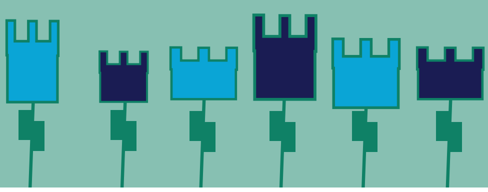
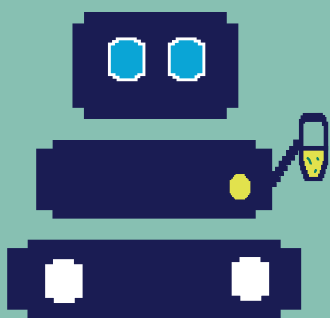
APSCE CTE-STEM

6th APSCE International Conference on Computational Thinking and STEM Education 2022

Conference Proceedings
15th - 17th June 2022





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CTE-STEM 2022 | Proceedings of Sixth APSCE International Conference on Computational Thinking and STEM Education 2022

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Keywords

Computational Thinking, STEM (Science, Technology, Engineering, Mathematics), Education, Games, Teachers, Programming, Reviews, Concepts

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Welcome from the APSCE SIG on Computational Thinking Education and STEM Education

Preface

The 6th APSCE International Conference on Computational Thinking and STEM Education 2022 (CTE-STEM 2022) is organized by the Asia-Pacific Society for Computers in Education (APSCE) and hosted by the Leiden-Delft-Erasmus Centre for Education and Learning (LDE-CEL). CTE-STEM 2022 is hosted for the first time in Europe by the Delft University of Technology (TU Delft), Delft, the Netherlands. This conference continues from the success of the previous four international Computational Thinking conferences organized by the National Institute of Education and Nanyang Technological University (NIE/NTU). This conference invites CT as well as STEM researchers and practitioners to share their findings, processes, and outcomes in the context of computing education or computational thinking.

As research shows the topic of Computational Thinking needs further clarification, embedding, practices. CT links to many highly relevant and important topics as programming education, data science and Artificial Intelligence applied in different educational and professional settings. Understanding the underlying algorithms of data and machine learning driven solutions, working on structured problem solving and scalability as also using big data and data sciences in diverse domains are key skills for future generations. To understand what skills future generations need and how we can train them to learn and apply these skills for solving problems relevant for society are of highest importance. This applies to issues of using computational tools in engineering, social sciences, management, and many other domains.

CTE-STEM 2022 is a forum for worldwide sharing of ideas as well as dissemination of findings and outcomes on the implementation of computational thinking and STEM development. The conference comprises keynote speeches, workshops, and paper presentations and therefore brings together researchers, innovators, and professionals. The International Teachers Forum is organized for teaching practitioners to share their practices in teaching Computational Thinking, Computing and STEM in the classroom. We believe bringing all these would create enriching experiences for educators and researchers to share, learn and innovate approaches to learning through Computational Thinking and STEM education. This year, teachers can participate in Lightning Talks to share ideas about teaching and learning CT.

Topics addressed in this volume

There are 27 papers in total, with 4 teacher forum manuscripts and 23 scientific contributions with 4 short submissions and 19 full research papers. 6 main themes are clustered in these proceedings.

Using and developing games and gamification approaches for CT and STEM education to embed learning in simplified or authentic contexts which enables focused learning and easy transfer as also fosters high motivation for learners (Chapter 1: Games in CT). Moreover, integrating and combining STEM education and computational tooling are the focus of the subsequent chapter (Chapter 2: STEM Meets CT)

What are the challenges of educators for teaching and learning with computational tools and how can we embed CT in Schools and link it to the core subjects (Chapter 3: Teachers and CT, Chapter 4: CT and Programming in Schools)?

Analyzing the effectiveness and understanding where the field stands is addressed in Chapter 5: Concepts and Reviews. Furthermore, assessing CT is at the core of building a skills model and measuring growth and skillfulness in a continuous, reliable, and valid way. A variety of models have been developed and are discussed in Chapter 6: Design, Assessment and Evaluation of CT in Formal and Non-formal Settings.

We are very happy to have 4 keynote speakers for the conference including **Dr. Georgi Dimitrov** head of unit Digital Education, European commission talking about the role of digital skills in future Europe, **Jens Mönig** from SAP talking about his innovations in programming and SNAP! **Prof. Matti Tedre** from the University of Eastern Finland talking about the role of machine learning and our understanding of the digital world and **Prof. Maarten de Laat** from the Centre for Change and Complexity in Learning, University of South Australia on his work on hybrid AI-human problem solving in the classroom.

On behalf of APSCE and the Conference Organizing Committee, we would like to express our gratitude to all speakers as well as paper presenters for their contribution to the success of CTE-STEM 2022.

We sincerely hope everyone enjoys and gets inspired from CTE-STEM 2022.

