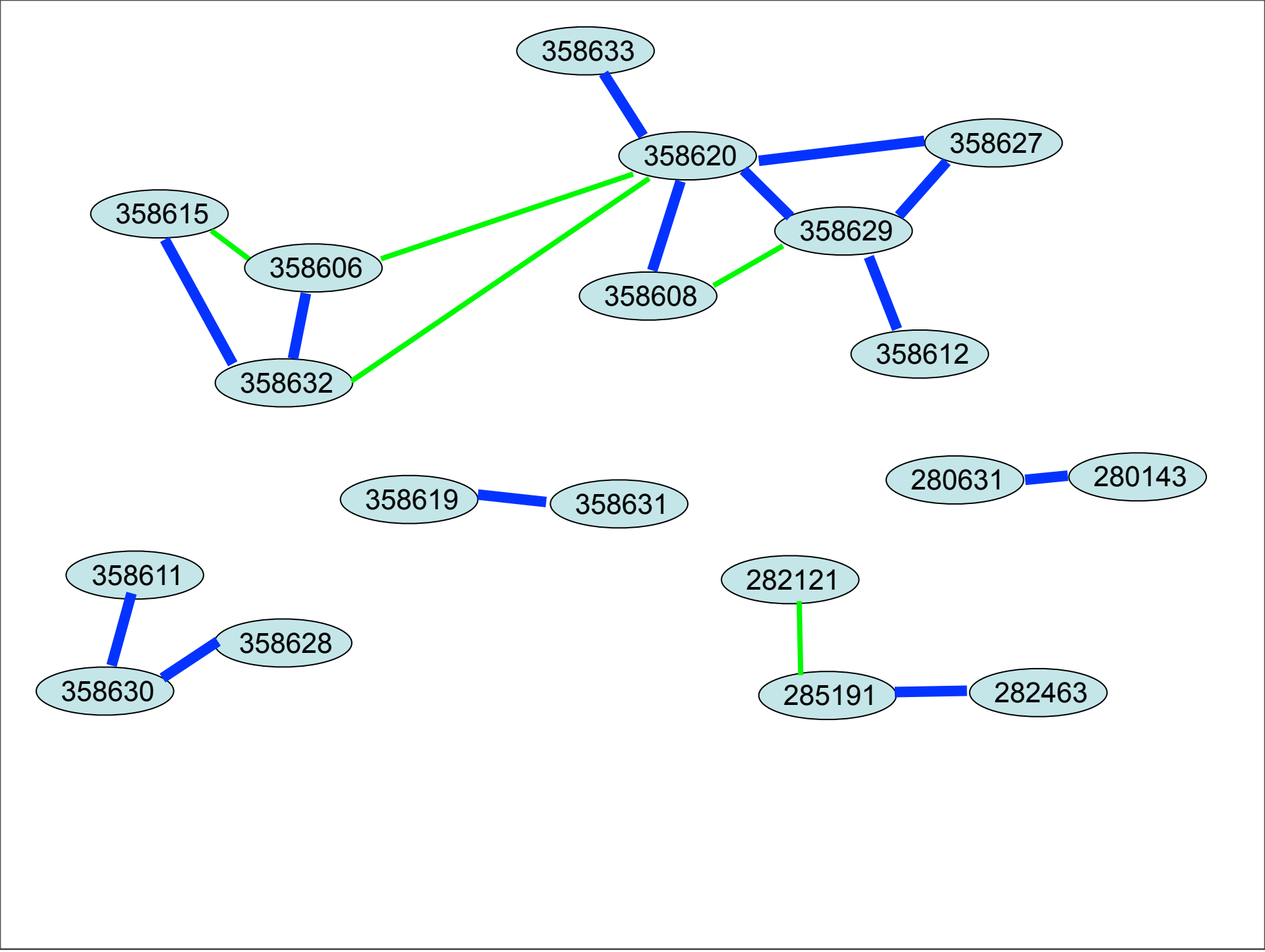
Student Ability


50
40
30
20
10
0
Number of Questions
-4
-2
0
2
4
6
Question Easyness

Cross-correlate questions

- (after subtracting off this basic model).
- Rather few question-question pairs show correlations, apart from those caused by different easyness levels.
- Most significant correlations were between different parts of single questions, and the same question asked in pre- and post-tests.
- But there were a few more statistically significant correlations.
- Almost all were conceptual questions.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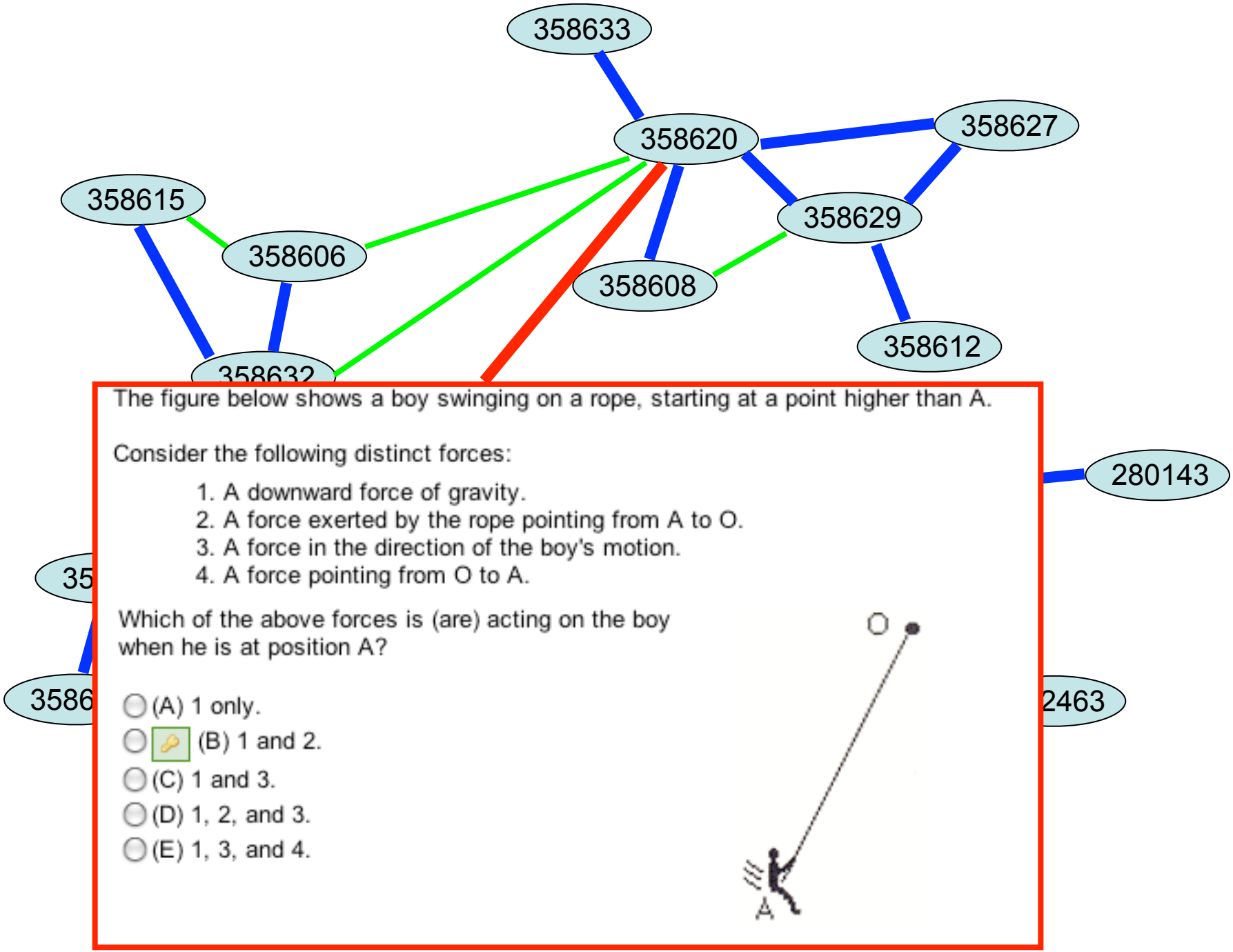
