Problem

- Print media conveys the notion of formal structures(equations and graphs) as being static entities. Students think of equation in component terms (LEGO like structures), and graphs as pictures.
- Print media is limited in conveying the dynamic nature of equations and graphs.

Design Principles

- Make equations and graphs dynamic and manipulable entities.
- Create an explorable explanation system

DPS

Insights

- Students by themselves are not able to understand the detailed relationships among the three components of the pendulum system. A teacher is needed.
- But they understand graphs and equations as dynamic systems coupled to real world phenomena.

Possible Extensions

Most scientific models have these three components, so this system can be extended to phenomena in biology, chemistry and engineering.

Problem

- A teacher has to **enact** in detail the textbook representations in the classroom, by drawing on the board, while the students have to mentally **simulate** what the teacher is enacting to understand the content.
- Specific case: Teaching **vibrations** in undergraduate **Mechanical Engineering**

Design Principles

- Reduce the **time** it takes for the teachers to enact the textbook in the class
- Make students explore and enact the system along with the teacher
- Build **new representations** which could lead to insights about the system

ExMV

Insights

- Engineering teachers have found the system useful
- Such systems are between **learning** systems and **discovery** systems (computational models). This is an explore-and-understand system.

Possible Extensions

- Many engineering cases where linear systems are coupled, leading to **nonlinearity**.
- The emerging nonlinear behaviour can be systematically **explored** and understood using ExMV like systems.

Problem

- Students do not understand the connection between geometry and algebra of vectors.
- This leads to mechanical algebraic manipulations without thinking in geometric terms.

Design Principles

- To connect geometry and algebra of vectors through interaction with touchable and manipulable vectors.
- Seeding imagination of vector operations like resolution and addition.

PSLV

Insights

- Students using the tool relied much less on algebraic equations when compared to the pretest.
- Students used gestures while explaining their thinking, indicating a shift to geometric way of reasoning.
- Students commented that interacting with the system gave them new insights about vectors.
- Unit circle as an integrator of geometry and algebra

Possible Extensions

- Trigonometry, 3D vectors, dot and cross product, curl-divergence, vector fields, calculus?
- Physical chemistry, biology, astronomy, organic chemistry

Problem

- The teaching practice is grounded by the textbook. So, the textbook needs to be augmented for effective use of digital resources in teaching.
- There are a large number of digital learning resources online, but they have not been incorporated systematically into classroom practice.
- Virtual lesson plans, combining textbook and digital resources need to be developed systematically.

Design Principles

- Tightly connecting the vector tool with the textbook such that it is directly usable in classrooms.
- Participation of teachers in the development and implementation of virtual lesson plans that help integrate the simulations into their teaching practices.

QR-PSLV

Insights

- This acts as an additional layer augmenting rather than replacing the textbooks. Both students and teachers move smoothly between the static and dynamic understanding of formal structures (vectors, trigonometry, algebra).
- In textbook based practice, the teacher enacts the vectors and the students try to imagine them individually. But, PSLV allows enacting the vectors in a collaborative manner.
- Encountering the tool, the teachers immediately suggested adding problems students could solve at home, which automatically flips the classroom.

Possible Extensions

Similar QR based designs can address many imagination issues in science and mathematics textbooks.

- The QR codes we use are available for download as pdf from our website. These can be printed and attached to textbooks.
- Reaches every classroom. Creates open source platform to compete against corporate digital books such as Apple's ibook.
- Various other online resources (such as videos and different levels of problems) could be curated by HBCSE to augment the textbooks.

Problem

- Data to understand engineering design practice is usually based on introspection and memory.
- This data constrains the access to the mental models and the design reasoning of the designers.

Design Principles

- Make different designers simulate their design process in a virtual environment.
- Create a common ground to collect data across participants.
- Allow collecting qualitative (discussions about the simulation), quantitative (activity logs) and process data (screen capture) in an integrated manner.

SPED

Insights

- Clearly brings out design process differences across participants.
- Richer qualitative data grounded in the on screen activity.
- This could be a novel and **effective** research methodology to probe design and similar practices.

Possible Extensions

This could be a new way of doing qualitative studies that seek to understanding expert practices.