

Augmented Reality In Education

By Aaditya Aji, IDC school of Design

Guide: Anirudh Joshi

P1 project, 2020

Project Approval

The project titled “Augmented reality in education ” by Aaditya Aji, is approved for partial fulfilment of the requirement for the degree of ‘Bachelor of Design’ at Industrial Design Centre, IIT Bombay.

Guide:

Chairperson:

Internal Examiner:

External Examiner:

Date: 25th December 2020

Declaration

I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission.

I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources, which have thus not been properly cited, or from whom proper permission has not been taken when needed.

Aaditya Aji

17U130012

IDC School of Design

Indian Institute of Technology, Bombay

Acknowledgment

I am immensely grateful and indebted to my guide Prof. Anirudh Joshi for his encouraging support and patient guidance throughout the course of this project. With deepest respect and appreciation, I'd like to express my gratitude to Prof. Prasad Bokil, Prof. Ravi Pooviah and Prof. Venkatesh for their inputs and constructive feedback.

I'd also like to extend my gratitude to friends and family who assisted and participated in the research study and provided valuable inputs.

Table of contents

1. Abstract	Page 6
2. Introduction.....	Page 7
3. Background.....	Page 10
4. Blended learning.....	Page 14
5. Primary research.....	Page 16
6. Content Analysis	Page 16
7. Breakdown of solid state chapter.....	Page 17
8. Learning approach in schools.....	Page 23
9. Interviews.....	Page 24
10. Analysis.....	Page 25
11. User behaviour.....	Page 26
12. User expectations and suggestion.s...	Page 30
13. Restated brief.....	Page 32
14. Alternatives	Page 32
15. Chosen concept	Page 38
16. Findings	Page 43
17. Discussion	Page 44
18. Conclusion	Page 45
19. References	Page 47

Abstract

Formal education acts as stepping stones for creating a learning environment for students throughout the high school and college journey. During the COVID pandemic, the schools had to be closed down and students were stuck at home with their classes happening virtually through online video conferencing tools and virtual classrooms which naturally affected the learning environment for the students. In conventional classroom environment, the day would consist of several subjects as periods along with extra curricular activities(ECAs) to create a balance, along with competitions, events, workshops, practical laboratory classes etc. which created a good learning environment for students. With the sudden change in the formal education sector, students could not adapt to the new ways of instructional learning which severely affected the performance of the students. The learning environment

that the traditional system created was missing from the virtual classroom approach. It was also interesting to note that the education sector was severely hit because there wasn't any significant change that had happened in the sector until recently with several online education platforms coming up in the form of open-source courseware or startups which tutor students. I thought it'd be interesting to explore the possibilities of new tech in the sector the way it has affected other growing sectors such as finance, health, etc.

In my project, I'm using AR to aid students in 3D visualisations of concepts explained in class 12th NCERT textbook which could help them understand the concepts better along with other supportive material which will help them develop curiosity and interest in the topics while maintaining a seamless self-learning experience under the pandemic conditions which was earlier fulfilled by the formal education system through

various activities and social learning environment in schools.

The AR mobile app can be used to scan images in the NCERT textbook which opens a 3D visualisation that the students can interact with, and explore to understand the spatial features, which further allows them to question and gain interest in the area, nudging them to read and know more about the topic. The app also provides additional learning material from Wikipedia, which can be used to read up about the relevant related topics and relevant instructional videos which can help a student understand concepts through instructional means which was missing due to problems faced in the virtual classroom environment, earlier students would interact with teachers and students in classrooms when they faced issues or doubts. This blended learning approach has proven to be more engaging for students and hence this opportunity could be used to develop a framework that can be used to create or curate more

educational content. Exploring that possibility and suggesting a solution in the direction was my primary motive of the project.

Introduction

As adults educated young people in the knowledge and skills considered important in their culture, education started in prehistory. This was done orally and through imitation in pre-literate societies. Story-telling transferred awareness, beliefs, and talents from generation to generation. As societies continued to broaden their understanding beyond skills that could be readily acquired through imitation, formal education grew.

Formal education in the current scenario occurs in a structured environment with the explicit purpose of teaching students, e.g. in a school setting with classrooms of many students studying together with a

qualified, accredited teacher of the subject. Many school systems are organised around a set of principles or values that control all educational decisions in that system. These options include curriculum, organisational models, physical learning environment design (e.g. classrooms), interactions between students and teachers, evaluation processes, class size, instructional events, etc.

In 2020, when the COVID-19 pandemic started, countries had to implement a lockdown with immediate effect which drastically affected all institutions and industries heavily, in a way no one had imagined. Ranging from the very complex financial institutions of the world to the massively growing tech industry came to a halt. One of the worst hit sectors due to the lockdown was the education sector which had failed to adapt to the unforeseen circumstances. Colleges, high schools and every other form of structured educational institutions were shutdown and the transition to a virtual set-up was very slow compared to the sectors.

Coincidentally, I came across a webinar hosted by CNN in which they discussed the effects of the pandemic in the education sector and how it would accelerate the disruptions in the sector using new technological innovations. Scott Galloway, a professor at the New York university Stern school of business, and a public speaker, author, podcast host, and entrepreneur, said, *“No other product on the market has such high margins and hasn’t largely innovated in over 5 decades”* in the discussion, which had me curious about the contribution that I could make to the education sector.

I started reading up about various rising technologies, when I came across Augmented Reality (AR) as one of the spaces which are currently in its early stages and how the growth and accessibility of it will drastically benefit various sectors such as healthcare, logistics, gaming and education.

How could augmented reality benefit the education sector? Amongst several scopes of improvement in the

current scenario– personalisation, information accessibility and information curation are key areas of focus in the education sector.

Education, like we discussed is mode of transmission of information; increasing accessibility of information in a digitally connected world became an easy task, hence websites such as wikipedia and niche forums and community spaces such Reddit, and open courseware portals such as Coursera, Udacity, MIT OCW became very popular and are still considerably growing. Information curation is a key aspect of accessibility itself, new startups such as Byju's, Unacademy, and non-profit organisations such as the Khan Academy carefully creates and curates information for students. New startups such WhiteHat Jr. creates personalised education experience for students.

How does augmented reality fit into this? The interfaces used by the aforementioned startups and websites are entirely digital, they serve the purpose of

additional sources of information which are used by the students to help them create a better learning experience for them during their self learning sessions. Most students still use physical textbooks as their primary source of information in their formal education spaces. Augmented reality could help bridge the gap between the physical resources and the digital resources, while maintaining the possibilities of interaction with the content that is visible on the screen.

If augmented reality offers such benefits, then why hasn't it massively disrupted the sector yet? That's an interesting question and while my take on it is partially informed and speculative in nature, it is not entirely objective and unchallenged. Firstly, AR requires a lot of processing in the computing device for the experience to feel seamless. The technology is old, but the rising popularity is due to three major reasons, one– increasing cheaper personal computing devices capable of running more operations, two– cheaper faster internet

accessibility which offers cloud services which does the computing in powerful servers and streams the information to the personal devices, and three, development of simpler AR frameworks which can run on web interfaces.

Secondly, content creation is a fundamental bottleneck of AR. Since, AR is virtual content in physical space, the content itself is preferred to match the surroundings and hence 3D, unlike screen interface which could have 2D content. 3D content creation was not very easy until recently with free simple softwares that are now available to the development and content creation community around the world.

Since AR is in its early stages, there aren't very clear guidelines about content creation and hosting, user experience goals, etc. although a lot of organisations including Big-Tech companies like Alphabet inc. and Apple inc. are actively trying to help develop a community of AR content development community.

My goal for the project was to explore the possibilities of AR and how design intervention could be used to accelerate the process of AR tech adoption through problem solving.

Background

What is Augmented Reality? A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.

To understand AR , it can be broadly categorised based on the devices used to access it and the different tracking methods used to create AR. These different kinds of AR come with its own set of advantages and disadvantages and understanding them is important to tailor a good design intervention for the problem statement.

AR can be accessed using,

1) Mobile phones - A native mobile app is capable of

accessing AR content, the advantage of using a native app based AR is that there are millions of devices which are currently capable of supporting it but the downside is that, mobile phone being a personal hand-held device, inherently comes with a small viewport, the app also



needs to be downloaded into the device.

Depending on how good the device is, the quality of AR may vary.

2) WebAR - when the content is accessible through a web interface, typically web browsers are able to access the content. While it doesn't require external installations, the

framework is not as powerful as the other devices.

The AR object in the picture here allows one to visualise the actual size of the product in a real world context.

