

Research Article:

Teaching ST Concepts during a Pandemic: Modes for Engaging Learners

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ABSTRACT

Amongst the pressing concerns in the thick of the current global pandemic, particularly in the context of residential colleges within higher education, is that of our ability as educators to create a sense of community amongst our students, as well as to effectively facilitate learning in the online environment. A faculty at a public university in Singapore strategised to meet these challenges of teaching in a pandemic on two fronts – creating a level of online and hybrid classroom that would integrate as much of the face-to-face (f2f) experience for undergraduate residents as possible to retain a sense of community, as well as using asynchronous material to support students in their learning. To encourage student engagement, education technologies such as gamification are also utilised. This article considers the employment and impact of those strategies in classrooms where ST modules are taught: “Committed to Changing Our World: The Systems Pioneers” ($n = 24$), “Thinking in Systems: Disaster Resilience” ($n = 48$) and “Thinking in Systems: Diseases and Healthcare” ($n = 32$) leading to a total number of 104 students, mostly in their first and second years and from various disciplines, invited to participate in the study. This article shows pedagogical examples of how we as educators can innovate by using available online tools, while embracing the principles of good teaching to best support our students in their learning.

Keywords: Classroom community, digital education, online tools, active learning

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INTRODUCTION

The current global pandemic has had widespread impact on a critical scale, particularly in the arena of education. For residential colleges within higher education, a key pressing concern is that of our ability as educators to create a sense of community amongst our students, as well as to effectively facilitate learning in the now indispensable online environment. At RC4 (RC4), which offers a “Living-Learning Programme” (Inkelas, 2016) within the National University of Singapore (NUS), the curriculum has a focus of “ST” – both a philosophy and a diagnostic tool that arises from the principle of interconnectedness in the world. Students at RC4 take credit bearing modules within the college that are a part of their academic degree. Internationally, educational institutions like RC4 are also termed “Living-Learning Communities” (LLCs) where, as the name suggests, the interaction and collaboration that arise from community living are at the top of what students expect.

For semester 1 of academic year 2020–2021, our faculty strategised to meet these challenges of teaching in a pandemic on two fronts – creating a level of hybrid classroom that would integrate as much of the face-to-face (f2f) experience for undergraduate residents as possible to retain a sense of community, as well as using asynchronous material to support students in their online learning journey. To encourage student engagement, education technologies such as gamification are also utilised. The basis for these strategies are established and validated practices from pedagogical theory: active learning that rests on Vygotsky and Cole’s idea of constructivism (1978), Hattie’s research in “visible learning” (2012) as well as Bloom’s taxonomy (Bloom, 1956; 2001).

This article considers the employment and impact of those strategies in three systems classrooms (one senior seminar and two junior seminars) – “Committed to Changing Our World: The Systems Pioneers” (CCW), “Thinking in Systems: Disaster Resilience (DR)” and “Thinking in Systems: Diseases and Healthcare” (DH) with a total number of 104 students invited to participate in the study. CCW, DR and DH are modules that teach ST, where students learn to see the world as an interconnecting system of parts that relate to each other, simplify complex issues and apply diagnostic tools as part of the problem-solving process to derive effective solutions. The students are mostly first- and second-year undergraduates attached to RC4 and majoring in disciplines from the Faculty of Engineering, School of Computing, Faculty of Science and the Faculty of Arts and Social Sciences. CCW ($n = 24$) deepens students’ understanding of System concepts such as “systems archetypes” and “envisioning” and uses a new level of hybrid classroom throughout the module where students experience f2f interaction on a rotational basis. In this instance students outside are projected onto the screen in the physical classroom through Zoom simultaneously, with the instructor always teaching in that physical classroom – community is built at the interface between the two groups as well as via group work either in the f2f environment or online (Zoom breakout rooms). DR ($n = 48$) teaches systems concepts related to disasters and engages students through the hybrid classroom. In this class gamification (Forest@Risk), in combination with recorded videos explaining the game set up and consultations after to analyse the data collected for Systems

modeling and simulations, is also employed. DH ($n = 32$) blends asynchronous material (video recordings in the main) and a cloud-based messaging app (Telegram) with the Zoom classroom (particularly making use of group discussions in “breakout rooms”) to support students as they learn to build systems models in their study of diseases and healthcare. In each case, the principles of active learning, where the student is engaged in the learning process and builds on his prior knowledge (and mental models) are adhered to, and a sense of community is also created via collaboration and teamwork.