With Best Wishes,

Professor Marcus Specht
Conference Chair, CTE-STEM 2022
Delft University of Technology (TU Delft), the Netherland

Dr. Christian Glahn
Conference Co-Chair, CTE-STEM 2022
Zurich University of Applied Sciences (ZHAW), Switzerland

Dr. Nardie Fanchamps
Conference Co-Chair, CTE-STEM 2022
Open University, the Netherlands

MSc. Xiaoling Zhang
Conference Co-Chair, CTE-STEM 2022
Delft University of Technology (TU Delft), the Netherland

Keynotes

KEYNOTE TOPIC: DIGITAL SKILLS

GEORGI DIMITROV *HEAD OF UNIT DIGITAL EDUCATION, EUROPEAN COMMISSION, DIRECTORATE GENERAL EDUCATION AND CULTURE*

ABOUT GEORGI DIMITROV

Georgi Dimitrov is responsible for the Digital Education unit in the European Commission, Directorate General for Education and Culture. He joined the European Commission in 2008 and was first involved in various roles in setting up the European Institute of Innovation and Technology (EIT). He then helped to develop and launch HEInnovate, an initiative by the European Commission and the OECD aimed at supporting universities to become more entrepreneurial. He led the development of the first Digital Education Action Plan adopted in January 2018 and also of the new Digital Education Action Plan 2021-2027 that was adopted in September 2020. Before joining the Commission, Georgi worked for a leading multinational telecommunication company and in a software start-up in Germany. Georgi studied at the University of Bonn (M.A.), the University of Erlangen-Nürnberg (PhD) and the Open University UK (MBA in Technology Management).

KEYNOTE TITLE: PROGRAMMING AS A MEDIUM

JENS MÖNIG *RESEARCHER AT SYSTEMS, APPLICATIONS & PRODUCTS IN DATA PROCESSING (SAP)*

KEYNOTE ABSTRACT:

Computers, apps and programming languages are still commonly referred to as tools that help us accomplish tasks by amplifying particular skills such as calculating and remembering. Yet as computers and their apps have evolved into channels of communication among us and our appliances, programming languages are becoming a medium letting us interface with the world and express our ideas. I will present the Snap! visual programming language and discuss its design principles from the perspective of encouraging learners to approach programming not just as a tool for production but as a medium for exploration.

Snap! Is a Scratch-like programming language that treats code-blocks as first class citizens instead of confining them to an editing modality. Embracing nested data structures and higher order functions Snap! let learners create arbitrary control structures and even custom programming languages with just blocks. Snap! has been developed for UC Berkeley's introductory computer science course named "The Beauty and Joy of Computing".

ABOUT JENS MÖNIG

Jens Mönig is a researcher at SAP and makes interactive programming environments. He is fanatical about visual coding blocks. Jens is the architect and lead programmer, together with Brian Harvey, of UC Berkeley's "Snap! Build Your Own Blocks" programming language, used in the introductory "Beauty and Joy of Computing" curriculum. Previously Jens has worked under Alan Kay on the GP programming language together with John Maloney and Yoshiki Ohshima, helped develop Scratch for the MIT Media Lab and written enterprise software at MioSoft. Jens is a fully qualified lawyer in Germany and has been an attorney, corporate counsel and lecturer for many years before rediscovering his love for programming through Scratch and Squeak. For leisure Jens likes guitar picking and strumming his mandolin.

KEYNOTE TITLE: FROM RULE-DRIVEN TO DATA-DRIVEN COMPUTING EDUCATION IN K-12

MATTI TEDRE *PROFESSOR AT SCHOOL OF COMPUTING, UNIVERSITY OF EASTERN FINLAND*

KEYNOTE ABSTRACT:

The popular approaches to K-12 computing education today are based on analyzing and describing problems in a way that enables their solutions to be formulated as series of computational steps. Rule-based "classical" programming paradigms have come to dominate K-12 programming education, with some of their relevant key concepts and skills described under the title computational thinking (CT).

In the 2000s a number of data-driven technologies, most prominently machine learning (ML), have become commonplace in apps, tools, and services. Understanding some key ideas related to ML is becoming crucial for understanding how many key elements of our digital environment work. The power of traditional, rule-based computational thinking (CT1.0) to explain ML-driven systems is, however, limited, and new approaches to computing education are needed. A body of literature on how to teach some principles of ML and data-driven computing in K-12 education is emerging, but that body of literature relies on a set of concepts and skills very different from traditional CT1.0. This talk outlines the key changes in the conceptual landscape, educational practice, and technology for ML-enhanced CT (CT2.0) and compares it to the dominant computing education paradigm.