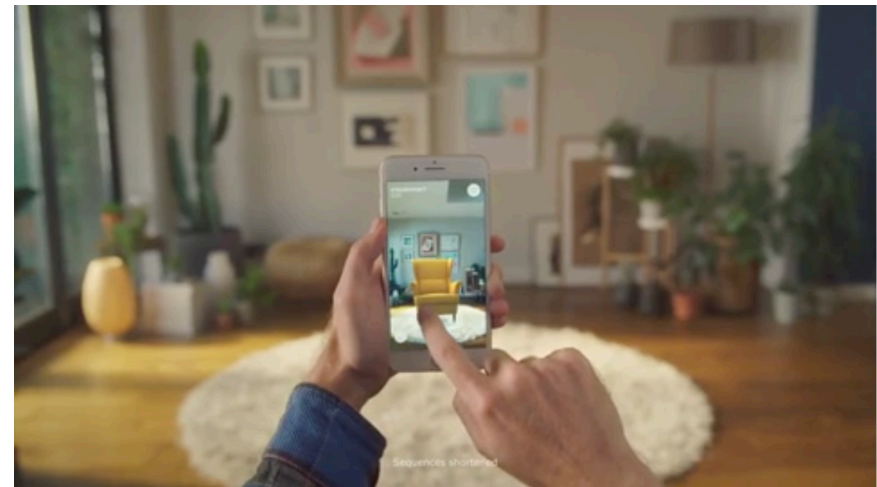


Image credits: IKEA Place mobile app

3) Head-mounted displays or smart glasses - The most immersive and rich experiences can be seen through dedicated AR headsets like HoloLens or Magic Leap. Basic visual overlays can be seen through

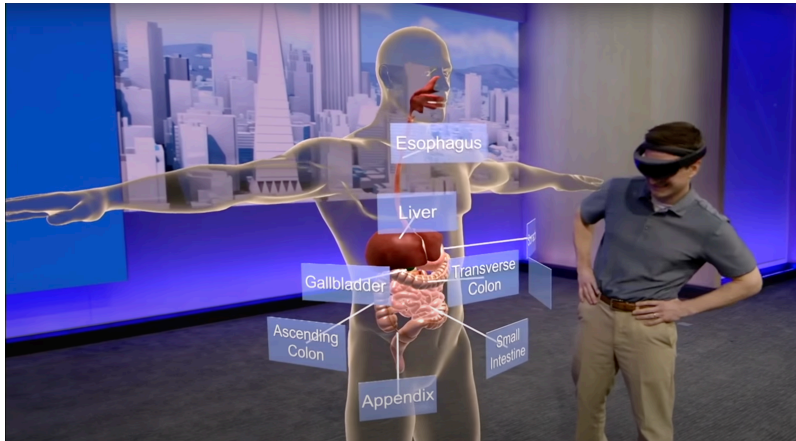


Image credits : Microsoft and Case Western Reserve University

A person using Microsoft holo lens to visualise the human digestive system

lightweight smart glasses like Focals. Currently, the powerful devices are very bulky and expensive and hence, a lot of people are not familiar with the devices. It's important to understand the device compatibility and popularity when creating content for a specific set of users. Understanding the nuances helped me decide that

the educative content needs to be hosted in a native mobile app.

Since AR is computer-generated graphics in a real world context which is displayed on an interface, the device needs to be capable of tracking the real world objects so the graphics can be placed in the real setting without clashing with real world objects.

AR can also be categorised based on the tracking that's used. AR tracking are of 3 types,



Image credits : YouTube AR stories

1) Marker-based - when we attach virtual content to a specific thing in the real-world e.g. a QR-code style pattern, an image, a 3D object, a face. Its good for binding content to a specific target, but it needs to be pre-configured and a constant clear view of the marker is require for it to function.

2) Markerless - Understanding the real world and using that information to position virtual content in it

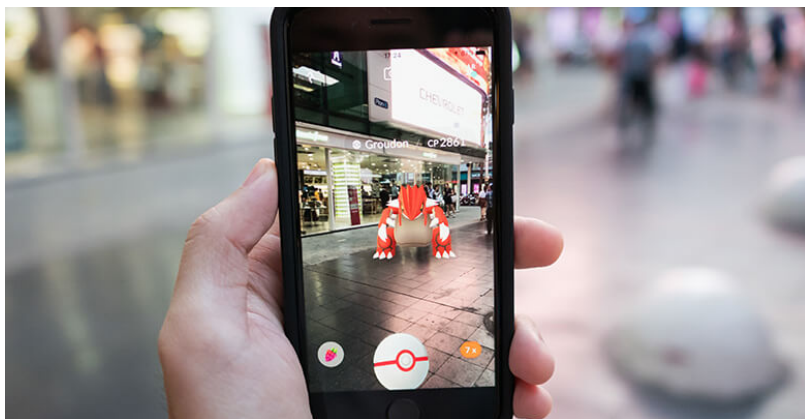


Image credits : Pokemon GO

e.g. placing virtual objects on a table. This method makes virtual content feel like it belongs in the real world. The technology is new and hence, limited. Its currently not as sophisticated as people hope and a lot of research and development is constantly being carried out in the area.

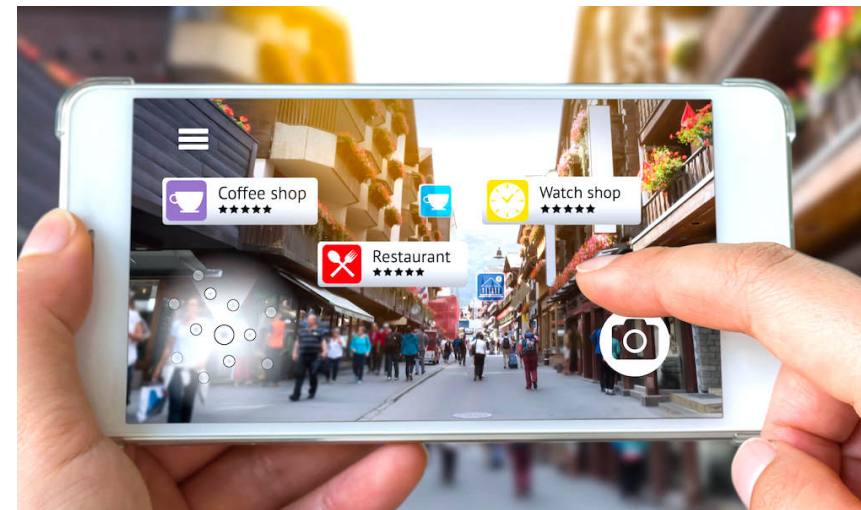


Image credit : Instabug Blog

3) AR cloud - A global virtual layer, where content can be placed and persist for all users. It's very nascent and a dominant network is yet to emerge.



In the project, I'm using image as markers in textbooks to show 3D visualisations.

There are already several ways the current education system has tried to make learning better using smart-boards and Blended Learning approach.

Blended learning techniques have proven to be useful and boost students academic performance. In a classroom setting, pre-covid scenario, blended learning was implemented using laboratory sessions, workshops, smart-boards which the teachers use to show animations, explainer videos, visualisations etc. But due

to covid lockdown, the blended learning approach was heavily affected and students were relying on mostly on virtual lecturers and self-learning techniques. My approach was to bring the blended learning techniques into the self-learning environment as well, by implementing AR.

Blended Learning

Blended learning refers to a combination of instructional delivery approaches. Blended learning integrates traditional face-to-face instruction with various electronic (Web-based) approaches and other activities. Blended learning includes formal and informal activities that promote learning. Blended instructional approach is becoming an increasingly common and desirable due to

several factors such as better Student adoption in terms of ease of use and convenience, better faculty adoption, cost efficiency etc.

Can AR be used in blended learning approaches?

There is already a lot of work being done in the area. in terms of instructional content, visualisations etc which are mostly targeted towards a more mature group of students for complex visualisations, like in the medical education sector for visualising anatomy, or to show the



Image credits : Research Center of Environmental Communication and Education, Greece

QR code being used to access AR content

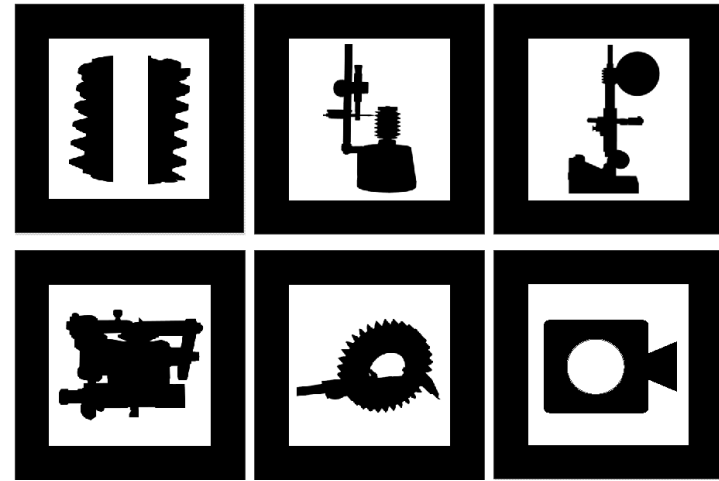


Image credits : Corpus ID: 37572468
Augmented Reality Textbook for Future Blended Education

High contrast image markers being used to access AR content on textbook

working of moving parts in an engine in a mechanical engineering course.

Existing methods vary from using using AR headsets to visualise marker-less AR content which are can be interacted with, or using QR code and high contrast image markers to access AR content.

The problem with the existing methodologies is that the textbooks need to be specifically made with the image markers for the content which is not feasible to implement in the existing textbooks in circulation. The content also needs to be made for the textbooks and there is no single platform where the content development can be tracked or coordinated, nor are there any guidelines about the content specifications.

In India, we have a standardised approach towards for high school education, which are the education boards that formalise a structure and a curriculum which is to be followed by schools.

India has both central and state boards which have their own specifications. The Central Board of Secondary Education (CBSE) is a national level board of education in India for public and private schools, controlled and managed by the Union Government of India. It affiliates 21,499 schools across the country. According to the

CBSE curriculum, secondary education schools need to follow textbooks by the National Council of Educational Research and Training (NCERT). Students from classes 6th and above of all streams studying in schools that follow CBSE board, hence use the same textbook series. Leveraging these textbooks would be a good way to create impact at a large scale.

Primary Research

The use case of AR is better for 3D visualisation related topics, hence I decided to look into mathematical topics, physics, chemistry and biology topics which could use 3D visualisations for better learning.