The Fully Hybrid, Partially Hybrid and Fully Online ST Classroom

The fully hybrid classroom

CCW uses a fully hybrid classroom in its module delivery. As a senior seminar, students taking this module are already cognizant of the foundational knowledge of ST and modeling that they have learnt in their junior seminars (the level 1 seminars are a pre-requisite). CCW deepens students’ understanding of Systems concepts such as “systems archetypes” and “envisioning”, taking them through a process of active learning and engagement where they encounter authentic case studies, translate these into ST causal loop diagrams in order to understand the network of stakeholders involved, and then teaches them to create white articles that showcase their solutions to global issues.

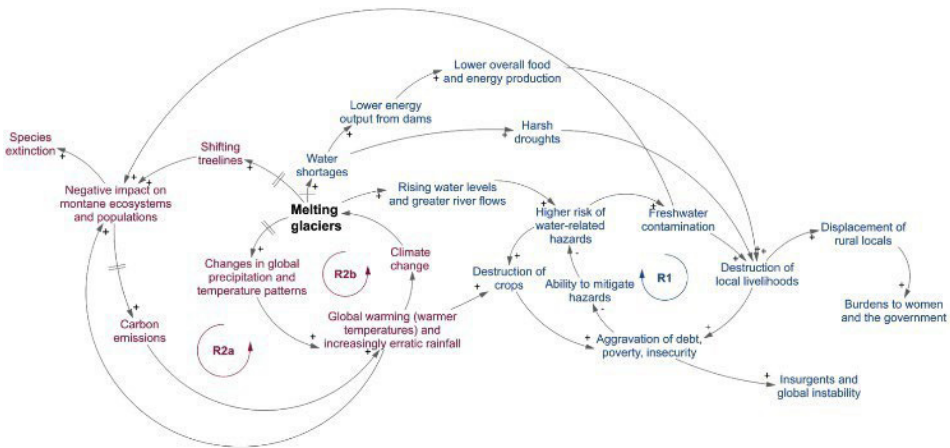


Figure 1. Causal loop diagram created by CCW students from “The Melting Himalaya” article

Thus, students activate their higher order skills (in Bloom’s taxonomy) – applying their understanding of ST philosophy and diagnostic tools to global issues, analysing how their solutions differentiate from those that are already in place, evaluate the strength of their proposition, and create a document that contains their ideas. In pre-pandemic times the collaboration that students have to engage in to go through this process takes place in the

physical classroom (15 to 18 students), however during the pandemic the need for social distancing made this very challenging – no more than 5 to 8 students could come to class. This challenge was met with the new hybrid classroom.

In the new fully hybrid classroom, students experience f2f interaction on a rotational basis (as shown in Figure 2). Prior to the pandemic a classroom can hold close to 20 students, however safe distancing measures shrinks that number to around 5. The students who do not meet f2f are projected from wherever they are onto the screen in the physical classroom through Zoom, with the instructor always teaching in that physical classroom. The desktop or the instructor's computer connects with Zoom and projects the online students into the main screen in the physical classroom, using an appropriate camera and microphone system (the ones that come with your laptop or desktop will not work). Students interact with one another as if they are all in the same physical space, without barriers. All students online can unmute themselves and speak freely, while those in the class speak into a microphone connected to the desktop so the students online can hear them. Two microphones are used, one attached to the instructor at all times. All the tools on Zoom are available for use for students both on the f2f and online environments.

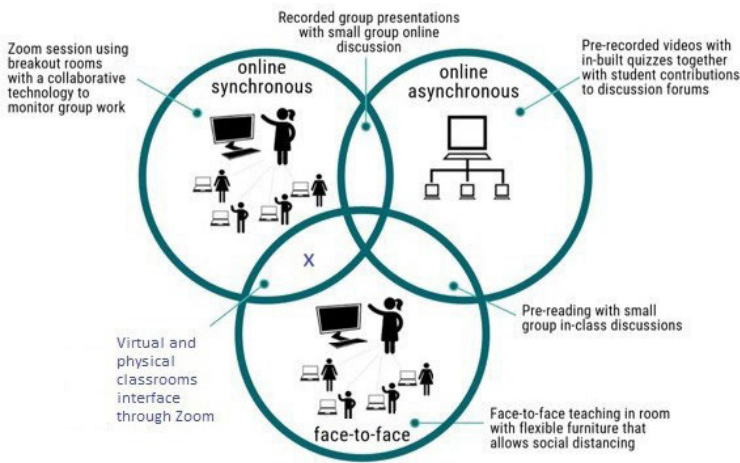


Figure 2. Adapted from A Guide to Hybrid Teaching (Centre for Development of Teaching and Learning, 2020) in Tan (2020)

