Effective use of mathematical equations in an online learning environment

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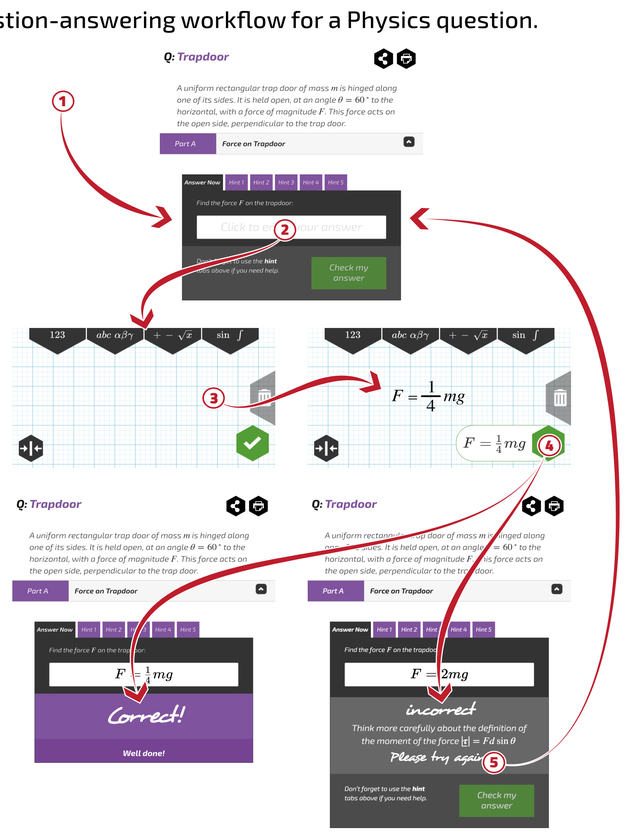
We developed a **free, STEM oriented, online platform supporting students and teachers in secondary education**. The platform revolves around automatically marked questions of various types: multi-choice, numeric, text-based, symbolic. Symbolic manipulation is an important skill in many STEM subjects, but **traditional computer-based symbolic entry systems can be inaccessible to our target audience**.

We developed *Inequality*, a symbolic system composed of

1. a web-based, graphical, cross-platform editor that allows students to work with familiar symbolic notation, and
2. a service that marks entered answers using model answers specified by our content creators.

We have two instances of our platform: **Isaac Physics** covers **Physics** and **Mathematics**, and **Isaac Computer Science** includes **Boolean logic** questions which use a similar notation to mathematics. The picture below shows an example of the question-answering workflow for a Physics question.



We analysed data from Isaac Physics as it has been running for longer than Isaac Computer Science, and has a dataset of **nearly 500 000 question attempts**. A preliminary analysis of the Computer Science dataset suggests that many of the results from the Physics platform can translate to Computer Science.

We looked at three key aspects:

1. the **performance** of students while answering questions;
2. how the students **use** *Inequality* to answer questions;
3. the **experience** of students using Inequality.

1. Performance

Many symbolic questions in Isaac Physics started their life as numeric questions. In this format, students were required to construct a formula and use it to compute a numeric answer. We converted 343 questions to the symbolic format. Students were equally proficient at answering questions correctly in both formats, however **students required fewer attempts when answering questions using Inequality 73% of the time**. The Boolean logic questions on Isaac Computer Science started as symbolic questions so we cannot repeat this analysis, but we hypothesise students will experience a similar benefit..

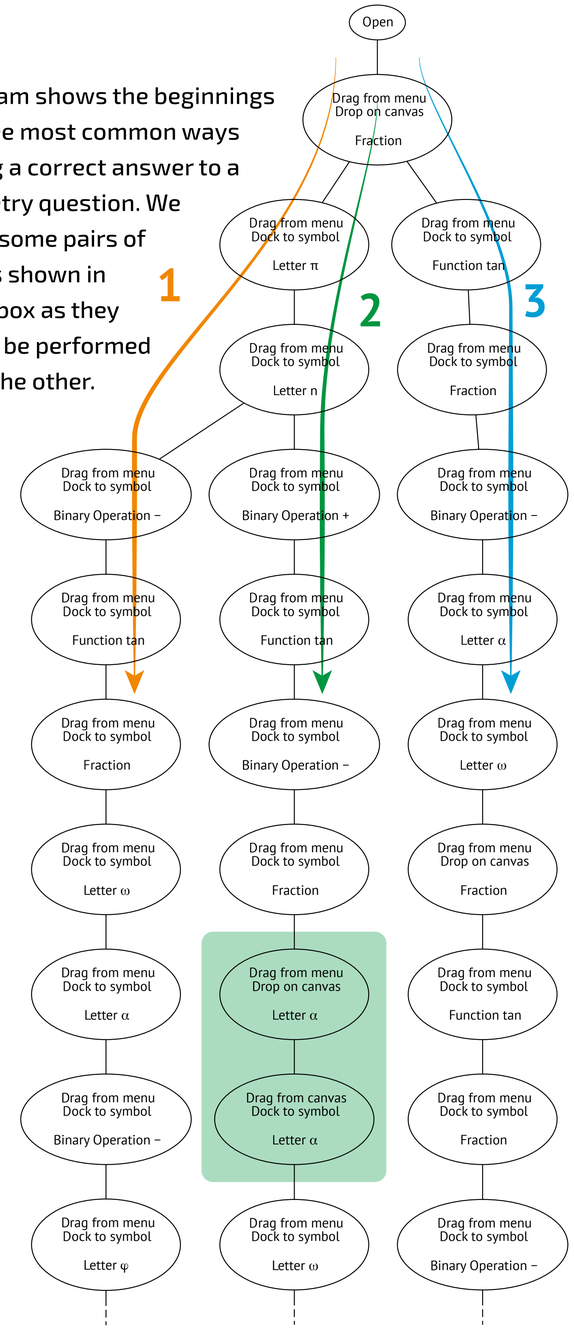
2. Usage

We looked at the way students use Inequality to answer questions. To do this, we created action trees from our system logs to explore every step taken by students in formula construction. An example is shown to the right. This analysis highlighted a few efficient and commonly chosen means of constructing expression for any given question. However, it also showed that many students like to perform manipulations in the editor, for example re-arranging a formula to reach the correct answer. The key finding is that *Inequality* **enables a high level of flexibility while working with symbolic notation**.

3. Experience

Students responding to a questionnaire reported being generally OK with *Inequality* despite a few usability issues which we have since fixed. We think that **its flexibility is a key part in this result**.

This diagram shows the beginnings of the three most common ways of building a correct answer to a trigonometry question. We combined some pairs of actions, as shown in the green box as they could only be performed one after the other.



References

A. Franceschini, J. P. Sharkey, A. R. Beresford (2019) *Inequality: multi-modal equation entry on the web*. In Proceedings of Learning @ Scale 2019, Chicago, IL, USA.