Content Analysis

Finally, I decided to work on chemistry topics. for classes 6 to 10. Here are my findings,

Class 7th

- Fibre to Fabric
- Acids, Bases and Salts
- Physical and Chemical Changes

Class 8th

- Coal and Petroleum
- Combustion of Flame
- Metals and Non-Metals
- Fibres

Class 9th

- Atoms and Molecules
- Mixture - Purification
- Particles - States of matter
- Structure of Atom

Class 10th

- Chemical Reactions and Equations
- Acids, Bases and Salts

- Metals and Non-Metals
- Carbon and its compounds
- Periodic Classification

Most of the topics were conceptual and theoretical with minimum applications in terms of numerical questions. Students who were facing issues in the topics or were unable to score well was not due to lack of understanding of concepts according to several students who were interviewed. Hence, I decided to focus on more complex topics which could use further clarity and in-depth understanding.

I shifted focus to class 11th and 12th chemistry syllabus and here are the topics explored,

Class 11th

- Some basic concepts of chemistry
- Structure of atom
- Classification of elements and periodicity in properties
- Chemical bonding and molecular structure

- States of matter
- Thermodynamics
- Equilibrium
- Redox reactions
- Hydrogen
- The s-block elements
- The p-block elements
- Organic chemistry- some basic principles and

techniques

- Hydrocarbons
- Environmental chemistry

Class 12th

- The solid state
- Solutions
- Electrochemistry
- Chemical kinetics
- Surface chemistry
- General principles and processes of isolation of elements
- p-block elements

- d- and f-block elements
- Coordination compounds
- Haloalkanes and haloarenes
- Alcohols, phenols and ethers
- Aldehydes, ketones and carboxylic acids
- Amines
- Biomolecules
- Polymers
- Chemistry in everyday life

After analysing the content and talking to students and teachers, I decided to start with 'The Solid State' chapter of class 12th Chemistry NCERT textbook which seemed like the most appropriate chapter with several topics that could use design intervention. This decision was made after having several conversations about the problems faced by students in various topics across chapters, the type of problems- conceptual, numerical, laboratory experiment, etc.

I interviewed two kinds of stakeholders, students and teachers. Students were of two kinds, current 12th standard students and students who've graduated high school.

While talking to students who've already graduated high school, my goal was to understand the studying pattern, how they managed to juggle between multiple subjects and multiple topics that were covered in each subject. Ideally, I'd have preferred to conduct contextual inquiry to better empathise with users in their working environment, but due to pandemic, most interviews were conducted via phone calls and some through video calls.

The interviews were unstructured but I also wanted to know how they specifically dealt with 'The Solid State' chapter, so I explicitly had to inquire about the chapter and the topics covered in the chapter. Specifically with the graduated students, it was important to understand if they faced issues, how did they solve it? If they tried

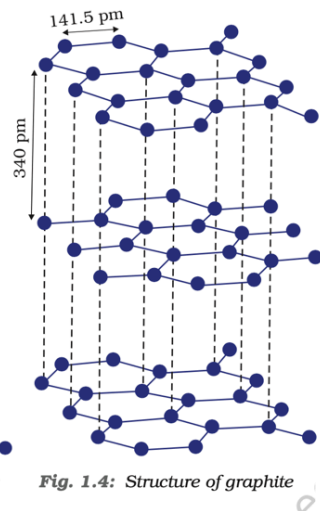
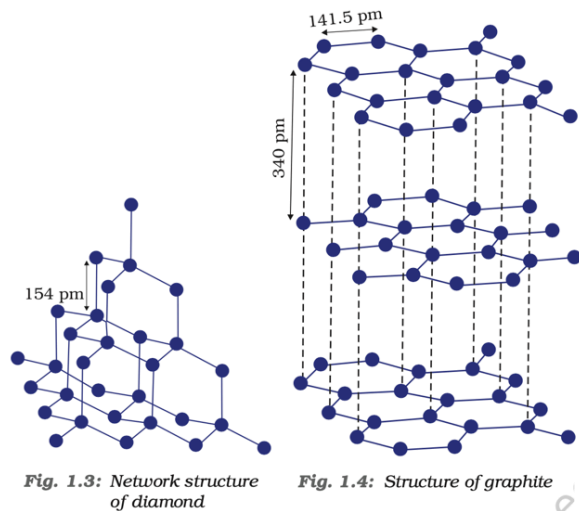
solving it at all? How were they dealing with similar topics in other chapters and perhaps other subjects too.

Breakdown of solid state chapter

A detailed analysis of the solid state chapter was required to conduct better interviews of the users to understand the pain points and their ways around it.

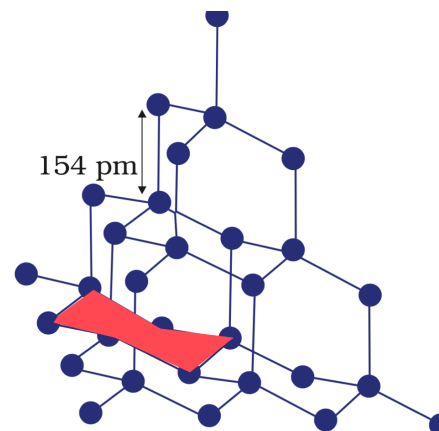
Certain topics were identified which were discussed with the graduated students during the interviews.

- 3D crystal structures - (quartz, graphite, diamond etc)
- Anisotropy
- Unit cell visualisation - Bravis lattices
- Atoms in unit cell (visualisation and numerical)
- Closed-pack structure and voids (visualisation)
- Packing efficiency (numerical)
- Imperfections in solid
- Electrical properties (conceptual)
- Magnetic properties (conceptual)



Structure of diamond and graphite

Some students conveyed that the diagram of the structure of diamond conveyed the network nature but they could not extrapolate the information in the diagram to the how the structure looks and what are the kinds of voids present due to the single angle that's provided in the diagram. Hence either diagrams from several angles or a 3D model would help in better understanding.



Some students failed to understand the voids and the different planes at which the atoms are situated and an interactive digital representation or a physical 3D model could easily solve the issue

Students would refer to online resources such as sketchfab or online videos which showed the structure in more

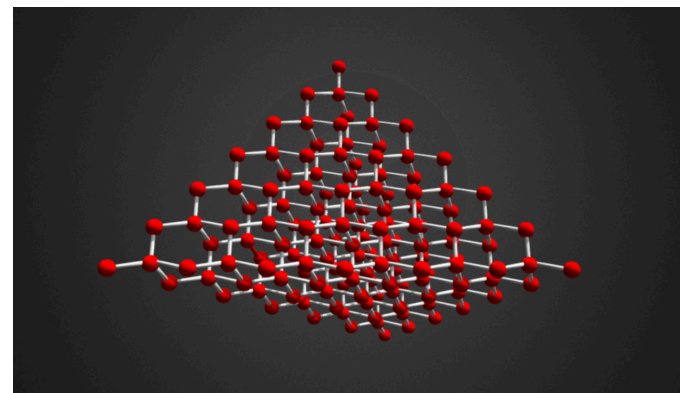


Image credits: Sketchfab

An intractable 3D molecular structure of diamond

detail, but they did not prefer the extra effort which they claimed broke the flow of studying.

For the number of atoms in a unit cell, the diagrammatic approach helped students understand the concept but they failed to extrapolate that information into an actual molecular structure in some cases like the body-centred unit and face-centred unit.

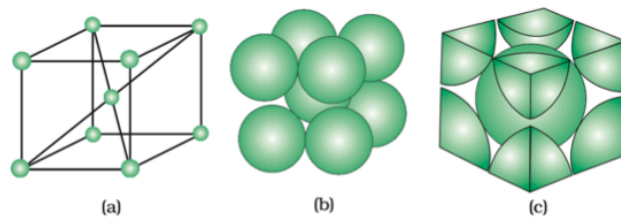
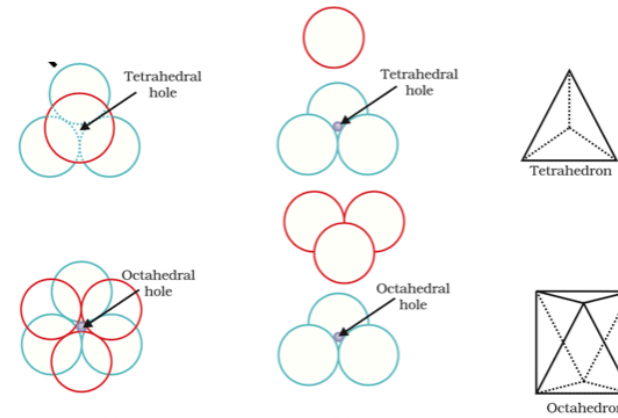
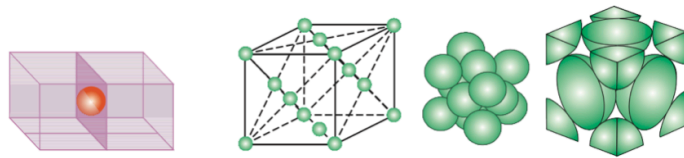
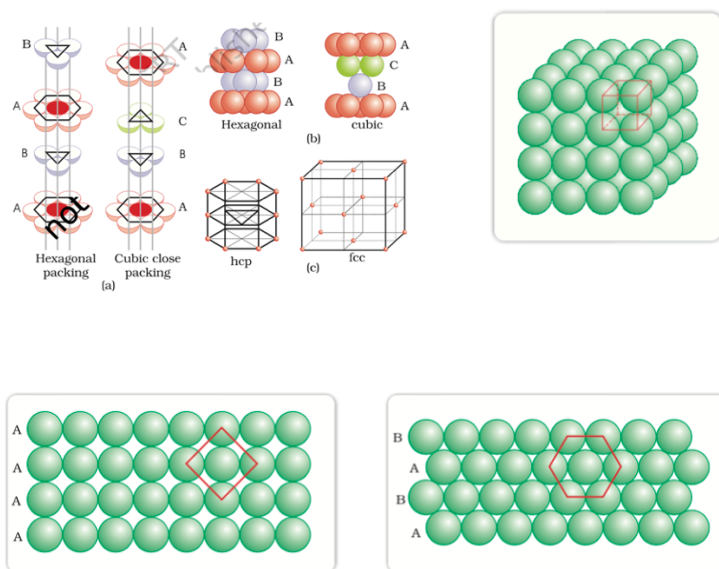