This hybrid classroom (as shown in Figure 3) was utilised for the entire duration of module delivery – one semester. This encompassed not only group discussions but also their (graded) presentations and included a talk by a visiting speaker.



Figure 3. The hybrid classroom (photo courtesy of Elgin Low Quan Bin)

The ability to project students outside of the classroom into the physical space allows for freedom of interaction that in pandemic times would not exist. This not only makes it possible for them to have f2f discussions with each other (and the instructor), it also facilitates the group work that students participate in when they translate resources into causal loop diagrams and white articles. Students gave feedback that the fully hybrid classroom was “more conducive for learning”, gave them the ability to “interact with one another quickly”, “have multiple short and quick discussions” and that it was “unique” and “fun”. They also expressed gratitude that those who were overseas due to the pandemic were able to enjoy the module.

The partially hybrid classroom

Disaster education is well-suited for RC4 as both seek for interdisciplinary understanding among its learners about the interactions between human agency and global changes through the integration of formal, non-formal (co-curricular activities) and informal (learning by doing) education (Yong & Samavedhamam, forthcoming; Shaw et al., 2011). The module DR: Thinking in Systems - Disaster Resilience, meant for Year 1 undergraduate students from any disciplinary faculty of NUS, has intended learning outcomes focusing on acquiring ST and System Dynamics Modelling (STSDM) skills along with an understanding of policymaking for DR. Problem-based learning with the application of STSDM in case studies of disaster contexts is a good start but relying only on case studies can lead to passive

learning and the much-needed dimension of experiential learning of disaster education may get ignored (Shaw et al., 2011). There is a need to devise pedagogies such that learners can engage in a safe environment to experience nuances of disaster situations, reflect, connect to discourse of disaster studies and further experiment for a deeper understanding of policy needs for resilience (Varma & Wei Liu, forthcoming; Varma & Balakrishnan, 2021). The lesson plan of the module is organised in three interconnected stages (as shown in Table 1). The first two stages scaffold students learning towards grasping key concepts of STSDM and disaster studies along with the acquisition of ST and computer modelling skills to facilitate model-based policy experiments (Serman, 2000, Simonovic, 2011). The third stage (as shown in Table 1) is a game-based pedagogy that is designed with inspiration from Kolb's experiential learning cycle (Kolb & Kolb, 2005).

For active engagement of learning to occur and to attain Bloom's higher order skills such as application, learners not only need interesting cases for application of any methodology but also experiences to reflect on the opportunities and challenges of application itself, to relate attributes of theory and practice and have deeper insights for policy. The pedagogy aims to create a safe space for students to experience "surprises, decision dilemmas and ambiguities" associated with real-world disaster situations, reflect and conduct model-based experiments using knowledge of the prior two stages (Varma & Wei Liu, forthcoming). This pedagogy uses a digital serious game called 'Forest@Risk' which is available online from games4sustainability.org. The game is designed on the theoretical foundations of the "tragedy of commons" phenomenon which establishes that over-exploitation of any common property resource, like oceans or forests, is certain in absence of a larger public authority, private property rules or self-regulation for equitable resource exploitation (Ostrom et al., 2007). Players share a common pool of trees and get emotionally connected to the context as the fate of the forest lies in their choice of harvesting trees as well as investments for building protection against surprises of earthquakes and floods (Solinska-Nowak et al., 2018).

The pedagogy helps students to reflect on the matches and mismatches between concepts learnt and experiences in the game and also apply such reflection in model-based experiments. An analysis of students' pre-and Post-game activities has helped in understanding that it improves students' understanding of human dimensions involved in an environmental collapse situation. It also facilitates creativity regarding policy strategies beyond the boundary of just the game. Further, it encourages students to critically think about not only policy strategies but also frameworks that guide just strategies as well as the goals and purpose of framing such policies (Varma & Wei, forthcoming, also see Figures 1 and 2).