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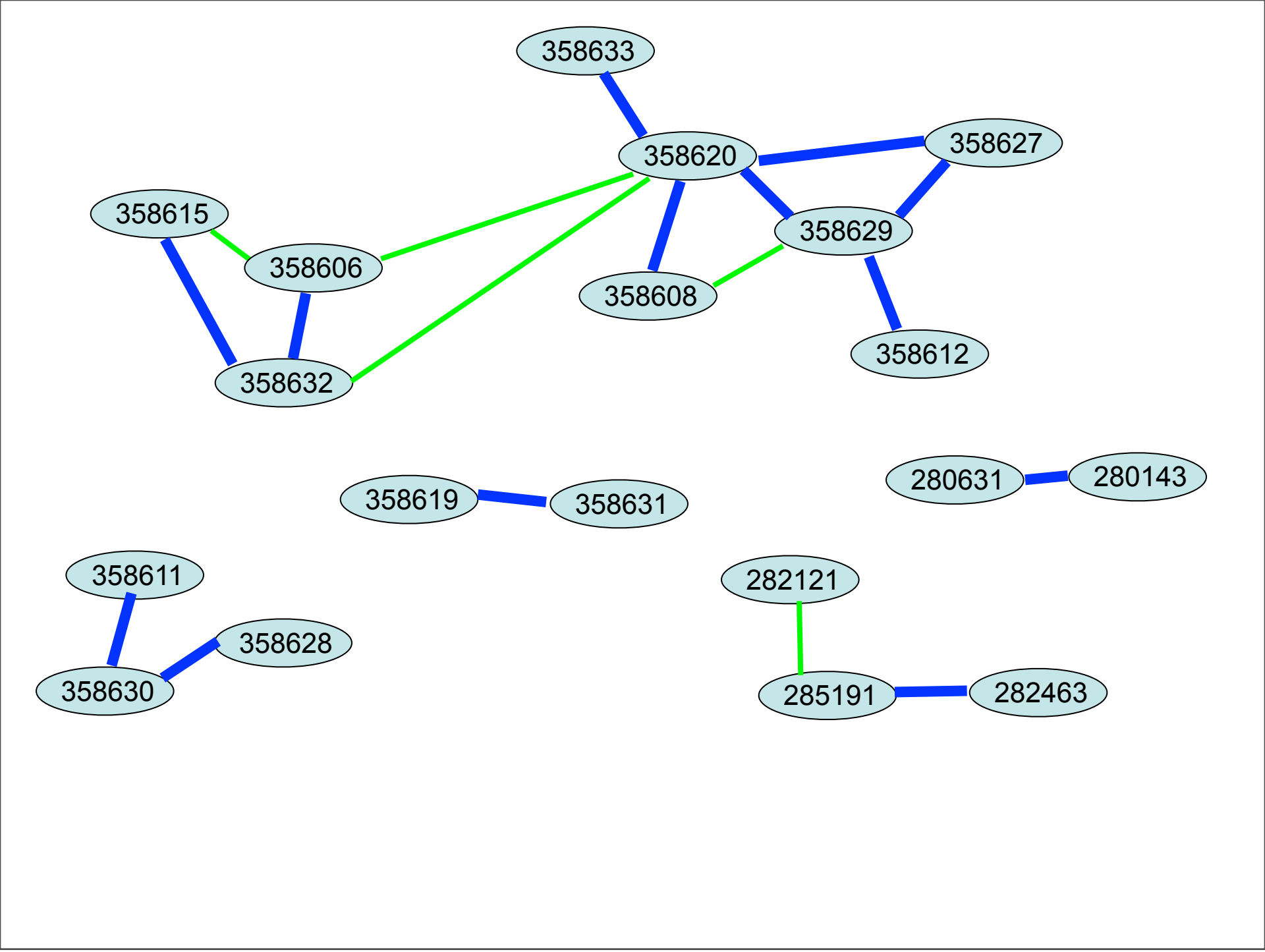
The figure below shows a boy swinging on a rope, starting at a point higher than A.
Consider the following distinct forces:
1. A downward force of gravity.
2. A force exerted by the rope pointing from A to O.
3. A force in the direction of the boy's motion.
4. A force pointing from O to A.
Which of the above forces is (are) acting on the boy when he is at position A?
(A) 1 only.
(B) 1 and 2.
(C) 1 and 3.
(D) 1, 2, and 3.
(E) 1, 3, and 4.
O
A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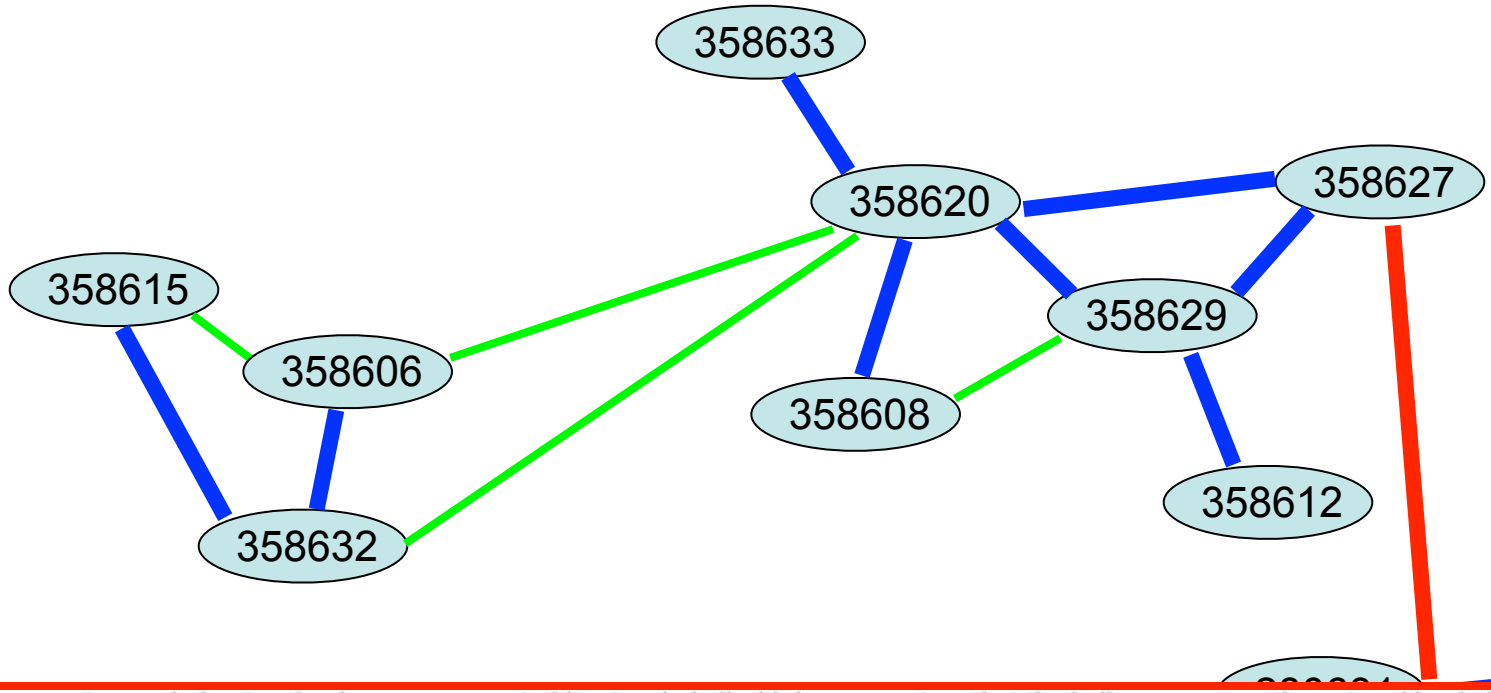