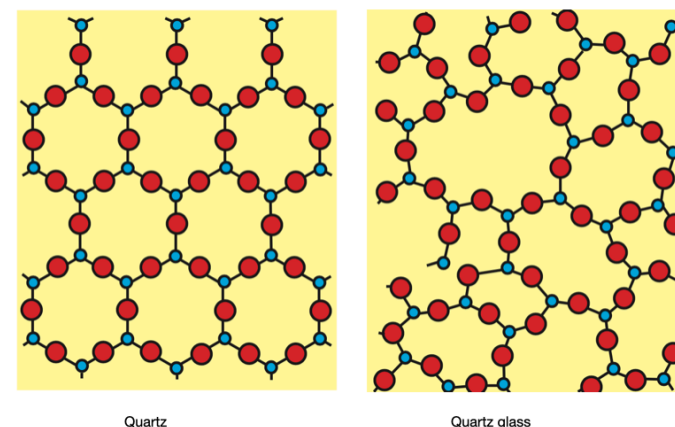
Fig. 1.14: A body-centred cubic unit cell (a) open structure (b) space-filling structure (c) actual portions of atoms belonging to one unit cell.



The same issue persisted when visualising the voids shown in the diagram which are marked as 'tetrahedral hold' and 'octahedral hole'. The layers shown separately helped the structure of hole but it took extra effort to understand where the tetrahedron shape is pointing in the diagram, if its 'into the page' or 'out of the page'.



The area enclosed in the red outlined polygon was confusing to certain students. The multiple layers of atoms helped understand the cross section but not the entire molecular structure, placing it into real world context was difficult for students to do.



Several students claimed that the diagram of quartz and quartz glass in the diagram was misleading because of the angle of the 3D structure which was shown. Silicon atom (blue circles) has 4 valency, which means it bonds with 4 neighbouring atoms in the structure, but in the diagram it shows only 3 bonds. The 2D representation of this structure was communicating the wrong idea about the structure and the students were confused about the actual structure in 3D space. Oxygen atoms (red circles) has a valency of 2 but the bonds are at an angle with the silicon atoms which is not visible in the diagram.

For the scope of the project, I decided to work on this specific issue that students faced.

Learning approach in schools

The learning approach followed by the schools of the students and teachers interviewed could be broadly divided into 3 different phases.

1. Information contact - A student is exposed to new information from the school setting from various people in the school in different scenarios. But considering the specific context of formal education, the information contact can be broadly categorised into 3 headings,

1.1. Reading - various resources which are growing because of internet and increasing accessibility of learning material, but just to name a few in the interviewee's context, resources such as textbooks, class notes, tuition/ coaching centre notes and

other resources, wikipedia, encyclopaedias, books, journals, magazines in libraries, etc.

1.2. Instructional - from professors, teachers, friends and peers, during discussions, debates and other classroom activity. Explainer videos that some teachers use as assistive resource with additional content to help students learn faster and/or better.

1.3. Laboratory Experiments/ Explorations - Most schools have science laboratories set-up which has resources and material to conduct scientific experiments as individuals or in groups. Students are encouraged to explore and be inquisitive about the experiments which are carried out in a collaborative environment. Workshops and competitions are also held in colleges which help students to learn more with an explorative and competitive approach.

2. Information retention - students don't retain every information they come across and hence the school system employs several methods which help students to retain information better, such as,

2.1.Problem solving exercises - this could involve class activities, verbal or textual.

2.2.Practice exercise - in the form of assignments, homework, etc.

2.3. Revision exercises and periodical tests

3. Information application - The students are expected to apply their learnings in real world context.

This process is carried out by conducting,

3.1. Examinations - most schools follow a semester based approach in which they have 2 major examinations that are carried out in the middle and at the end of the academic year, along with several other tests which are graded and reported (this varies for different schools)

3.2.Competitions - competitions at the schools are conducted to encourage students to apply concepts and learnings and put themselves in the context of other students and how they perform, this allows students to identify their strengths and weaknesses and adapt better.

All three phases of learning are important target points for design interventions, so I decided to focus on 'Information contact'. I will discuss in brief about design interventions that were possible for other target phases.

Interviews

As was mentioned earlier, I interviewed two major stakeholders in the system. Teachers and students. During the interview with teachers, I tried to understand their teaching approach and the goals they set for themselves with students, this would be helpful in understanding if and how the students were able to

follow the teacher's intent and approach. I tried to understand how the teaching strategy differed in the virtual setting, which was a drastically new experience for all teachers, and the challenges they faced, compared to the physical classroom setting. I tried to know their take on the increasing digitisation in the area of instructional methodologies, to try to understand how comfortable they are with the transition and how open they are to change.

The second type of stakeholder was students, who were further of two kinds, graduated students, who studied the concepts and successfully passed all examinations. Their context was from the time when classrooms were not virtual. The students were mostly highly reliant on self-study methodologies and since they'd already dealt with their pain points, it was important for my process to understand their side of story. The second type of students were the ones who are currently in 12th standard, which means they did their

entire schooling in normal conditions and had to shift to virtual classes due to pandemic. The sudden paradigm shift in their mode of learning must have affected their approach and retention. It was important and interesting to understand the various things which changed for them and the things which did not. One of the interesting outcomes of the interviews were that the students were heavily dependant on self-study and according to most of them the most effective strategy for self study and introspection of topics and concepts which helped them in better in-depth understanding of the concepts. I will discuss about these specific points in detail.

Analysis

Summarising insights from the primary research and how everything connects to the broader problem area. Learning is a complex process and varies from person to person and context to context, but focusing on a part of

the process by identifying patterns, in a given context will allow us to work on a better design intervention.

User behaviour

Some of the patterns noticed in the users were taken into consideration for the final proposed solution.

Studying Pattern: There was not a very proper schedule followed by the students even though most of them tried to implement a schedule for themselves mostly at the beginning of the semesters. Students were aware that it was not practical to not have a fixed schedule. Different students have varied strengths and weaknesses, and hence the schedule could not have been predicted. Over the course of the academic year, depending the subjects, chapters and the topics, the students put in varied amounts of time and effort, e.g. a topic which required more attention and practice for

student#1 may have been simpler and easy to grasp for student#2. Most students still put extra hours during assignments and periodical tests, and most importantly during semester examinations when students revised and put in extra time and effort specifically for subjects prior to the respective examinations. To work on a design intervention based on studying patterns would be difficult as the requirement differs from student to student. But how do language-learning applications such as 'Duolingo' use scheduling as a design intervention would be interesting to look at. Maybe the way they have gamified the learning experience? But it was interesting to note that students became more serious prior to examinations, perhaps due to a sense of urgency? Schools have time-tables which help students compartmentalise their learning through-out the day, would they like to continue that for the rest of the day? Would that help them? To answer these questions, I inquired more about the way they've been studying after

schools hours. Most students have/ had tuitions and coaching classes, which were held during weekdays or weekends, or simply alternative days.

Students who had additional coaching/ tuition classes during weekends clearly preferred to not have a time table after school hours, they claimed that it became very difficult to compartmentalise their studying hours throughout the day, which affected their retention. This is not suggestive of a common pattern, rather a subjective approach by the students that I interviewed. Students who had tuitions and coaching classes during weekdays claimed to be mostly exhausted by the end of the day. The remaining day would be spent of finishing homework, assignments, practical files and reports when required.

Cross-Referencing: Both type of students heavily depend on multiple resources to study any topic, any chapter. It could vary from the school textbook, to YouTube explainer videos, visualisation websites,

questionnaires, summary points, revision notes, talking to friends to understand concepts when in doubt, etc. Due to increasing accessibility, this trend is not likely to slow down and students find it really difficult to manage multiple resources and keep track of information that they've come across on multiple sources. Out of the interviewed students, no one was very impressive about notes handling or keen on disciplined resource management. A better note taking solution could be suggested? A better resource management tool could be designed? But it was observed that most students prefer taking notes by writing that typing, so a software tool would not be ideal. Moreover, writing has better information retention than typing.

Students prefer note taking by writing in notebooks, but almost half the students preferred reading on screen due to better accessibility and the possibility of multiple reading sources in the same screen on multiple tabs. It was interesting to note, that during the studying hours,

students would refer to textbooks and screens for reading, but write notes alongside in notebooks. It was also interesting to note that the graduated students used more physical textbooks as additional learning resources compared to the current students, who are mostly using their laptops and mobile phones for information consumption except for their NCERT textbooks. The students who were enrolled in coaching or tuition programs were given study-material via email and hence all most of the resources ranging from reading material, revision notes, to questionnaires and test booklets were now distributed virtually compared to traditional booklets and worksheets. The students claimed that the availability of all a major chunk of their additional learning resources being digital, it became easier to manage compared to when they had to maintain multiple drawers, physical folders for a grand variety of additional learning resources which were distributed in physical form. NCERT textbooks were very

important for the users because of the language and approach that the textbooks used which according to users were much simpler to grasp than other resources that they've come across except for visualisations, which validated my hypothesis. To solve the issue, they'd depend on YouTube videos or other interactive resources which were easier also done using smart-board by the teachers in a physical classroom scenario.