During the pandemic as teaching had to move from f2f seminars to online and hybrid modes, the three stages had to be adapted accordingly. Table 1 summarises the three stages, pedagogical strategies for each stage and how it is practiced in the two different teaching modes. Students' testimonials (shown in Table 2) after the partial hybrid mode of teaching which had a mix of hybrid seminars for synchronous learning, sharing of recorded videos

for asynchronous learning and follow up with one-to-one online and f2f consultations illustrate the usefulness of this mode for the pandemic era.

Table 1. Three stages of pedagogical strategies and their practice in different teaching mode

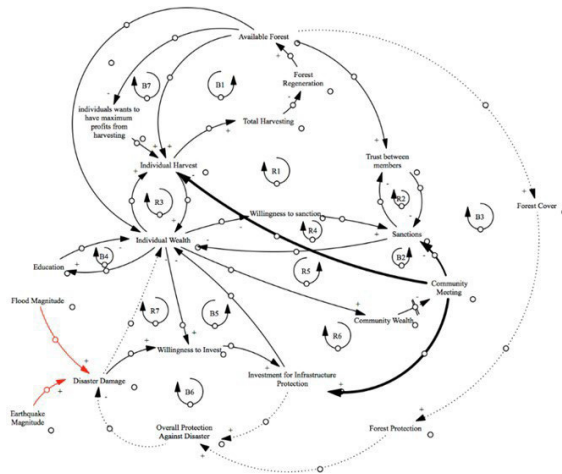
Stage number	Stage	Pedagogical strategies	Face to face seminars	Partial hybrid
1	Introduction to STSDM concepts	Exploration of simple to complex cases of policy failures engaging student groups to draw and communicate through ST-based diagrams	Lecturer uses whiteboard and marker pens to demonstrate and then facilitates students to draw in the whiteboards of the seminar room which is followed with group presentations	<p>1. Online seminars on Zoom and f2f seminars are conducted simultaneously. Lecturer uses “whiteboard” and “breakout room” applications of Zoom for group activities among online students while the f2f seminar students continue using of whiteboard and markers pens in the seminar room</p> <p>2. Students and lecturer in the seminar room interact with the online students using webcam and microphones.</p> <p>3. If any student group had mix of online and f2f seminar students, then the seminar students connect with their online peers using Zoom in their laptops and external headphones with microphones to prevent echoing in the seminar room.</p> <p>4. Group presentations were conducted for all the three type of groups i.e. online students, f2f seminar students and mixed group students.</p>
3	Experiential learning using digital serious game	A game-based pedagogy, using an online serious game called Forest@Risk, is designed.	Pre-game: Lecturer introduces theory behind the game through case study and videos.	Pre-game: Lecturer introduces theory behind game through case study and videos which are shared online prior to seminar. Students participate in seminar after watching videos and form teams to anticipate the outcome of the game.

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Table 1 (continued)

Stage number	Stage	Pedagogical strategies	Face to face seminars	Partial hybrid
			<p>Students form teams and are encouraged to anticipate the outcome of the game and present their hypothesis using ST-based diagrams in whiteboards of seminar room.</p>	<p>Teams present their hypothesis using ST based diagrams using whiteboards of seminar room as well as zoom ‘whiteboard’. Interaction goes on among online students, lecturer and seminar room students through microphone and webcam.</p>
			<p>Game Student teams sit in separate tables and play the online game using one laptop per group.</p>	<p>Game: The digital game is accessible to both online and f2f seminar students. Online teams as well as teams which have members both in seminar room as well as online use the ‘breakout room’ application of Zoom to play the game.</p>
			<p>Post-game: Student teams are encouraged to reflect on the mis/matches between pre-game hypothesis and game-experience, use game data to formulate computer models and experiment with policies to improve trend. Experimentation is carried from seminar activity to formative assignment with group consultations with the lecturer.</p>	<p>Post-game: Student teams are encouraged to reflect on the mis/matches between pre-game hypothesis and game- experience, use game data to formulate computer models and experiment with policies to improve trend. Experimentation is carried from seminar activity to formative assignment with group consultations through online as well as f2f consultations with the lecturer.</p>