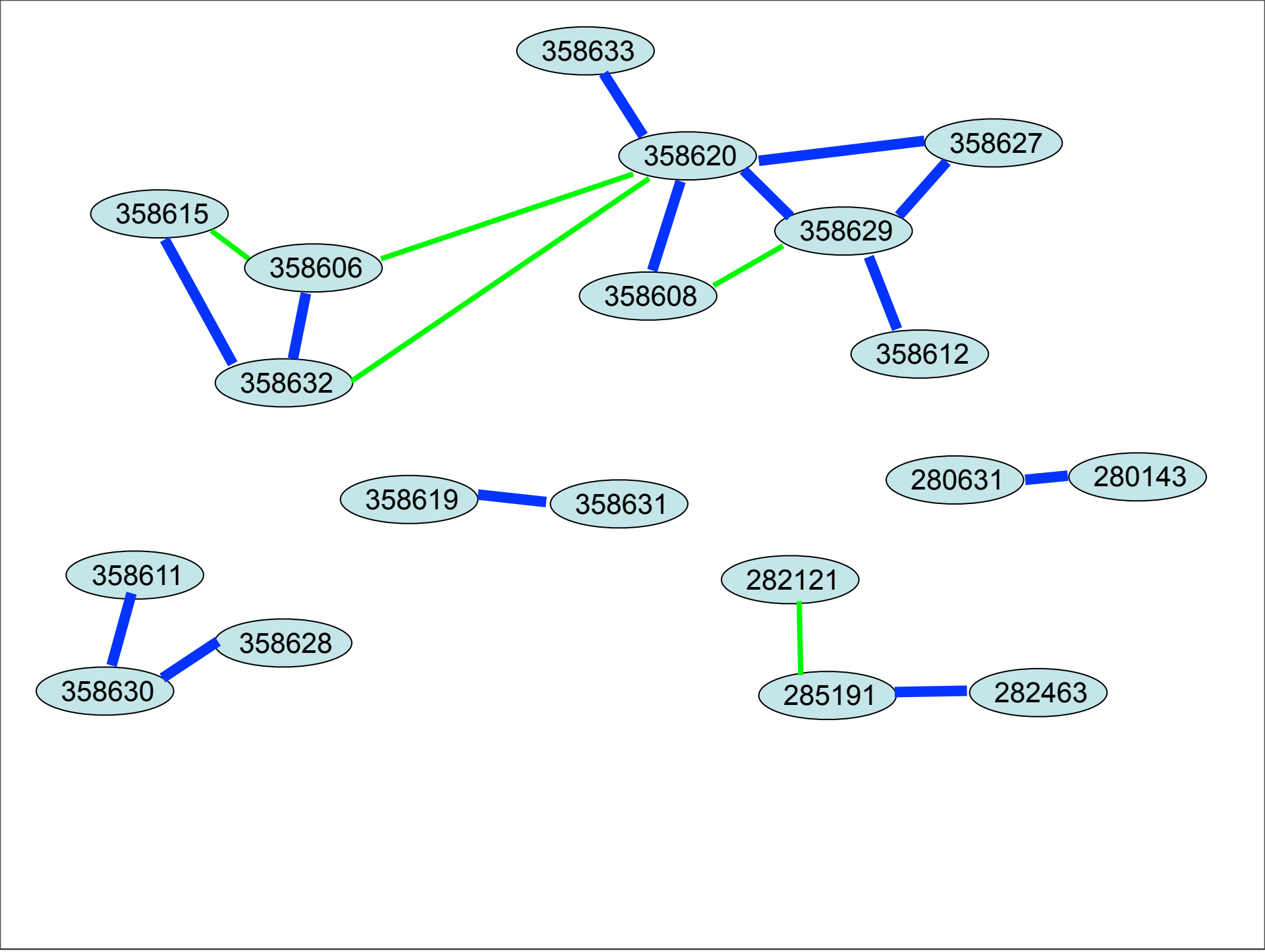
Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court.

Consider the following forces:

1. A downward force of gravity.
2. A force by the "hit".
3. A force exerted by the air.

Which of these forces is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?

- (A) 1 only.
- (B) 1 and 2.
- (C) 1 and 3.
- (D) 2 and 3.
- (E) 1, 2, and 3.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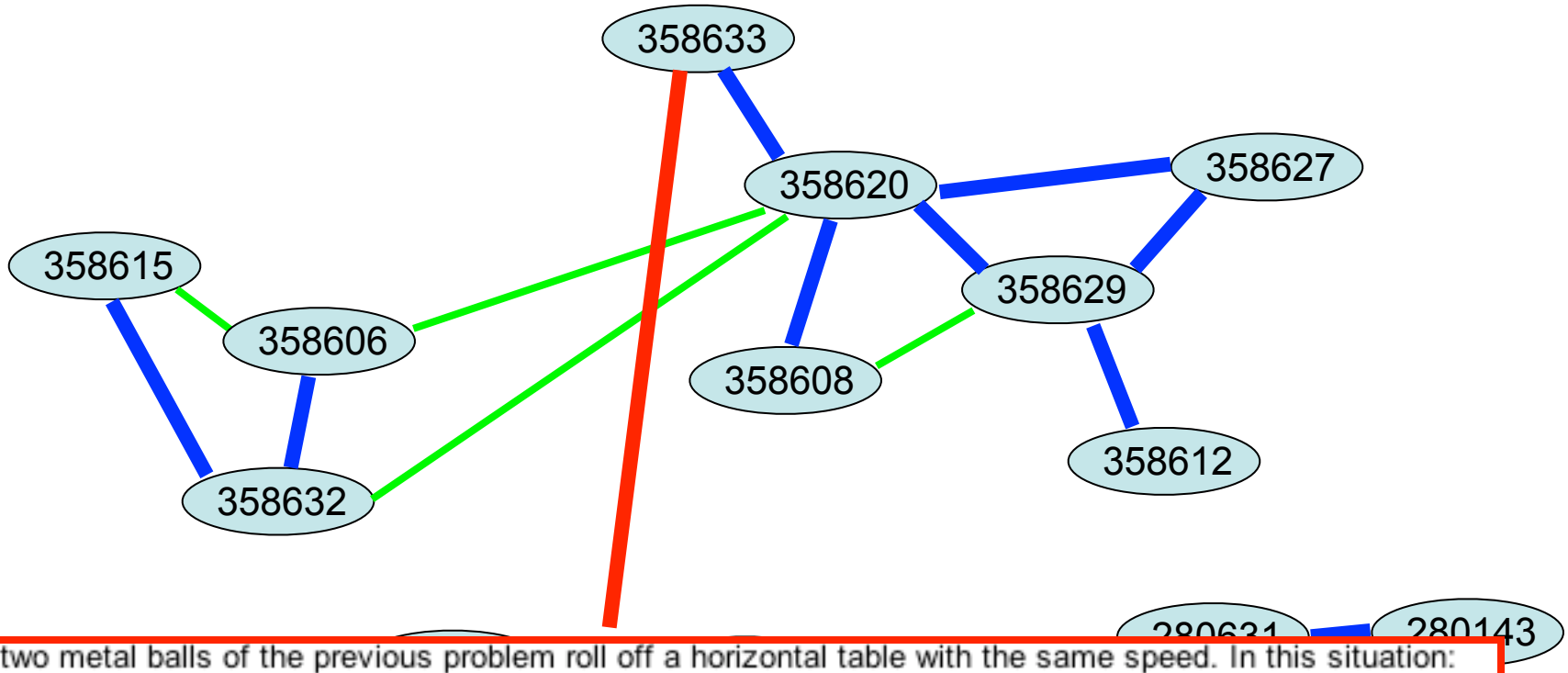