Most students were dependant on both physical and digital content for information consumption and some claimed that managing these two forms separately was difficult and sometimes they faced a break in the flow of studying compartmentalising the approach towards two different forms of information consumption might be difficult for users? Bridging this gap could help make the learning experience better.

Digital resources were mostly accessed using laptop because user preferred the real-estate that the laptop screens offered and its better user experience for

multitasking, which I'm assuming is a function of the real estate and user interactions that the laptop allows.

Mobile phones display is smaller and also being the point of interaction for users, inherently would carry some limitations in terms of multitasking.

But users preferred to use mobile phones due to the portability and ease of use that the device offered.

Although some users did mention that a mobile phone could be distracting for them and hence they try to stay away from the mobile phones. The users felt they gained a lot through cross-referencing and due to the benefits they don't mind having to go through several resources for a thorough understanding of concepts, they explicitly stated that they'd rather have to not depend on multiple resources and content should be curated end-to-end.

Perhaps better content creation and curation could help but that is fundamentally contradicting with the blended learning model. So, maybe bridging the gap that users feel when they refer multiple sources could be worked

on. Users have expectations but it's important for a designer to question their expectations when their needs could be catered to without doing exactly what they suggest.

Discussions: Several users claimed they frequently reached out to friends, teachers to clarify doubts and discuss topics. This two-sided information exchange was very helpful for the users according to them and even when someone else was explaining concepts to them like in classroom lectures but instead the lectures being accessible to on-demand. One-on-one interaction, may it be with friends/ peers or teachers allow faster cycles of information contact, questioning, grasping, hence a personalised approach towards learning proves to be helpful for students and like mentioned earlier, there are several ways its already being carried out, from personal home tutors, to multimillion dollar startup called WhiteHat Jr. has the same approach. A very close model would be lecture videos being available on-demand like

several specialised YouTube channels, or education platforms such as Khan Academy. Possible design interventions could include better curated video playlists or creation of lecture content which are better than all the existing videos by identifying the gaps and problems.

It is also interesting to note that when the students have taken responsibility of identifying their strengths and weaknesses and according allot time to solve their problems, they've claimed to retain and apply learning better. Users, in situations when they understood concepts in-depth using not only the resources which were available to them by default from school/ coaching classes but also additional resources from the internet or other books, they were able to perform better during examinations. Perhaps one way to look at it is the students who cared enough to explore more resources and put extra efforts learn better.

Revisions: it was noted that students would practice concepts, numerical questions using questionnaires that

they've acquired from the internet, the additional learning resources given to them by the coaching centres or questionnaires, tests, assignments which were shared by the class teachers. But the most common form of revision was from the questions that the NCERT textbooks have throughout the chapter in form of topic-based exercises and a question set that every chapter has at the end of the chapter. Interestingly, the final Board examinations which are held at a central level consider questions from these question sets and hence practicing them becomes a priority for students.

User expectations and suggestions

When during the interview, it was casually mentioned about the possibilities of AR, few interesting solutions came from the users.

In the current context with virtual classes going on, laboratory experiments cannot be carried out, some

users suggested creating laboratory experiments in virtual reality or augmented reality as a fun activity that students could do while at home while not having to actually do the experiment. The students were keen about this idea but when such a possibility was discussed with the teachers, they didn't support it. It sounds good an interesting at first but students are likely to lose interest. Moreover, laboratory experiments aren't only about the result and outcomes of reactions, but experiments such as acid-base titrations have to be done carefully and with precision which an AR interface would not have allowed. But creating mixtures and chemical reactions as a fun activity could be an interesting approach towards getting students interested in the subject. Interestingly, there are several games in which reaction mechanics are used such as Little Alchemy, and the very popular Minecraft, while there are mobile applications which have been made to visualise chemical reactions, such as 'BEAKER - Mix Chemicals'.

Users also discussed the availability of a huge database of resources that are accessible and shared the concern about how they will not be inclined to use another new resource unless it proves to be significantly better than any alternatives they have been currently using. Students stumble across many YouTube channels which make quality content for specific content but depending on that channel for a spectrum of topics is not ideal because in most cases the channel is unable to maintain the quality and rigour through all videos.

Some users shared the concern of finding it difficult to sometimes understand questions in the textbooks and visualise the question specifics before they get to solving it. Sometimes the diagrams are not self-explanatory and due to visibility of only one plan and having extrapolate information from the question to the diagram becomes an important step towards solving the problem.

Restated Brief

For clarity in direction of progress and focused effort, I had to redefined the brief and goals, by narrowing down context and dealing with very specific problems.

To create assistive educative content for students which helps in conceptual understanding of fundamentals and spatial visualisation in chemistry for class 12th NCERT textbook - starting with "The solid state" , considering the pandemic conditions, to allow a rich, and seamless self-studying experience.

Alternatives

Explainer video playlist with NCERT textbook as the framework for the content: It was noted that a all students irrespective of their studying patterns, or attending physical or virtual classes, were using NCERT textbook as their primary resource for concept

understanding for class 12th CBSE syllabus. The textbook, although is explained very well in terms of text, sometimes, according to users fails to connect to the real world, the lack of that application and connect in real-world context makes it difficult to retain information. All users have at some point used explainer videos for concepts and topics from the NCERT textbook, that have proven to be helpful than the textbook alone. So breaking down the content, understanding the approach that those videos take to explain the concepts and using the insights to create a playlist for all topics that are covered in the NCERT textbook would be one way to tackle the problem. More specifically its targeting the 'information contact' phase to help users learn better. By testing it with a user group, iterations to the content can be made to better align it to users affinity towards learning better. The goal of this specific design intervention would be to allow people to not depend on textbook to learn topics, the primary persona here would be users who prefer be

taught and explained to, students who prefer audio-visual format of information consumption than reading text.

This comes with certain disadvantages, the persona here is very specific. Although audio-visual information consumption could be helpful for one type of student, another might have better information retention through reading; this design intervention would not prove to be helpful for such people. The solution would not be inclusive and hence it wasn't right to go in this direction.

Creating visualisation for NCERT textbook questions: several students shared the concern of wanting visualisations for questions because they do not come with diagrams. A 3D visualisations which could be interacted with, for all questions which could use that type of content would help them bring the question's specificities to a real world context and hence understand the question better and perhaps pave path towards answering the questions quicker. The blended learning approach could also help in better engagement

for students who do not try to solve the questions given in the textbook which are very important for final year board examinations that are take questions directly from these question sets. Such an approach might help all students to understand questions in an easier way but most importantly for the students who aren't interested in solving the questions. Although the engagement factor could help students, teachers weren't supportive of a design intervention like this because they believed that the questions are designed in a manner which needs the students to visualise the questions which validates the student's understanding of the concept. The teacher termed this method as "spoonfeeding", which could hinder a students understanding of the concept. This solution could still be considered as a a step towards creating assistive content for student who struggle to understand questions.

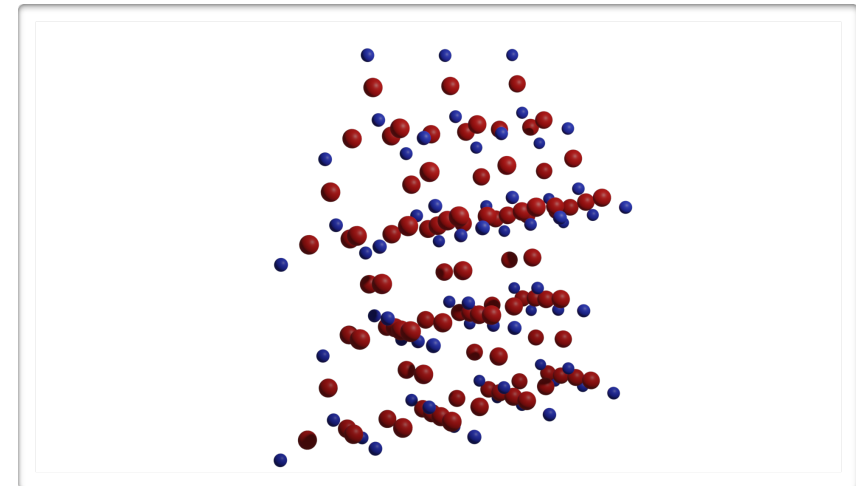
Summary notes: some teachers would distribute revision notes for certain topics from specific chapters.

A condensed set of pointers and questions which are help in revising the the knowledge and testing the conceptual understanding. The students like the resource material to refer to after going through the chapter as a recap. But if the approach is broken down, understood and applied to all topics and chapters, it could help as a key resource for students to revise the chapters from prior to evaluations.

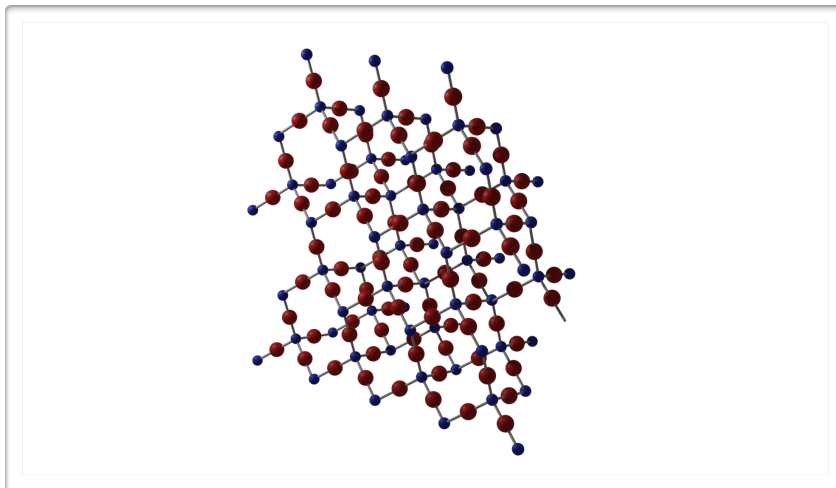
The goal of this design intervention would not be to be an alternative for the chapters but rather an additional resource that students could use to recap the information. This specifically targets information retention phase in the process of learning. If tested out with user groups, and proven to be helpful, such a resource can be made part of the curriculum so that students are able to retain information better.