KEYNOTE TITLE: AI IN THE CLASSROOM – STUDENTS COLLABORATING WITH AI TO SOLVE COMPLEX PROBLEMS

MAARTEN DE LAAT *PROFESSOR AT ENTRE FOR CHANGE AND COMPLEXITY IN LEARNING, UNIVERSITY OF SOUTH AUSTRALIA*

KEYNOTE ABSTRACT:

Applications of artificial intelligence (AI) are set to transform society, including how people work and learn. This growing ubiquity of AI in society poses significant challenges for educational systems: what will citizens in the 21st century need to know about, and do with AI? Currently there is very little research and experience on how schools and teachers adopt AI into the classroom and how our students work and learn together with AI.

In this keynote I will present some current work at our Centre for Change and Complexity in Learning to help address this issue. I will showcase some initiatives where students will work together with AI to solve complex problems. Our mission is to offer an AI learning environment where students can take ownership over AI, experiment with it and develop AI to follow their imagination. The environment is a social space for exploration and critical evaluation, it's safe and inspiring. This is how we want students to treat AI. Rather than that AI is done to you, students should be able to play with AI, and through play, shape it so that AI starts to work for you and help you to go beyond your own capability.

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Computational Thinking, History and Non-formal Learning-A Well-crafted Blend!

Irene SILVEIRA ALMEIDA*, Ajita DESHMUKH

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ABSTRACT

Computational thinking (CT) is one of the core skills required for 21st century education. As we transition from STEM to STEAM by incorporating Art, it becomes imperative to see the application of CT in Humanities. The subskills of CT can be integrated in both -formal and informal teaching-learning practices of Humanities. This paper studies guided learning practices by the instructors that enable application of CT subskills of decomposition, pattern recognition, and abstraction by students of Post Graduate History Course. This qualitative study explores development of CT skills through Historical thinking using a specifically created WhatsApp group as a communication channel for the purpose of fostering and guiding Computational Thinking Skills. This study further explores how informal learning through WhatsApp communication aids in the development of CT skills of abstraction, pattern recognition in the process of discussions and Historical thinking. The qualitative analysis of WhatsApp posts illustrate how the CT skills are nurtured and applied by students without any formal knowledge of the same. Higher frequency of learner-to-learner messaging mirrors watercooler and corridor communication and dramatically moves learning away from solely instructor-learner directional communication chains specific to traditional learning spaces. This corroborates the importance of free and informal learning space in the development of CT skills in students beyond the domain boundaries of STEM.

KEYWORDS

Computational Thinking, CT in Humanities, non-formal learning, WhatsApp groups, SMS language.

1. INTRODUCTION

In today's technological world, computational thinking comes across as a concept of increasing importance. Given the need in contemporary societies for citizens who can understand, control and work with technology, this field acquires great relevance. Computational thinking has been making inroads into education and is being advocated at diverse schooling levels. Although initially linked to the domain of computer sciences, computational thinking has deftly crossed over to other disciplines. Jeannette Wing (2006) contributed to the popularization of computational thinking and viewed it as a fundamental skill on par with reading, writing and arithmetic. Computational thinking involves thought processes that are used to solve complex problems. The problem-solving skill is considered a universal skill in the 21st century and has supplanted the focus on rote skills. In this context, it is recommended that students be exposed to it as they engage with core disciplines in their educational trajectory. However, computational thinking and its sub skills have been assuredly less prominent in humanities than in traditional STEM domains. Computational thinking has rich cross-curricular potential and its appropriation in STEAM domains attains particular relevance in this respect (Merino-Armero, J.M, 2022). Recent research in computational thinking integration into language classes has shown that narrative content demanding interpretation lends itself well to computational thinking activity (de Paula, 2017). Researchers and practitioners are increasingly working towards integrating computational thinking into curriculum in a broad spectrum of disciplines spanning graphic art, languages, humanities, astronomy, history, geology, biology etc. (Settle, 2012, Czerkawski, 2015). Studying History involves familiarizing and dealing with large amounts of information. Learning of History is based on Historical Thinking that typically involves multiple CT skills. Unfortunately, students in a History class often remain passive listeners and consumers of content related to historical figures, events and chronology leading to rote memorization. Introducing content necessitating computational thinking into History is challenging and calls for innovative pedagogical practices such as integrating informal learning into formal learning. Gunbatar (2019) lists decomposition, abstraction, algorithm design, debugging, iteration, and generalization as a set of subskills. Decomposition involves separating the problem into manageable steps. Computational thinking also calls for representing data through abstraction such as models and simulations, all of which are applicable to learning of History. Integrating computational thinking in History class necessitated modifying this approach to an active engagement with content. Widespread availability of digital texts makes it easy to obtain information. However, students often lack skills in interpreting the texts and arriving at valid conclusions. Puzzles and enigmas were used to provide a problem-solving approach to an otherwise passive acquaintance with historical events. Puzzle-solving requires information gathering, sifting through data, making intuitions, testing intuitions and making sustainable claims as a solution. Decomposition, abstraction and pattern recognition constitute vital strategies for efficient puzzle-solving. The development of CT skills as integrated in learning of History is of critical importance today since these will also effectively help students to identify fake news, critically analyze the stories circulated over social media and otherwise enable them to pick fact over fiction. These skills are the most sought-after skills in various industries and jobs of the technology-driven society, thereby preparing them to be 'industry-ready'.