The two metal balls of the previous problem roll off a horizontal table with the same speed. In this situation:

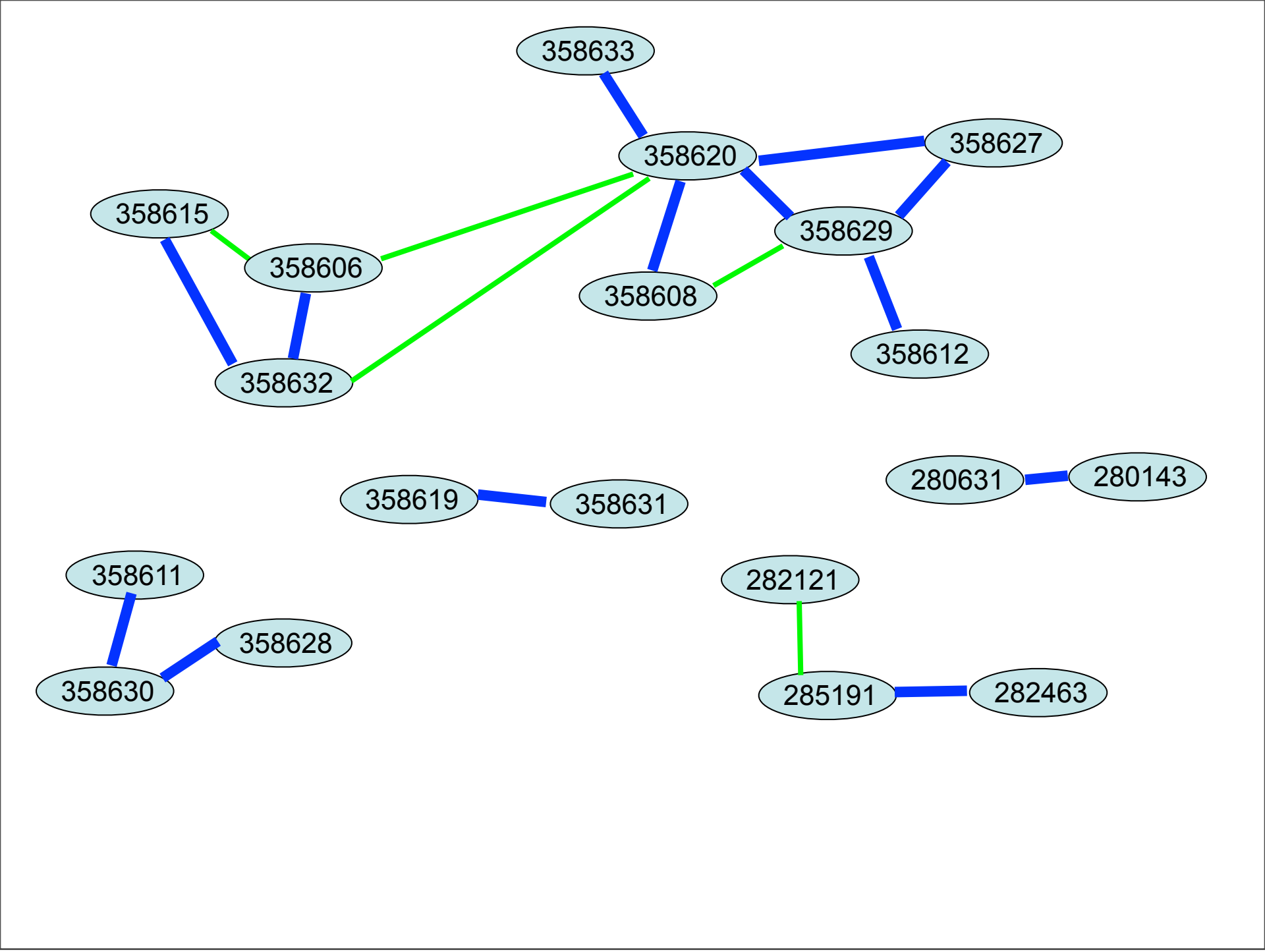
(A) both balls hit the floor at approximately the same horizontal distance from the base of the table.

(B) the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.

(C) the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.

(D) the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.

(E) the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.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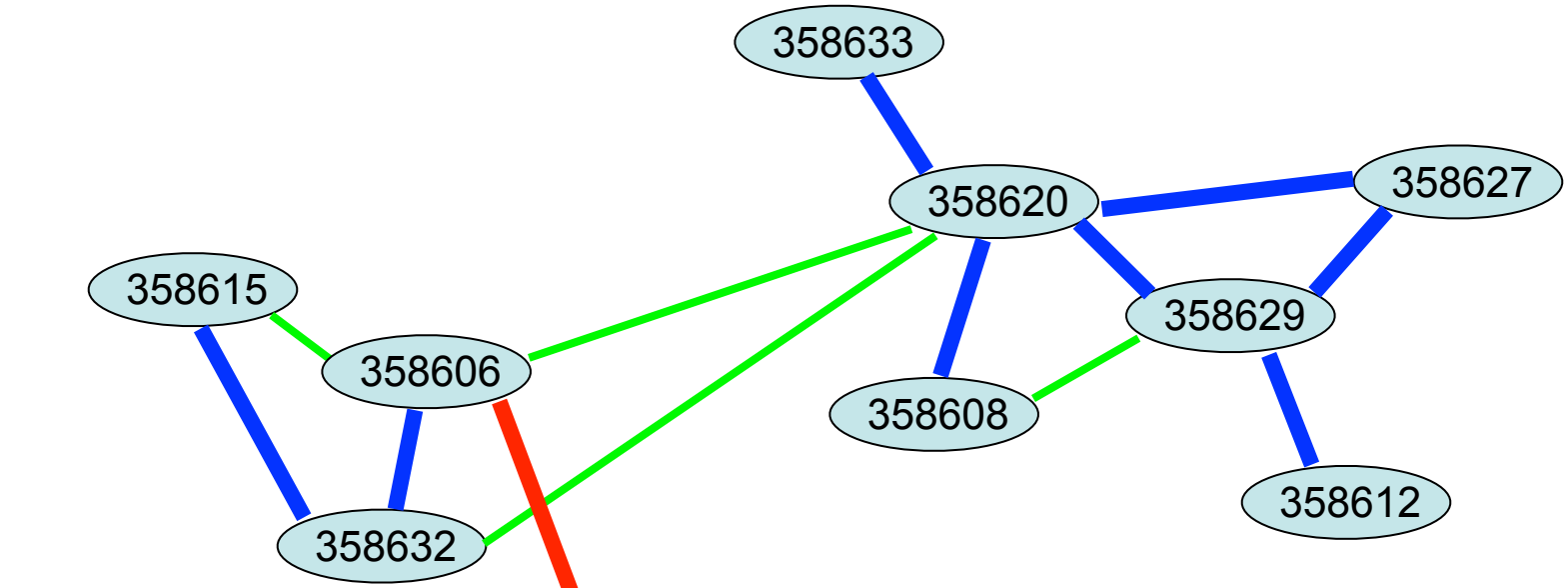
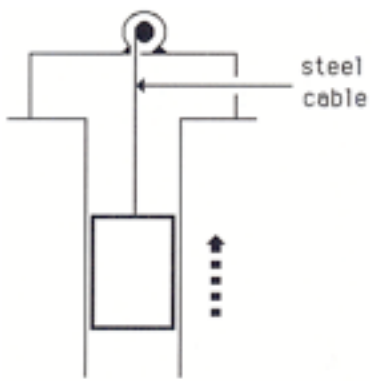
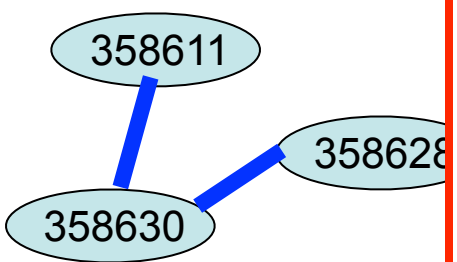