Better evaluation criteria: Many students shared the concern about the way the system conducts examinations to test a student's knowledge. Working on

the evaluation criteria to understand the lacking points with respect to the users and then making a better framework 'information application' phase could be a good way to solve thr problem. Several applications are trying it currently in interesting ways such as using gamification to engage users better with the content and disguise tests as games which use positive and negative reinforcements as nudges which allows users to apply their knowledge.

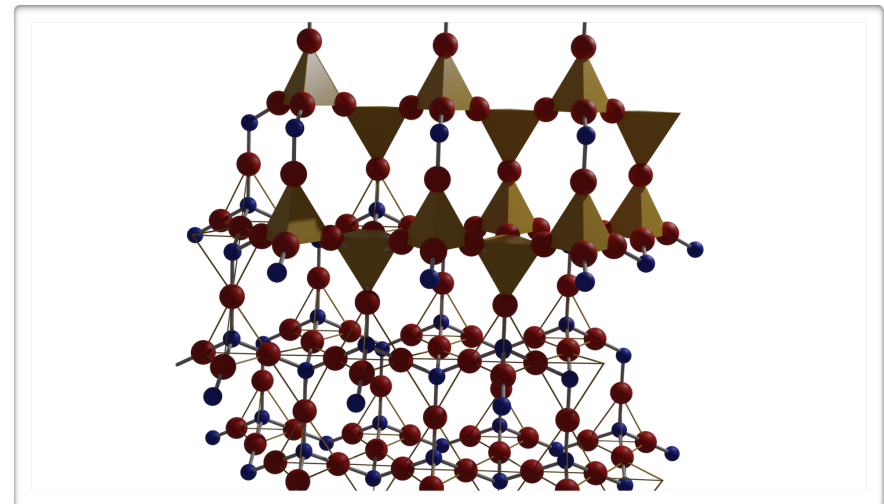


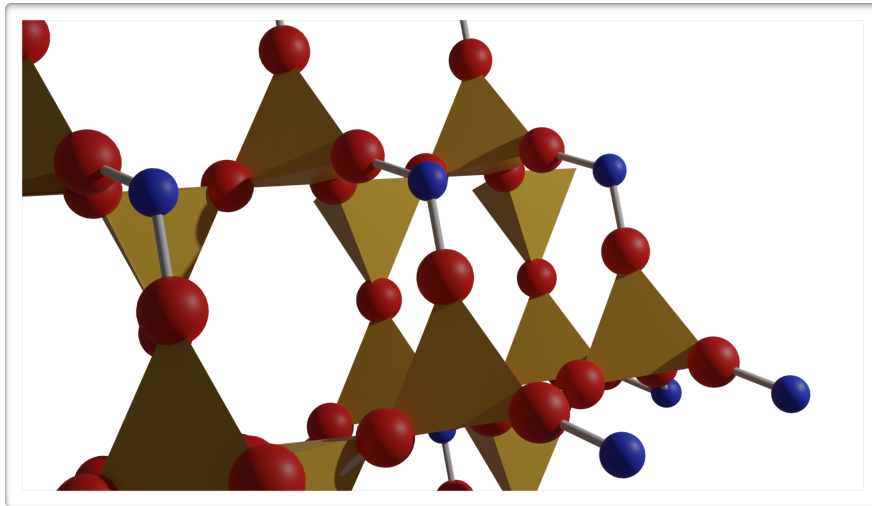
In real world context atomic bonds don't exist, but, without showing the bonds, the relative distance between atoms and the planes of individual atoms was not clear to the students even with a 3D interactive model. The bonds are important in understanding the relation between different atoms and to understand the valency of the individual atoms in the model.



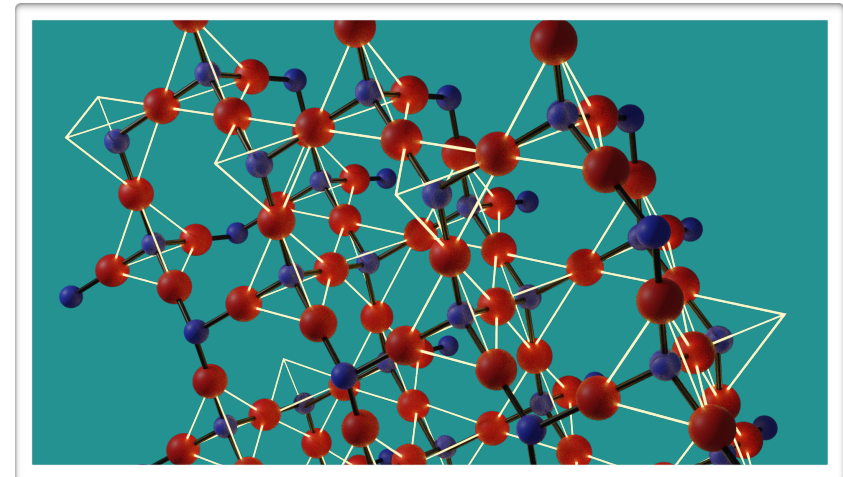
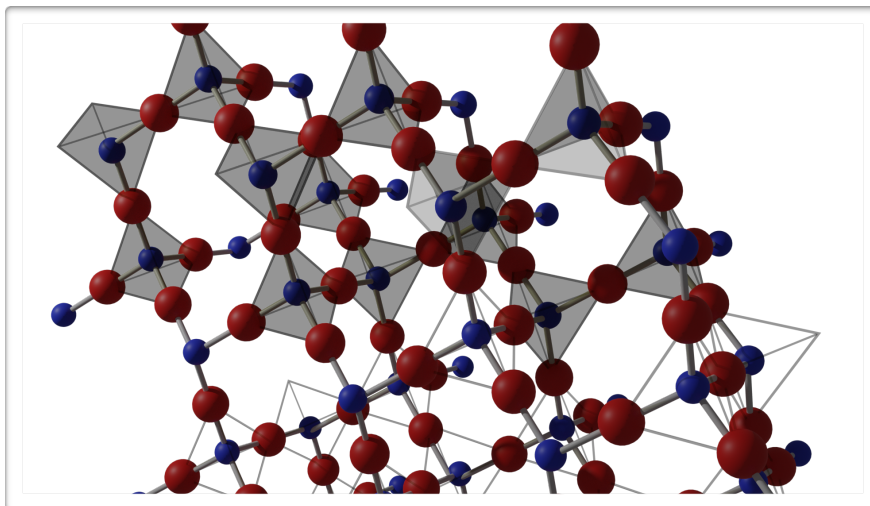
When all the bonds are shown, the model became a bit overwhelming with information to understand the the structure, although the relationship of the atoms became more evident in this design.

Another issue with this design was the bravais lattice structure wasn't clear and could not be isolated.

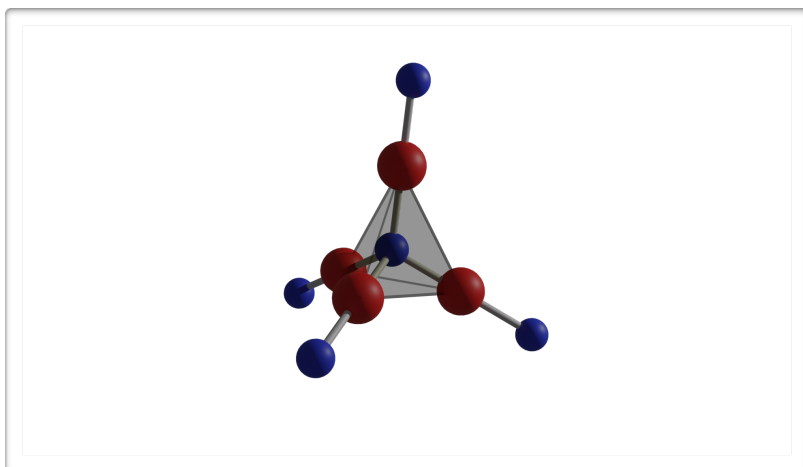




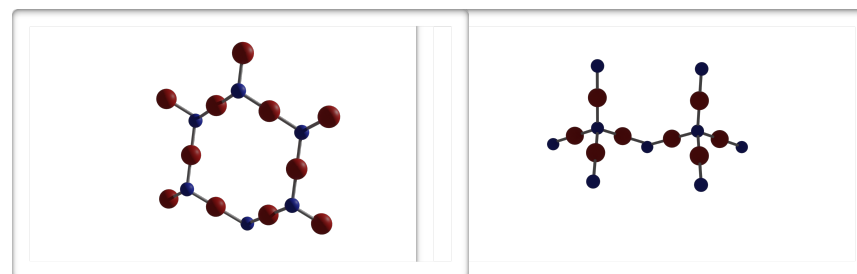
Superimposed the structure of the bravais lattice along with the molecular structure and the bond lines, but since it was a tetrahedral shape, the silicon atom was getting hidden in inside the structure. Hence I tried a transparent void structure and the wireframe void structure separately and together, but that led to slight confusion due to multiple representations.