2. METHODS AND PRACTICE

The present research is an attempt to blend historical narratives with computational thinking sub skills in an informal e-learning environment. Given that computational thinking is inherently a problem-solving approach, content generally taught in History class was reworked into historical narratives with inbuilt puzzles and enigmas. The implementation of the study began in December 2017 as part of the 4-month semester spent studying Representation of French History in Visual Art and Literature in Goa University, India. 11 students enrolled in the course and were part of the study. The analysis of this study involved qualitative analysis of the WhatsApp group Chat. The chat was analyzed for sentiment and content after the course. The participants were anonymized for the study by giving them codes such as HS1, HS2, HS3 and so on. This study does not study the development and/or application of CT skills as well as communication within the WhatsApp group with respect to gender. The WhatsApp group-activity that forms the basis of the project was complementary to classroom discussions and spanned the entire duration of the course. In a pre-pandemic era where teaching was primarily in offline mode and most teaching activity restricted to the four walls of the classroom; this mode of communication was chosen with the primary objective of channelising the sustained collaborative engagement of familiar chat room scenarios towards the cultivation of problem-solving skills. The familiarity and informality, any-time, seamless and cross member communication would offer a platform to boost autonomous fact finding, knowledge acquisition and problem solving leading to collaborative learning among the group. The resulting group cohesion could assist slower learners in developing computational thinking sub-skills like decomposition, abstraction and pattern recognition.

3. RESEARCH QUESTION

This explorative qualitative study is guided by the following research questions: Does Historical thinking lead to development of CT skills and vice versa? Does informal learning, especially using social media aid the development of Historical thinking and thereby CT skills? How does Historical thinking develop CT skills, especially of Pattern Recognition and Abstraction?

4. THE STUDY

A WhatsApp group of 11 students and the instructor was specifically created. The student members were given orientation of the functioning of the group prior to the enrolment in the group and were encouraged to freely use the space for class related communication. In addition to functioning as a notice board (announcements related to class venues, timings, test schedules and modalities, exam preparation etc.), the WhatsApp group was designed to function as an informal space where content related to history would be decomposed by students in a fun and competitive set-up.

To begin with, students were informally provided questions on History. Correct answers were rewarded with a thumbs up emoticon (👍). Informal positive reinforcement was then used to motivate learners to solve history-based puzzles and enigmas. At times, clues were provided and learners were gently prodded into pattern recognition by keywords and vital links in information. Students attaining 20 thumbs- ups were declared winners, leading to applause and appreciation from all. The informal ambiance was carried over in class as well: students were encouraged to interrupt, ask questions, and discuss during classes. The WhatsApp group acted as a supplement to this informal styled learning of French history and allowed for extended learning hours and freedom to engage with a wide array of sources as per individual choices. It is pertinent to note that the puzzles and enigmas were generally posted on WhatsApp prior to class discussion on the topic. Preference for a flipped classroom approach ensured higher levels of engagement and authentic problem-solving versus a passive revision/ recall. Carefully crafted questions announced puzzles and enigmas through an original format of common-place narratives. Since the narratives were laden with explicit and implicit meaning, they would often demand interpretation. Participants were thus nudged towards computational thinking as they opted to eliminate irrelevant details, search for defining patterns and work backwards towards the solution.

5. PUZZLE DESIGN

Initial questions were kept fairly straightforward and simple so as to create comfort levels and build confidence. Gradual introduction of elaborate puzzles and enigmas led to deeper reflection and use of computational thinking sub skills in the quest to type out the first correct-response post. Through trial-and-error, observation and practice, the complex puzzle-sets drove acquisition of problem-solving skills and ensured that students comprehended, interpreted and re-verbalized information to fulfil puzzle-solving norms. Earlier response styles replicated problem solving skills at a fairly basic level: students resorted to identifying key terms, searching for related information, finding the answers and posting the content verbatim. Such learning patterns were slowly discouraged. Students were steadily weaned away from copy-pasting content and prodded into drawing their own conclusions by such humorous posts: "*But this is the last time Wikipedia scores… Next time we want you answering/ It wasn't Wikipedia this time* 😑*/ Miss Wikipedia not a member of this group*". Instructors emphasized on development of complex problem-solving skills and crafted question posts accordingly. Simplistic answers were disqualified and interpretation was necessitated, valued and incentivised. The basic guiding principle being computational thinking skills through historical narratives, the question posts were appropriately designed to lead participants toward targeted subskills like pattern recognition, decomposition and abstraction. Reproduced below are a few examples of question posts.