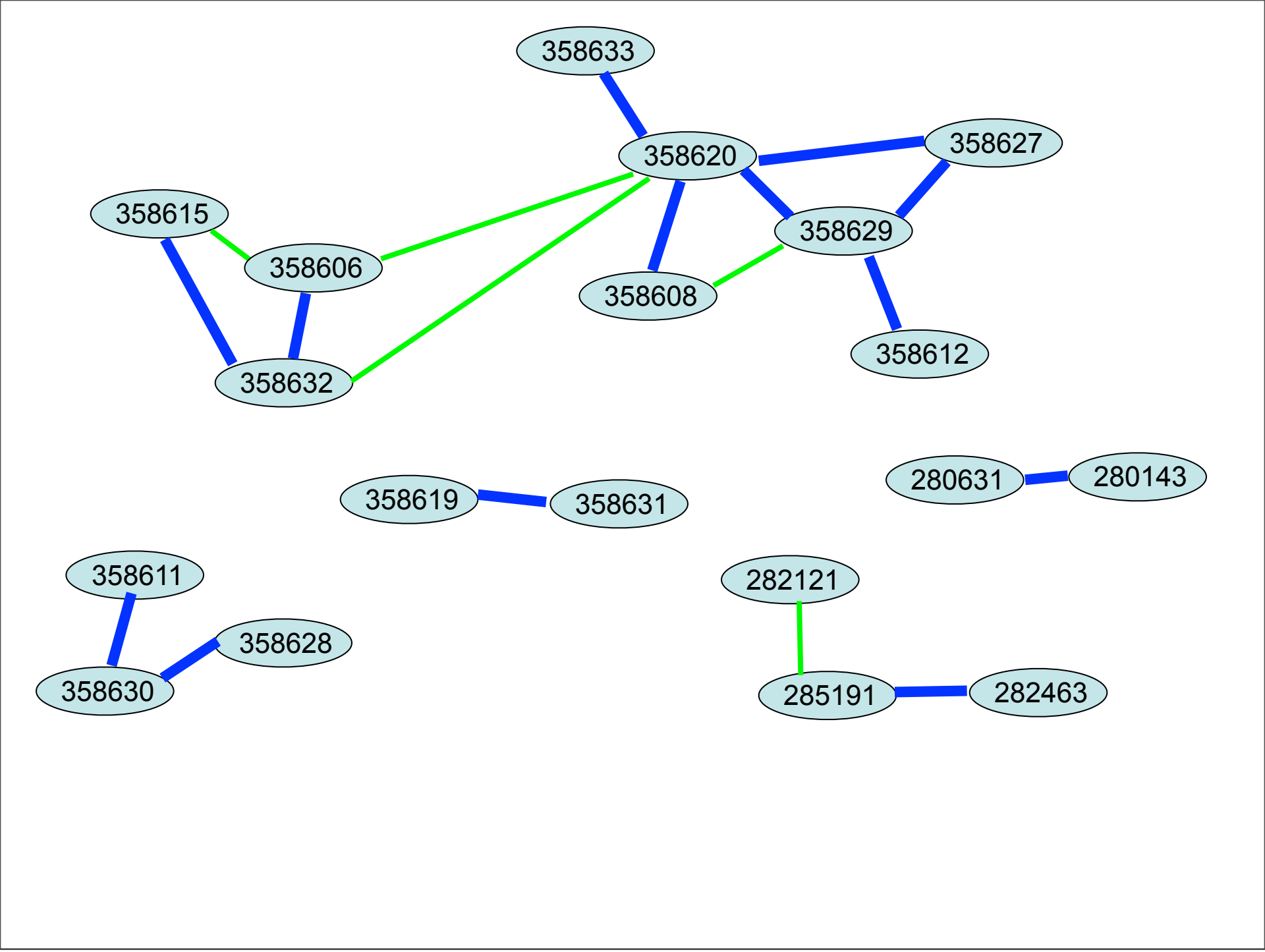
An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:

- (A) the upward force by the cable is greater than the downward force of gravity.
- (B) the upward force by the cable is equal to the downward force of gravity.
- (C) the upward force by the cable is smaller than the downward force of gravity.
- (D) the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
- (E) none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable.)



Elevator going up
at constant speed

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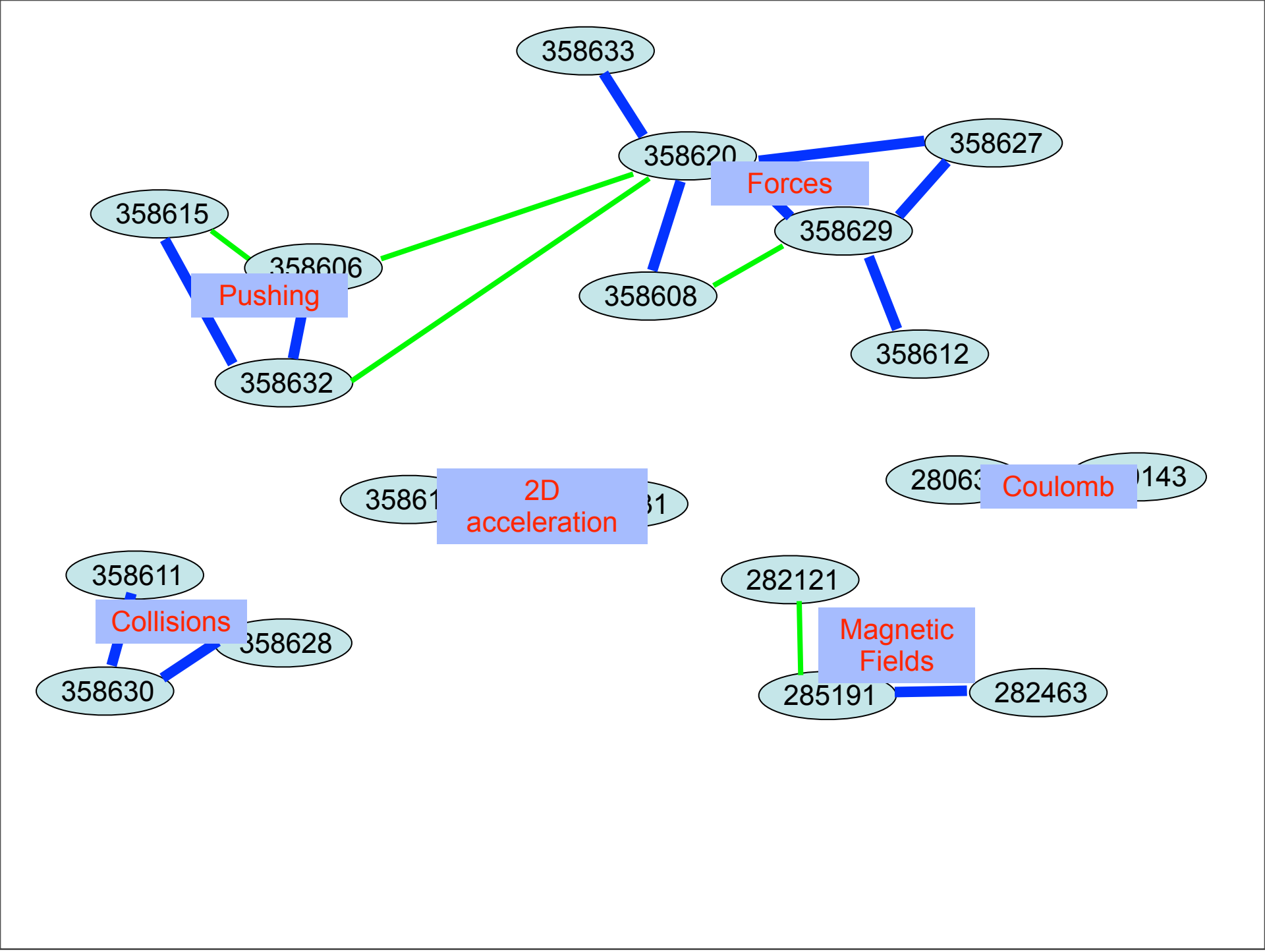
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What does all this mean?