Instead of trying different solid/ wireframe structure to show the bravais lattice, tried a lit-up structure to represent the tetrahedral structure, although the model became better representative, it caused issues when the model was viewed on the phone due to lack of contrast on the page and the labelling was difficult for a complex structure like this especially with too many lines.

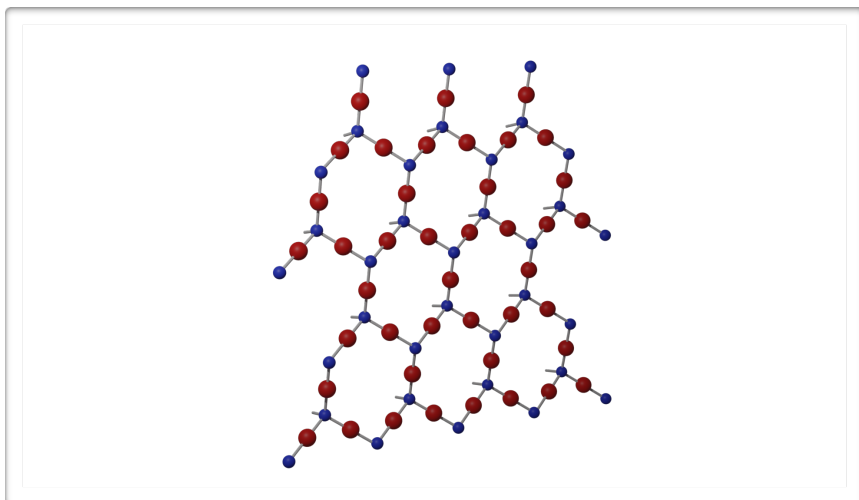


To simplify the representation, I started with the basic lattice structure. Along with the bravais lattice structure. Although it was a cleaner representation, the larger context was missing 3D model and students did not feel there was a connection between the 3D model and diagram in the textbook. Hence the scope was increased to give a larger point of view of the structure.



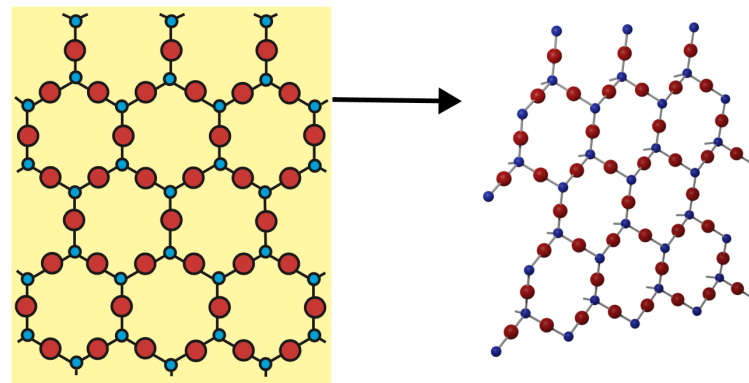
Two separate variations were tried, simple but representative, gradually increasing the complexity gave a better understanding of the structure and the final

version which was chosen was the replica of the structure from the textbook due to one major reason that the students were able to relate the model to the diagram better.



This still lacked context for multiple layers and design was not enough for the students to extrapolate to the actual 3D structure of the molecular structure.

3D representation of the image with the valency of silicon atoms(blue circle) clearly shown. students are able to relate the model to the diagram.

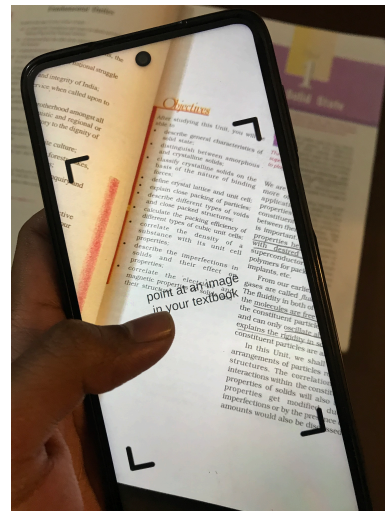


Chosen Concept

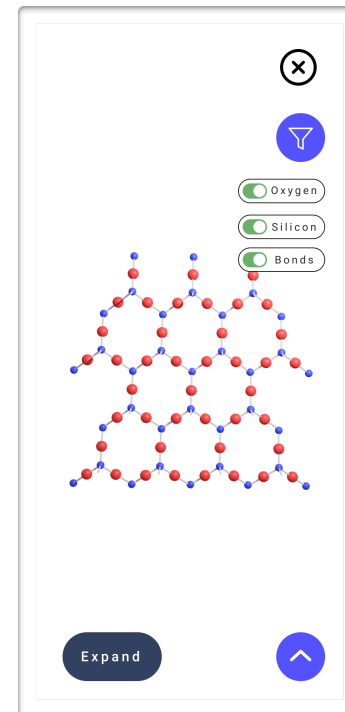
A mobile app for visualising diagrams and images in NCERT textbook, in real world context using AR which can be used to cross refer to other helpful resources that users are already using but by preserving the flow of the learning process. The solution uses blended learning principles to target the 'information contact' phase. Students can point at images in the NCERT textbook which opens an interactive 3D visualisation of the diagram, along with useful additional information which helps students to gain interest in the area and understand the topics in depth, the holistic approach aims to nudge students to want to learn more about the topic rather than restrict them without distracting with irrelevant information; the students also don't have to spend time surfing the internet for resources because the content in the app is curated specifically such that it helps the students in an already familiar way by giving

information using 3 different approaches- experimentation/ exploration, reading, and instructional content which are in form of lectures or explainer videos.

The application opens with the camera that the student can use to scan any image in the textbook.

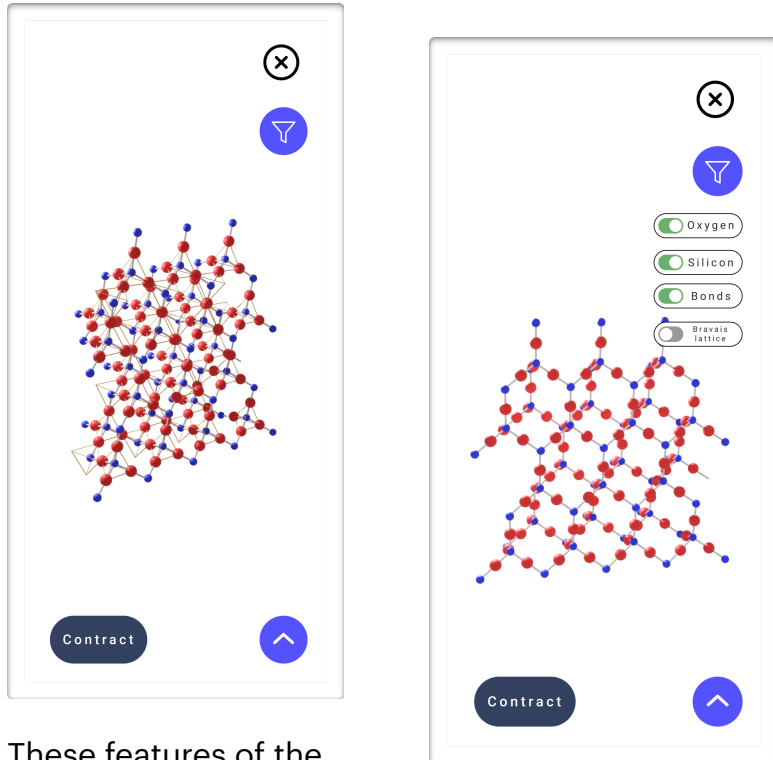


The quartz image opens up a visualisation which one can interact with to see the structure from every angle.

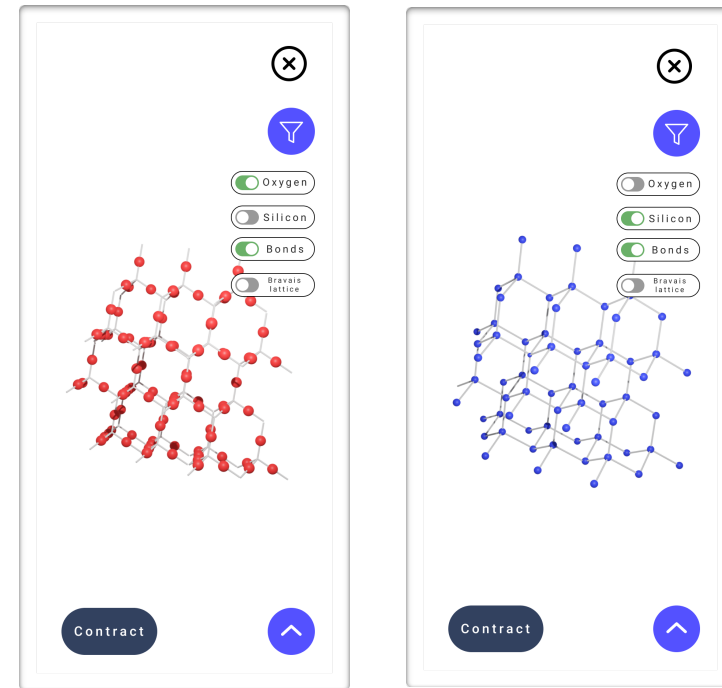


The first model that's shown is the replica of the image with only one layer of the structure. But to understand the entire structure, the student can click on the 'Expand' button which will expand the 3D model to multiple layers of the structure so the student can understand the relationship between the atoms,