6. DISCUSSION OF WHATSAPP CHATS

The WhatsApp posts reproduced below are verbatim. No corrections in spelling or grammar have been made. Emoticons have been retained.

6.1. Pattern Recognition

In one of the initial puzzle-sets, major historical events from the 12th to 14th centuries were dealt through decomposition. Question posts introduced dramatic events surrounding key historical figures of the time. Framing of questions around a central thematic thread ensured that responses could be obtained through pattern recognition. Acquaintance with historical facts, sifting through extensive information, and deciphering the narratives were key steps in puzzle-solving. In the example below, the pattern is constructed around KING and later extends to QUEEN and /PRINCE. Posterior puzzles would build on QUEEN and PRINCE; supplementary unnumbered question posts on QUEEN and PRINCE conclude the set and function as a transition toward the subsequent Puzzle set.

"1. Which king is a Saint? 2. And which King's envoy slapped the Pope? 3. Which king owed his crown to a teenage girl? 4. Which king dealt with his enemy by making him son-in-law? 5. Which king divorced his queen because she bore only daughters?AND what happened subsequently to the ex-queen?And... who is the black/dark prince?"

As seen from the student reply posts below, multiple students have attempted to answer in random order. Considering this discussion, they were required to look up on the Internet (out-of-class), and correctly match historical figures to each of the patterns. Patterns were built around motifs of major players on the French historical scene in the medieval period- King, Queen, Pope, Prince, Saint, Commoner/peasant girl. The motifs were augmented with action–based relations between the players: King becoming Saint, King defying Pope, Commoner girl assisting King, King entering into marriage alliance with enemy King, King divorcing Queen in the absence of a male heir, Actions of the defiant Queen, Actions of a Dark enemy Prince. Recognising the pattern constituted the first part of the challenge, searching for details that correspond to the patterns and ignoring irrelevant details made up the second part. This challenge was based on pattern-recognition and understanding, and did not call for memorizing and recall. Content required for puzzle solving had not been dealt with earlier, but was easily reachable on the Internet through skilful use of keywords in search engines. Attentive reading and drawing links between patterns were required to obtain correct answers. Answers were obtained not by chance but through careful thought and understanding. Student posts provide precise reasons for the association of patterns with specific historical players, thus proving that they have successfully confronted both challenges.

"Edward IV also known as Edward of Woodstock is the black prince" (HS1).

"Charles VI makes Henry V his son-in-law" (HS3)

"Louis IX of France" (HS9)

"1- his compassion for the poor and suffering people and other acts of charity.

2.Known as saint Louis"(HS9)

"The Black Prince's Ruby was given to Edward III, by Peter of Castile, as an appreciation for his services in regaining the throne.

It is one of the oldest parts of the Crown Jewels"(HS5)

Only 3 of the 7 puzzles (42%) were correctly attempted, the remaining were ultimately explained in following class sessions. To improve on the students' ability to recognise patterns, a subsequent puzzle highlighted similarities and differences between protagonists. The pattern in the puzzle below is centred on WOMAN with its different categories- LADY, QUEEN, PRINCESS, NOBLEWOMAN, PEOPLE'S WARRIOR, MOTHER, WIFE… The puzzle draws on similarities (Qt 4- similar to Charles Martel, similar achievements/ Qts 1 & 3 relation to multiple (2-3) French Kings/ Qts 2&5- unexpected people attaining the crown, throne). The puzzle equally capitalizes on differences to induce pattern-recognition. (Queen to 2 French Kings v/s mother to 3 French kings, princess marrying a king and becoming queen v/s a mother marrying her son to a princess and making him king, Charles Martel associated with a hammer v/s Jeanne Hachette associated with an axe due to martial exploits). Similarities and differences are a combined force that drive the narratives and are conducive to the interpretation that is key to the WhatsApp puzzle-solving. Pattern-recognition thus yields result in problem resolution and not only later helps in recall during exam preparation but more importantly, finds application in Humanities Education.

"1. Which French lady was queen to 2 French Kings? 2. Which French Princess later became Queen of.... France? 3. Which Italian noblewoman became mother to 3 French kings? 4. Which Frenchwoman earned a nickname similar to Charles Martel for... similar achievements? 5. Which French noblewoman managed to put her son on the French throne?"