- Damned if I know at this stage…
- Suggestions most welcome…

- And now - on to some teaching innovation experiments.

What were we trying to fix?

- Attitudes: “physics is the boring solitary memorisation of hundreds of unrelated equations”
- Lack of Transfer: “the exam questions were too different from the examples in the book”
- Conceptual misunderstanding

Some innovations

- Role-plays
- Think-Pair-Share/Clickers
- Mastery Learning
- Case studies
- Randomised questions
- Computer game questions
- Instruction-free labs
- More…

Role-plays

European Princess hurt in Canberra crash

From our Canberra correspondent

Princess Cristina Balmoral and her male-model boyfriend Mr Bruce Chubb were involved in a car crash this afternoon in Canberra.

The celebrity couple were driving down from the viewpoint on noted beauty spot Mt Ainslie when her multi-million dollar sports car left the road, collided with a parked car and fell down a steep slope. Rescuers pulled Cristina and Bruce from the wreckage, and they were transported to the Canberra Hospital by helicopter. A hospital spokesman said that both were in a stable condition.

Princess Cristina is second in line for the throne of Scotland. Her wild lifestyle and lavish celebrity parties have recently made her a staple of the gossip magazines. She had been romantically linked to a string of actors and wealthy businessmen.

Student Quotes

"You had your own sorts of breakthroughs when you found out another piece of information, and it was like Oh Wow! This fits in with this, and now we know this, and . . . you actually felt quite intelligent."

"We enjoyed these tasks more because it gives us the sense that we're the first ones to discover these things, and it gives us a sense of pride in what we were doing, whereas if we read it out of a book we wouldn't get the same sense of pride."

What had they learned?

"The way that as a group of people, we as humans try and answer the way things are using a collection of seemingly unrelated facts."

"There are no right answers, only theories based on observations."

"Astronomy isn't all stiff attitudes and boring theories."

"The best way to learn is to ask questions. Never accept an answer or a theory without thinking it through, and if you disagree, without argument."

Use

- In over 40 universities around the world.
- Now taken by over 50,000 students.
- Subject of a number of publications.

Think-Pair-Share


Rusty

Formal Group Structure

- We assign students to deliberately heterogeneous groups of 3.
- Marking scheme designed to foster collaborative work (“Win win”).
- For example - bonus marks if your group members do well, group contracts, peer evaluation, formal group roles. We’re still working on this…

Quotes from student feedback

- *Normally, in a course one wants to do the best which means one is willing to idly watch as others flounder, and the reverse happens when the shoe is on the other foot. I love it how that isn't happening now.*

- *I like how we think in class and answer questions. Every question we got right feels like an achievement and gives a good feeling about the test.*

- *I like the way that the lectures are carried out. It is fun and at the same time, you learn much more rather than just sitting down there and listen to the lecturer. You will tend to sleep in that case.*

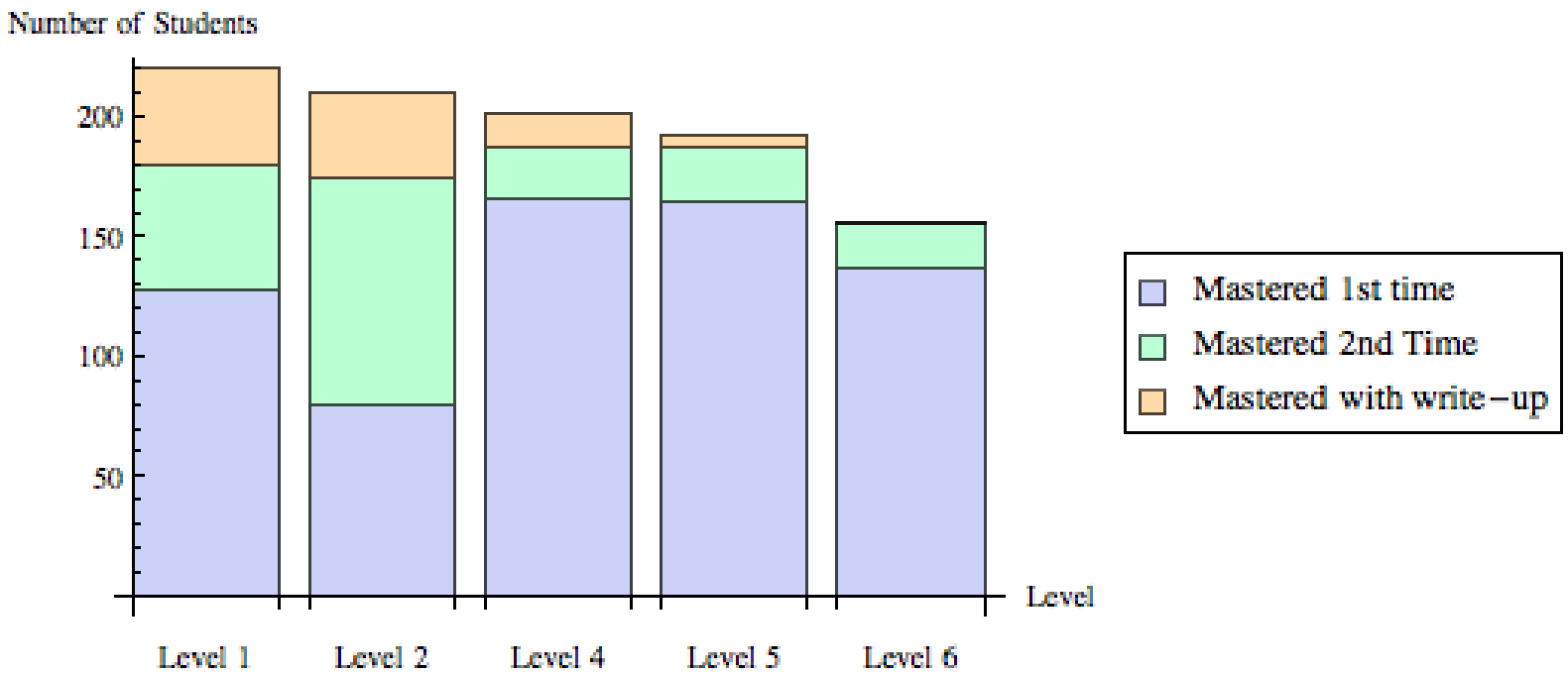
Big gains in conceptual tests

- Roughly double the learning of conventionally taught classes, for no more work.