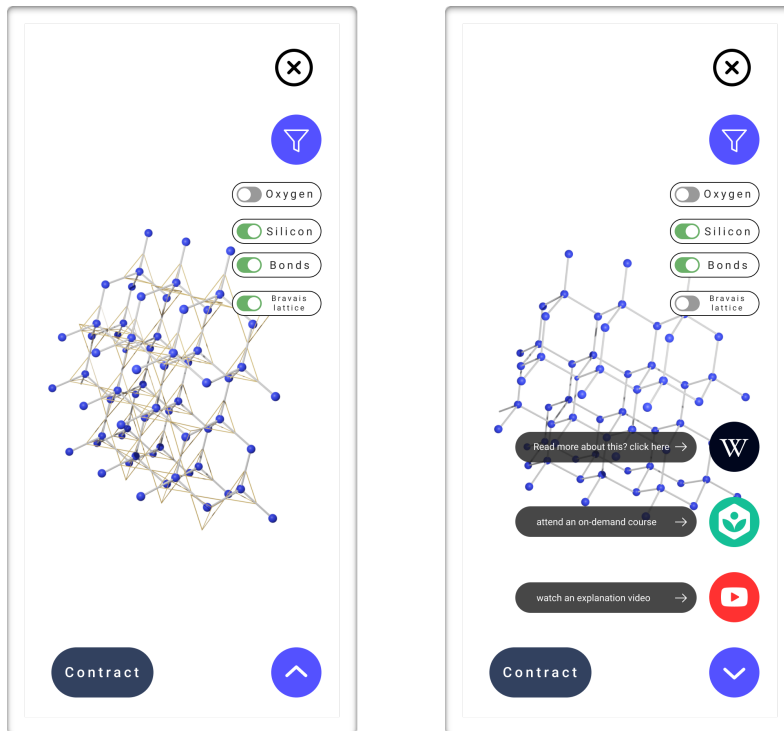
valencies and bonds and the bravais structure that's formed in the crystal.



These features of the molecular structure are available as toggle buttons to switch the visualisation ON/OFF according to the user's requirement.



eg. in the first image, all the oxygen atoms are visible
In the second image, only the silicon atoms are visible but it gives an idea about the tetrahedral shape that's formed due to the valency of silicon atoms (4).



The first image here shows the bravais lattice structure including the silicon atom at the centre of every tetrahedron.

The app also provides additional learning material which includes one reading content, one instructional explainer video and an on-demand lecture from

khanacademy. The second image shows how the options can be accessed.

The solution in itself is not an isolated product and hence does not try to be an alternative to any existing resource but rather an assistive resource and hence, the solution adoption is also smoother.

A framework has been planned so that the content creation and curation process can be open-sourced without much friction. The process of uploading the the content is very simple and laid out in an intuitive flow which can be hosted on a website for developers and designers to contribute to.

The framework is as follows:

- Explore and experiment -
 - 3D graphic visualisation of the image marker. In a 3D model format (.obj, .fbx)
 - Short description about the visualisation (30 characters max)

- Reading - Relevant Wikipedia page link
- Instructional -
 - Relevant course link from khan academy
 - YouTube link which explains the concept

Findings

Since nothing on the already printed book could be changed to give nudges for the users to want to use the app on diagrams, they needed to be told explicitly that the 3D visualisation of the diagram was available on the mobile app. The experience was fairly seamless considering the first screen they see is the AR camera which is used to detect the image markers. The digital graphic was part of the real world which made the users not feel disconnected from the textbook. Users were inquisitive enough to click the buttons. Users shared the concern of having to switch between apps due to the API call that the mobile app does. Users at first did not realise that the 3D graphic could be interacted with.

When users clicked on the wikipedia link, they'd visit subsequent links which were in that Wikipedia page.

User experience of AR is something that a lot of users were not familiar with; contrary to traditional mobile apps which use swipe and pinch gestures, AR allows people to move around and explore rather than use touch gestures because AR content is supposed to replicate real world behaviour, hence some users pinched and swiped to zoom and pan the graphic respectively.

The users did not understand the context of the 3 links provided, curiosity made them click the buttons, not a need. The 'need' could be better communicated with users to give context to users by giving UI nudges to users.

The book to App flow is not obvious as discussed earlier, but the App to book flow was fairly obvious to users. They were able to identify that the app is being used WITH the book. Users don't understand jargons, using a nudge like "Detect image marker" was confusing

to the user, hence even though they figured that the app is not supposed to be used in isolation, they didn't understand the Hint text. The text was later changed.

Users conveyed that the app was clean and fairly easy to use because it was not filled with many features but focuses on bridging the gap between the real world resources and digital resources. Some users who showed keen interest in reading up more about the the topic wanted to keep track of the visited links and perhaps even bookmark some of the online resources.

The second run of evaluation was done after making some user experience changes, adding better hints and nudges and adding the swipe and pinch interaction that the users found more intuitive.

It will be interesting to know how frequently the app is used, especially when users are not in a 'control group' context. My initial hypothesis was that the app would have been used limited number of times only during the 'information contact' phase but with additional bookmark

functionality that are attached to image markers, the app could be used repeatedly during both 'information contact' and 'revision' phases. It will also be interesting to know how the use of the application reflects in their 'information retention' and 'application phases' like during class exercises and semester examinations

Discussion

The app was successful to bridge the gap between physical textbooks and digital resources for an enhanced blended learning experience during self-study, compared the existing ways that the users adopted to deal with the problem. It is difficult to quantify the results and how well the goals were achieved. Although, the students did claim that the app allowed instant access to an interactive-engaging learning experience without any hassle of surfing the web.

During the course of the project, I realised that the problem that the specific problem that I have been focusing on is not something the user realises that he/she has been facing. In such problems where one is trying to enhance the experience, giving the users an active feedback of solving the problem is also not easy. It is debatable if “invisible design is good design or not”. That being said the solution is positioned as a good point for transition into creating AR content. A solution like this does not have dependancy on the textbook prints to change immediately. With the existing prints, the AR content was made accessible and hence allowing developers to make content for the use case without having to wait for the publishers to adopt the technology. The frequency of the problem is less, and considering the functionalities that the application currently offers, I would argue that the solution is fairly nascent. This solution can act as stepping stones for a larger potential where content development is easier and widespread,

the devices capable of viewing AR is cheaper and more accessible, and perhaps the possibilities become endless and exciting for a future with smart-glasses or affordable headsets becoming the norm.

The hypothesised framework can be used to make an open-sourced platform which allows developers and designers to create, curate and host the content.

Conclusion

There are several learning resources, both physical and digital and there are several pedagogies which help students learn better. A blended learning approach which uses experimenting, exploration, instructional and reading learning material to help build interest in the topics and also to seamlessly be able to relate NCERT textbook content with digital resources was found to be useful for students in a self learning environment.

Important resources are curated and hosted on the mobile app with intuitive interactions which helped

students to not break the flow in studying which occurred earlier while they constantly switched between notebooks, textbooks, online learning resources.

The resources although was given upfront for people who want to access them quickly does not stop them from following up on the information and keeps up the spirit of learning.

References

1.A mix of in-person and online learning may boost student performance, reduce anxiety. *ScienceDaily*, 2020. <https://www.sciencedaily.com/releases/2018/06/180620174609.htm>.

7.Blended learning: The integration of traditional learning and eLearning - IEEE Conference Publication. *ieeexplore.ieee.org*, 2020. <https://ieeexplore.ieee.org/document/6110953>.

4.Ivanova, G., Aliev, Y. and Ivanov, A. Augmented Reality Textbook for Future Blended Education. *Semanticscholar.org*, 2020. <https://www.semanticscholar.org/paper/Augmented-Reality-Textbook-for-Future-Blended-Ivanova-Aliev/f74f080d578e377d518efb30c83e9cd93b5e8af2>.

11.Mueller, P. and Oppenheimer, D. The Pen Is Mightier Than the Keyboard. *Psychological Science* 25, 6 (2014), 1159-1168.

6.Muradkhanli, L. Blended learning: The integration of traditional learning and eLearning. *Semanticscholar.org*, 2020. <https://www.semanticscholar.org/paper/Blended-learning%3A-The-integration-of-traditional-Muradkhanli/a0e6e59c7359bd81d281eb0b5843bc6f602e274e#citing-papers>.

3.Saliba, G. and Rankine, L. Blended learning. *Semanticscholar.org*, 2020. <https://www.semanticscholar.org/paper/Blended-learning-Saliba-Rankine/3646de49ef61d3bfb4325564492305b2dcb79133#paper-header>.

10.Smoker, T., Murphy, C. and Rockwell, A. Comparing Memory for Handwriting versus Typing. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 53, 22 (2009), 1744-1747.

8.Theodorou, P., Kydonakis, P., Botzori, M. and Skanavis, C. 2020. <https://www.researchgate.net/>

publication/

326208201_AUGMENTED_REALITY_PROVES_TO_BE_A_BREAKTHROUGH_IN_ENVIRONMENTAL_EDUCATION.

2.Today, E. 5 rising innovations making education a fun experience. *India Today*, 2020. <https://www.indiatoday.in/education-today/featurephilia/story/5-rising-innovations-making-education-a-fun-experience-1594948-2019-09-03>.

5.Wang, Y. Exploring the effectiveness of integrating augmented reality-based materials to support writing activities. *Semanticscholar.org*, 2020. <https://www.semanticscholar.org/paper/Exploring-the-effectiveness-of-integrating-to-Wang/b4b9d743abd7b135f0b5832a6fe111ef73e5f619>.

9.Weaver, B. and Nilson, L. Laptops in class: What are they good for? What can you do with them?. *New Directions for Teaching and Learning* 2005, 101 (2005), 3-13.