This puzzle-set registered a higher success rate than the previous one (50%), and an additional question (below in bold) was instantly thrown in to intensify the challenge. The chat that ensued shows that 2 puzzles were promptly answered, and another 2 led to sustained attempts until the correct answer was finally obtained. The attempts showcase claims based on pattern recognition and historical reasoning as students try to substantiate their claims. Debunking incorrect claims and arriving at the correct answer involved a further engagement with similarities and differences, thus reinforcing pattern recognition skills. (Mary is associated with Scotland, not France; Joana of Flanders is a noblewoman, although fiery, not connected to a weapon similar to Charles' hammar; in contrast to Mary of Scotland, Margaret of Valois is a French born Princess who marries a man who ultimately becomes King of France)

"3.Catherine de' Medici" (HS3)

"1. Eleanor of Aquitaine" (HS7)

"2. Marie Antoinette" (HS6)

"3. Catherine de Medici"(HS3)

"1. Anne of Brittany" (HS7)

"5. Judith of Brittany"(HS3)

"5. Judith of Bavaria" (HS7)

"2. Claude of France" (HS10)

"4. Not sure but is it Joan of Arc? She was nicknamed the maid of Orleans

For her role during the Lancastrian phase of the hundred years war" (HS8)

"No. Similar to Charles MARTEL"

" Catherine de Medici 1. Anne of Britanny 2. Claude de France".

"But there is one more answer. Anyone? ???"

"Judith incorrect. Keep trying for 4. & 5."

"2. Emma of France" (HS3)

"Now I feel it's Marie Thérèse of France".(HS3)

"No".

"2. Adelaide of Aquitaine" (HS3)

"No"

"Mary, Queen of Scots? She married the dauphin of France-Francis II. Later, In 1559, he ascended the throne as king so she would be queen Ans 2" (HS7)

"But was she a french princess to begin with?"

"I don't think so. So wouldn't qualify"(HS3)

"She was Scottish. But wouldn't marrying the Dauphin make her princess?" (HS3)

"4. There is a Jeanne Hachette but she is a peasant's daughter."(HS6)

"While Joanna of Flanders is a noblewoman nicknamed Fiery Joanna"(HS7)

"Oh the name is Joan the Hatchet"(HS6)

"Jeanne hachette. The hatchet. 4".

"French born princess in french royal house. Then becomes queen of France. Strange coincidence"

"Margaret of Valois 2nd question" (HS10)

"Yes. Marguerite De Valois".

6.2. Abstraction

The puzzle-set on WOMAN was followed by a single question post: *"Find the men behind these women. And mention the relation".* To arrive at answers to such a question, participants would be required to engage in extensive reading on the times and achievements of the 5 female protagonists. Computational thinking skills of abstraction would be predominantly used at this point. Through sustained practice, participants grew adept at focusing on the required information and ignored the many irrelevant details that habitually clog information gathering processes. Filtering of key details to obtain answers within short time spans meant that participants gained abstraction skills as they repeatedly engaged with such questions. Reproduced below are participant posts that bring out noteworthy trends in collaborative learning through abstraction. Instructor posts provide feedback that extends beyond mere categorizing of the response as being correct or incorrect. Instructor connects with earlier seen historical figures, encouraging pattern recognition or provides key information that guides abstraction. Instructor also creates a time bound challenge and pushes participants to simultaneously use multiple computational thinking skills in a race towards the correct response. The series of posts below feature multiple participants posting at very short time intervals, thus contributing to a near synchronous online learning experience in which individual thinking processes are visible and allow for systematic gains through observation, imitation and inference. Fragmented participant posts are indicative of real time application of computational thinking as students speed up response time.

The posts below highlight building and testing of abstractions as students propose claims with reasons, test them out until problem resolution. Most of History includes abstractions of histories and biographies as well as abstract projections of events of the real world. Abstraction evidently comes into play in the process of filtering out the details that are unimportant and hamper resolution (Charles IX, Louis III). In the case of Margaret of Valois, the initial option proposed, Charles IX, plays a secondary role in her elevation by arranging for her marriage. Her place in History is assured by her marriage to a man who would eventually become the first King of the House of Bourbon. Students would be required to compare and weigh both pieces of information before arriving at the conclusion that her husband Henry IV whose achievements are well-documented should be given precedence over her brother Charles IX, a weak and unpopular king. In the case of Catherine of Medici, it would be convenient to think of her third son as the source of her power, yet it is her husband, Henry II who through his premature death created a power void leading to her elevation and giving her a much-desired opportunity to do away with her rival, Diane of Poitiers. Her sons, Francis II and Charles IX reigned during the initial years following her husband's death and their youth/dependency provided her a golden opportunity to manipulate and exercise true power. In both cases, the more obvious answers are often discarded in favour of more justifiable stronger options. Exercising such choices forms an integral part of abstraction. Students were able to eventually choose the correct options over the more obvious information. A post that may go unnoticed is the discreet answer pertaining to Claude of France. The student appears to have successfully sifted out the irrelevant information (the fact that she was born to a French King, Louis XII, and was thus a princess of France) before providing the key point in the one-liner post: *For Claude of France - Francis I who made her his queen.* The wording of the answer displays confidence on behalf of the student who has successfully done the underlying abstraction needed to arrive at Francis I, the well-known Renaissance King who married Claude of France, thus changing her status from Princess of France to Queen of France. The student would have had to understand, through related readings, that this is far from the fate of most Princesses who go on at best, in rare cases, to become Queens (by marriage) to foreign Kings but hardly ever become Queens of their own country. It is commendable that the student utilized abstraction at multiple levels in a background exercise before posting the correct answer in a single attempt.