Mastery Learning

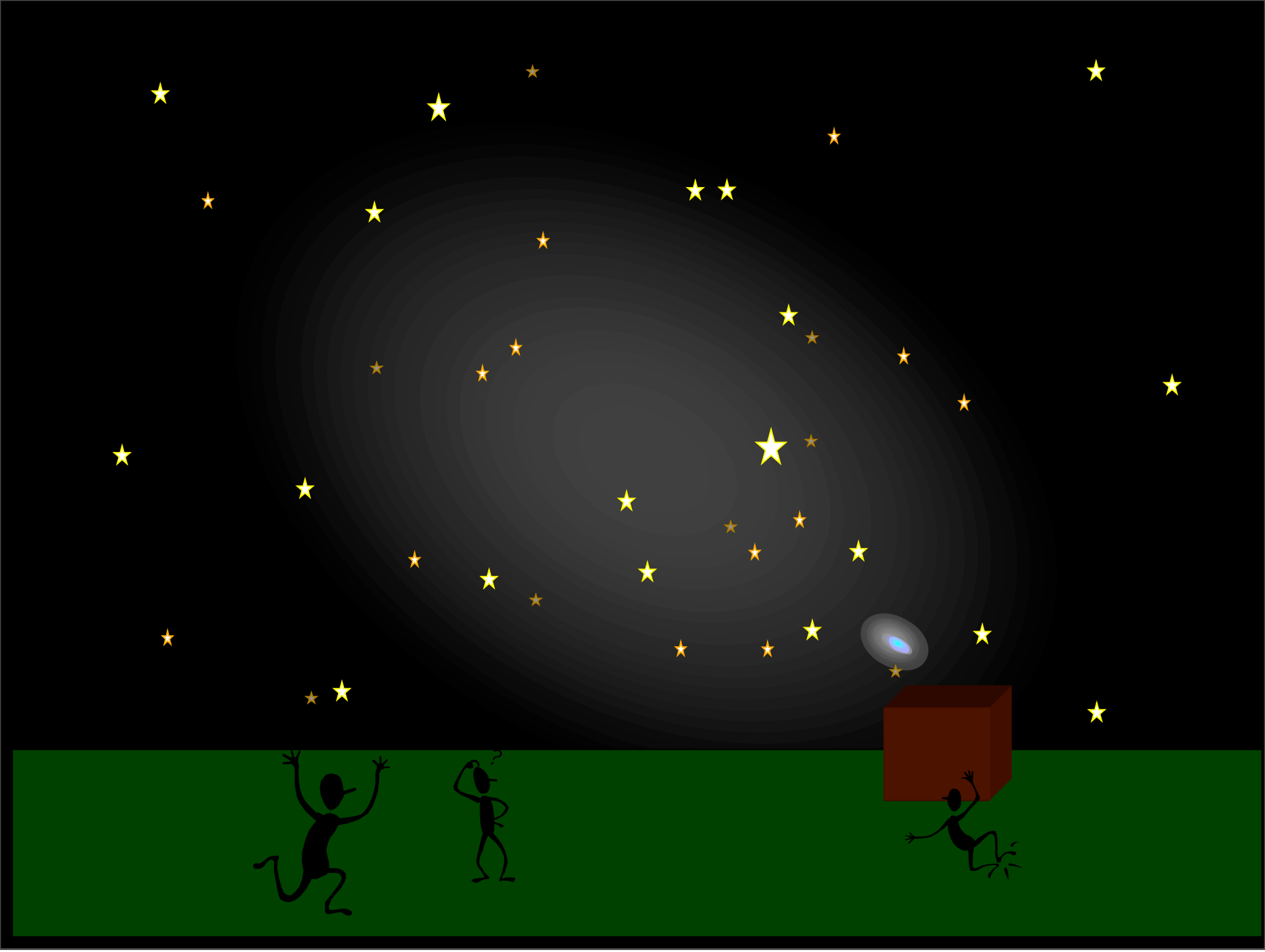
- *The basic idea behind mastery learning is that any student can learn anything well, but that it takes some students much longer than others. We should therefore let students proceed through a course at different speeds, while insisting that they totally master each section of the course before moving on.*

How did it work?

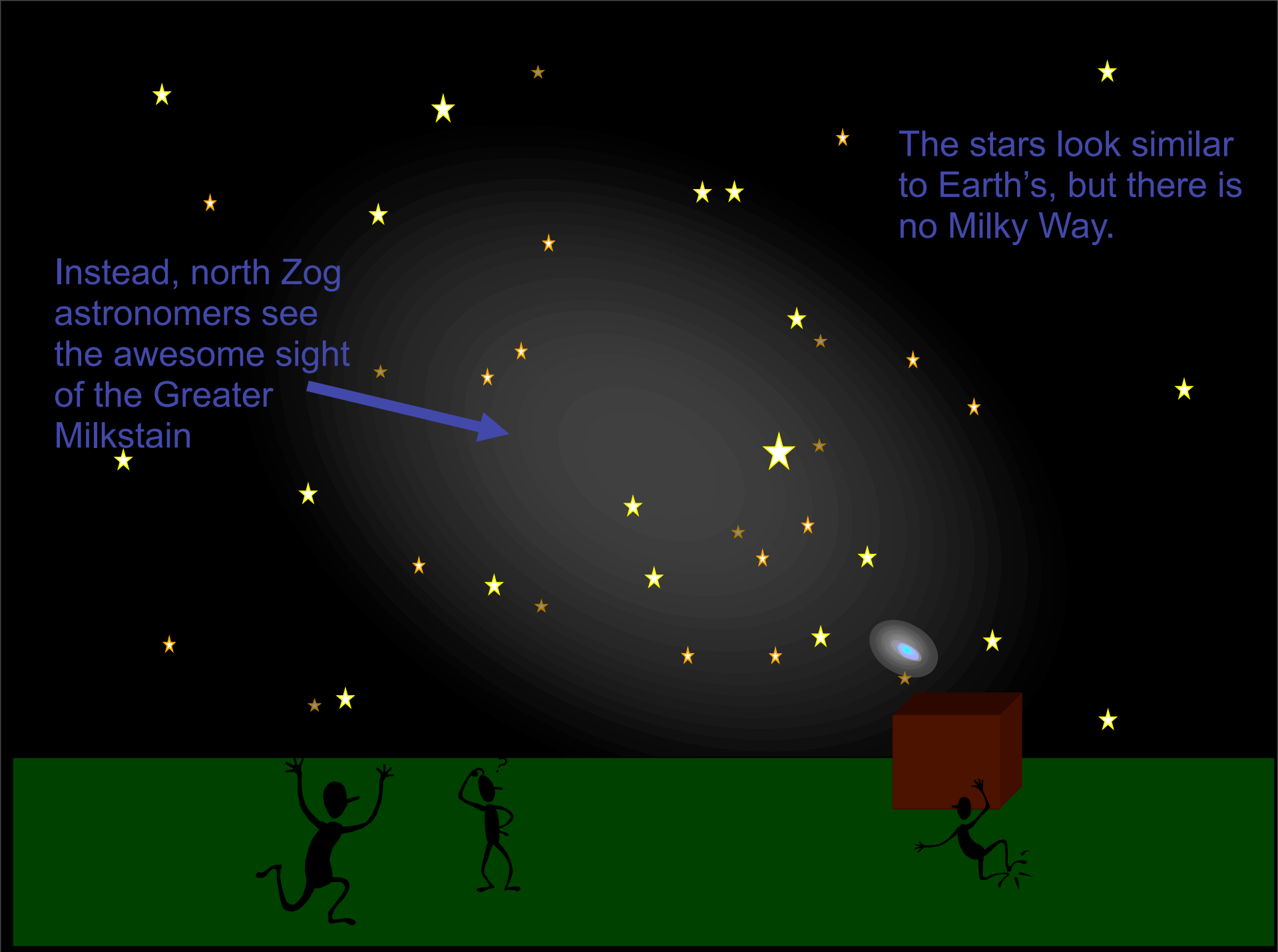


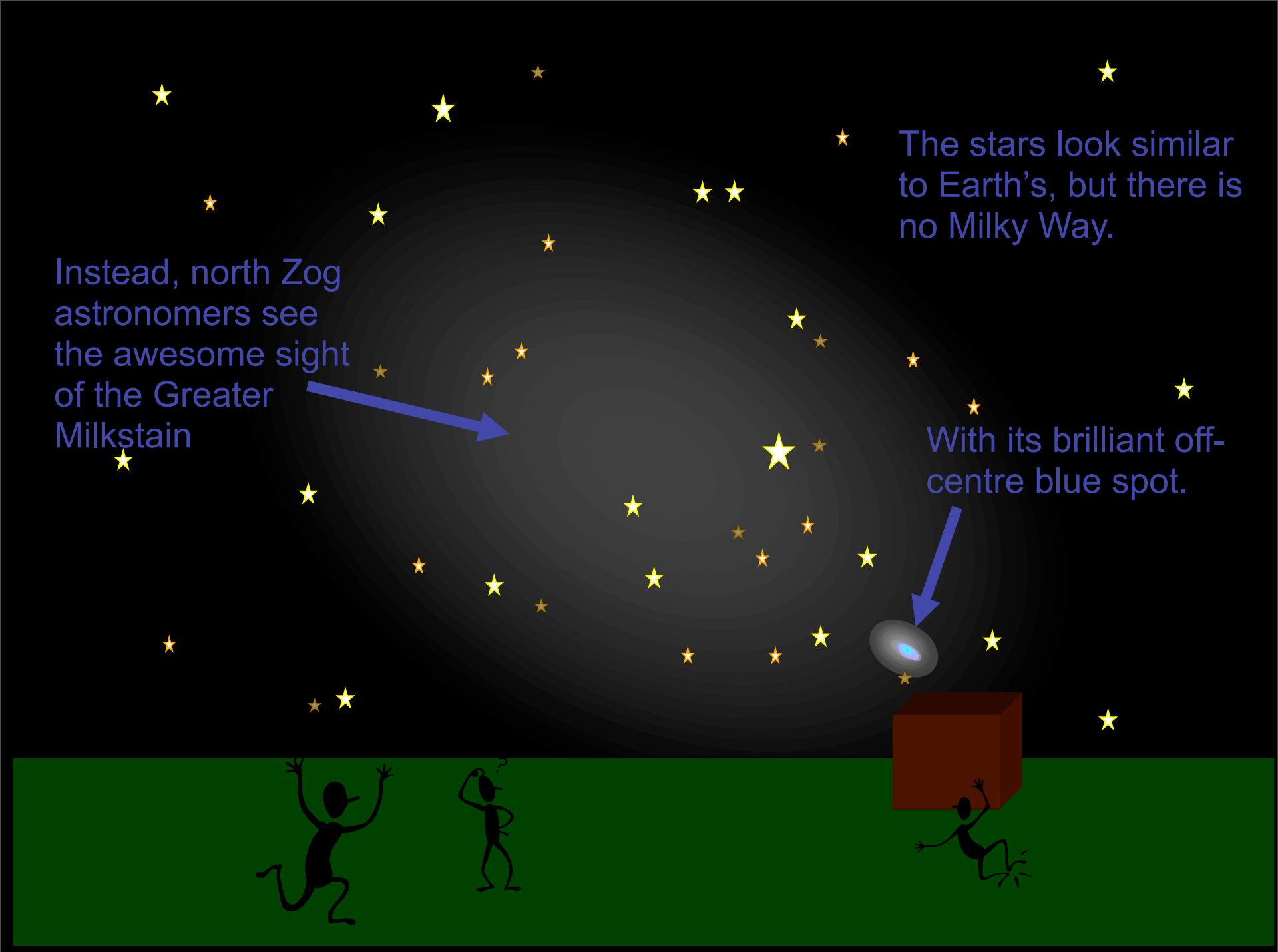
No change to exam marks

Case-Studies

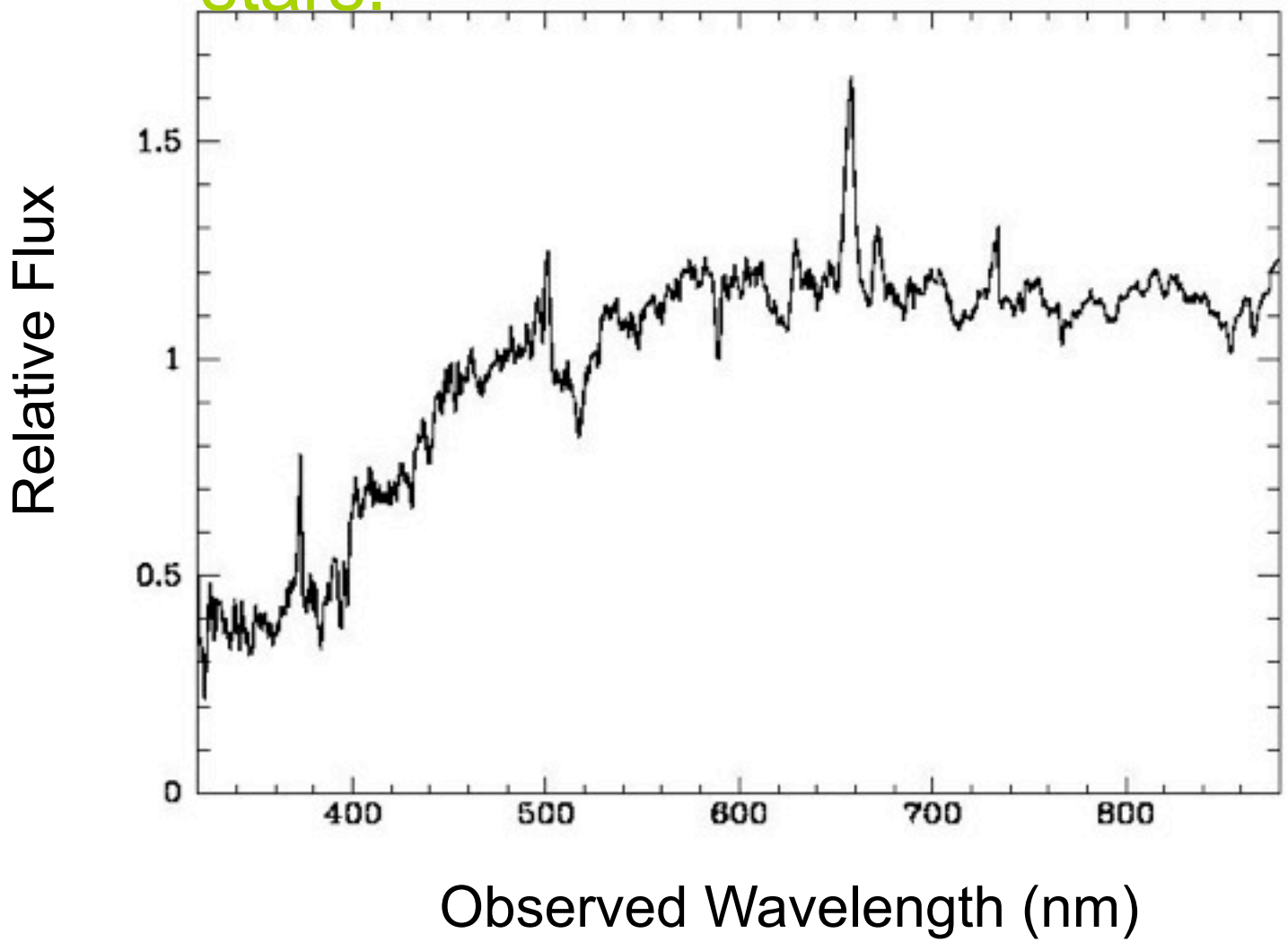



The stars look similar to Earth's, but there is no Milky Way.


The stars look similar to Earth's, but there is no Milky Way.
Instead, north Zog astronomers see the awesome sight of the Greater Milkstain


The stars look similar to Earth's, but there is no Milky Way.
Instead, north Zog astronomers see the awesome sight of the Greater Milkstain
With its brilliant off-centre blue spot.

- All four fuzzballs had similar spectra: spectra resembling those of typical stars.



What did students say?

"The only assignment that made me think, rather than reach for a text book."

"Real life situations where you have to think as real astronomers do. I thought this was very good and very important."

"I was compelled to do the assessment task especially early because it was so goddamn interesting."

Overwhelming opportunity

- And little competition.
- Not as much career suicide as is generally believed.
- Lots of fun…