Students also drew on previously acquired knowledge and skills to make connections, showcasing an interest for in-depth learning. Pattern recognition is intuitively being reutilised by a student who connects a historical figure from this puzzle-set to the previous puzzle-set (post in bold). The student introduces Mary of Scots, another well-known historical figure, in relation to Catherine of Medicis. "*Which Italian noblewoman became mother to 3 French kings?"* is a question from the previous puzzle-set that leads to the discovery of Mary of Scots, the wife of a son of Catherine of Medicis, the Italian noblewoman. *" Which French Princess later became Queen of.... France?"* from the preceding puzzle-set also serves as a lead to Margaret of Valois and Claude of France, two Princesses of France who through strange coincidences become Queens to Kings of France. This implicit understanding would be vital in the abstraction that becomes necessary to arrive at the correct answers involving the men behind these female protagonists in the current puzzle set.

"Can u consider Charles IX the Impt man behind margret of Valois.? HE was one of her brothers who arranged for her to marry king Henry III of Navarre who would later go in to become first Bourbon king of France .

So technically he was responsible for her position" (HS4)

"He is not of considerable importance. And not the one who made her queen"

"She owes her queenship to which man?"

"Umm...ber husband?"(HS4)

"Name. Hurry up"

"Henry III of Navarre Later Henry IV Of France"(HS4)

👍

"for Jeanne hatchette, is jt Louis IX ? Cz he acknowledged her heroic deeds by instituting a procession called "procession of the assault". also married her to her lover". (HS2)

"Is it IX?"

"XI Sorry". 😞(HS2)

👍

"For Catherine de Medici is it her third son Louis III?"(HS8)

"Incorrect"

"Catherine's husband Henry II" (HS11)

"I thought it's him but he would exclude her from evrythng nd shower favours on Diane de Poitiers" (HS5)

"For Claude of France - Francis I who made her his queen"(HS1)

"is Mary Queen of Scots the daughter in law of Catherine de Medici? I might be wrong".(HS5)

👍 *"Claude. Francis"*

"Henry finally died on 10 July 1559. She now enjoyed more power than she had as the queen and quickly started exercising her authority". (HS11)

"So it could b she benefited from his death"(HS11).

"Right. She did. So she exercised great power during whose reign? Thanks to which man? Men"

"Her sons Francis II and Charles IX"(HS11).

"Because they were very young when they became the king.(HS11).

She ruled as queen mother on their behalf".(HS11).

"And even though her son Henry III was an adult, he was dependent on her for politics and administration".(HS11).

"Correct. 3 sons. Kings. Francis II Charles IX Henri III" 👍

6.3. Decomposition

Key events in the French Wars of Religion were dealt with in informal tones reminiscent of contemporary tabloid headlights. Solving the puzzle-set below would necessarily entail engagement with multiple sources and application of decomposition and historical reasoning.

"The bloodiest wedding in French History. 1. When? Date 2. Where? Exact site-venue 3. Bride and groom? 4. Why bloody? 5. Not a love marriage. Also UNLIKELY match. Why? 6. The end. Did they live happily ever after? 7. Bride's ex? 8. Did the ex or hubby pose a threat to the bride's Bro later? 9. Bride's relations with bros? Good or not? Explain 10. Mother of the bride? What party? 11. Party of bride's ex? 12. Party of groom's friends?"

Through this original puzzle-set, the entire topic (events of French Wars of Religion) was required to be decomposed into elements that fit the narrative. Grasping each of the decomposed bits led to the overall puzzle-resolution and an understanding of the entire topic. Participants successfully navigated the diverse events spanning decades to solve the puzzle which registered a 100 % success rate. In so doing, they independently figured out connections between events, reasons for and consequences to incidents, and identified the major players. The quest for such responses required supplemental related readings that stimulated an understanding of events that flowed decades later and which were not explicitly mentioned in the question posts. Interpretation of historical facts to fit in the requirements of the narratives entailed higher levels of historical thinking and problem-solving.

"1. 18 August 1572" (HS10).

"2. Notre Dame Cathedral in Paris"(HS1).

"3. Margaret of Valois and Henry of Navarre"(HS3).

"4. It was hoped this union would reunite family ties (the Bourbons were part of the French Royal family and the closest relatives to the reigning Valois branch) and create harmony between Catholics and the Protestant Huguenots..

Sorry that 5".(HS1)

"6. No. Their marriage was nullified".(HS9).

"7. Henry, Duke of Guise"(HS3).

"4. Bloody because of the clash between the catholics and protestants. It was also known as the French war of religion"(HS10).

"4. Bloody because six days after their marriage, the massacre of Protestants began on St. Bartholomew's Day"(HS11).

"6. Six days after the wedding - massacre of Huegeunots. Though Henry's life was spared, they were kept as prisoners, Henry

finally escaped n returned back to France but Marguerite was not allowed to follow him. Then in 1582 when she did go to bear an heir, but didn't succeed. Eventually goes to the Duke of Guise n tries to oppose Navarre's succession to the throne - no happy even afte4. After he became king their marriage was annulled n he married someone else"(HS3).

"10. Catherine de Medici. She was a Catholic".(HS7).

"9. Bride's relation with Henry III wasn't good"(HS8).

"11. Catholics"(HS3).

"12. Protestant Huguenots"(HS3).

"8. With no Valois heirs, Henry of Navarre was next in line to the French throne".(HS9).

👍 *"9&10"* 👍 *"1, 3, 6, 7, 11, 12"*

👍 *"4. The Massacre a few days later. Hence bloody".*

"Qts 2, 5, 8 need more explanation and precision. Still open".

"2. They were wed outside Notre Dame cathedral because Henry was not Catholic".(HS3).

"Because she was in love with Henry I, duke of guise"(HS8).

"Also unlikely match because they were of different religions?"(HS3).

"Yes different and warring religious faiths at the time.. 👍 2. 👍"

7. OBSERVATIONS

7.1. CT Skills and Historical Thinking

Historical thinking and Problem solving involve lateral thinking over linear thinking. It also involves critical analysis and fact checking before proceeding. The absence of traditional class timings and the possibility of round-the-clock chatroom activity allowed for sustained efforts towards problem-solving. Students gained from interaction in terms of multiple perspectives and built upon these to consolidate learnings, to conclude and to arrive at the correct answers, in case of quiz or a puzzle.

It is observed that students do not rely on memorization or merely the prescribed textbooks but refer to multiple sources to draw a conclusion or respond which is the basis of Historical Thinking and is related to CT skill of decomposition. Only upon decomposition based on multiple historical resources can there be analysis and pattern-recognition. This also suggests the movement of students from being passive consumers towards actively engaged in the learning process of History. The students are actively involved in identifying similarities, trends, patterns and sequences in Historical events.

A steady progress was seen in the students' ability at puzzle-solving. Over time, decomposition and pattern recognition skills were developed, leading to prompt correct responses, identification of gaps in historical knowledge as well as critical analysis of the facts presented in the puzzle. It was observed that students mapped the historical event in contemporary events and attempted to relate the underlying socio-political thought processes and the evolution of these thoughts and society as a whole. This also demonstrates the skill of abstraction and deep analysis of trends of society where the students kind of create a mental timeline- an algorithm of sorts- if not as a timeline as an artefact. This demonstrates the application of CT skills in the Humanities domain.

A distinctive improvement in the way students handle data is observed.

7.2. Classroom Benefits of applying CT Skills

Inclusion: Students who were initially slow learners in class and showed disinterest in the subject were drawn by the WhatsApp group's informality and quizzing and manifested a strong presence in the chatroom. By observation, imitation, trial-and-error, they learnt to use decomposition and pattern recognition in the quest for correct answers.

High Motivational levels and Student Engagement: It is established that it is very tricky to calculate 'student engagement', especially in the context of social media used for educational purposes. Few of the crucial parameters are: the time of engagement, duration of engagement and nature of engagement. Engagement with the subject matter/ content taught outside the classroom hours, especially when it is not related to completion of assignments/ homework is an indication of higher levels of engagement. The WhatsApp group witnessed high student activity outside classroom timings and well into night time. Competition and time constraints played an important role in promoting problem-solving. Following a question, the delay between posts was often short and sometimes less than a minute. Running a race against time often prompted students to post "*Wait/ trying/ finally/No wait/*" indicating their involvement, engagement and the competitive edge. It is also observed from the above instances of expressions that students were comfortable in expressing their emotions which is a parameter of engagement (Appleton.J., Chrisenson.S., Kim.D., Reschley.A., 2006).

8. CONCLUSION

Teaching- Learning History with CT has been helpful in multiple ways as seen in this study. Firstly, the fast-paced posting and the direct inter-student communication flow was indicative of the success of collaborative learning. Secondly, it provides for the application of disciplinary concepts, analysing evidence and evaluating sources. Computational thinking serves as a toolkit for development of historical thinking. Integrating CT skills empowers History students and also, largely social studies students and curriculum to have a far-reaching and flexible approach and speak the language of the 21st century.Additionally, response precision and speed further corroborated the efficacy of group based learning and computational skills. The WhatsApp group puzzles, repeated incentivisation, and the informal nature of learning in and outside the classroom contributed to high engagement levels. These benefits were suitably channelised to foster a conducive learning environment for developing computational thinking subskills.

Most importantly, as students become familiar with techniques and skills, they think across time and space using History to study not just the past but to explore the present as well as the future.

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