(a)



(b)

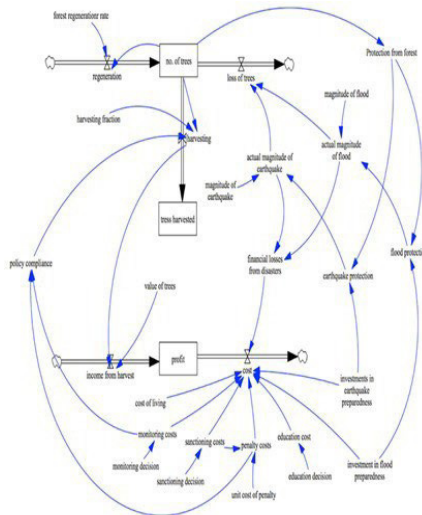
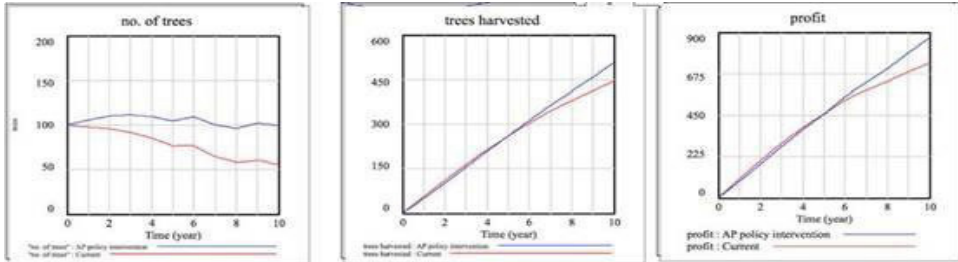


Figure 4. Sample of students work from: pre-game diagrams and Post-game model-based experimentation. (a) Pre-Game ST based diagram; (b) Post-game transformation to system dynamics model; (c) Model-based experiments.

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Figure 4 (continued)

(c)



Note: Red lines in key system elements (number of trees, trees harvested and profit) illustrates simulation results without policy and blue lines of the same system elements illustrate simulation results with policy.

Student feedback related to the partially hybrid classroom was largely positive, with students commenting that “despite the restrictions” of the pandemic, “good learning and discussion” was facilitated, with the lecturer going “above and beyond to offer individual consultations” and “clarify” students’ doubts. Moreover, students also claimed that when they were “participants of the system internally” they were provided “new perspectives into why certain policies work and why some don’t”. The game was particularly successful, students explained that the “real-life application” helped them to understand policy at a much greater depth, and also led to an increase in “class bonding”.

The fully online classroom

DH is a Level 1 module taught to Year 1 undergraduate students who come from diverse disciplinary background. This module covers two major aspects: (1) introduction to the concepts of ST and System Dynamics (ST/SD); (2) exploring case studies under the theme “Diseases and Healthcare” through ST/SD language. The Year 1 undergraduate students enrolled in this module will not have any prior knowledge on ST/SD. The essence of learning ST/SD language requires a “shift of mind” in students (who are beginners), to transform their mind from conventional linear thinking to circular thinking while approaching a complex problem (Senge, 2006). Hence, it is an interesting challenge to effectively cater the module to the beginners so that the learning activities can catalyse the shift of mind that is needed to start thinking in systems.

This module adopts two major strategies to achieve this “Shift of Mind” in the learners who are beginners:

1. Approach 1: Inspired from ST/SD researchers and educators (Fisher., 2017; Richardson, 2011; Richardson, 2014a; Richardson, 2014b), DH is scaffolded in such a way that learning starts from delivering basic concepts using “simple toy

stories”, moving gradually towards “modelling based on canned description” and finally reaching to the stage of “building models from scratch”.

2. Approach 2: Forrester (1996), the father of SD, emphasised the need of creating Learner-Centric Learning Environments while introducing the concepts to beginners. Hence, this module offers collaborative learning communities which offers safe zones for learners to engage with their peers from different disciplines and build confidence in learners to apply the ST/SD applications to various real world problems.

This module has been taught for past six years and the mode of delivery was f2f until before the pandemic (for about five years). The mentioned two strategies have been effectively incorporated in the f2f classes (pre-pandemic) in three stages, each of which involve using different learning tools (as summarised in Table 1).

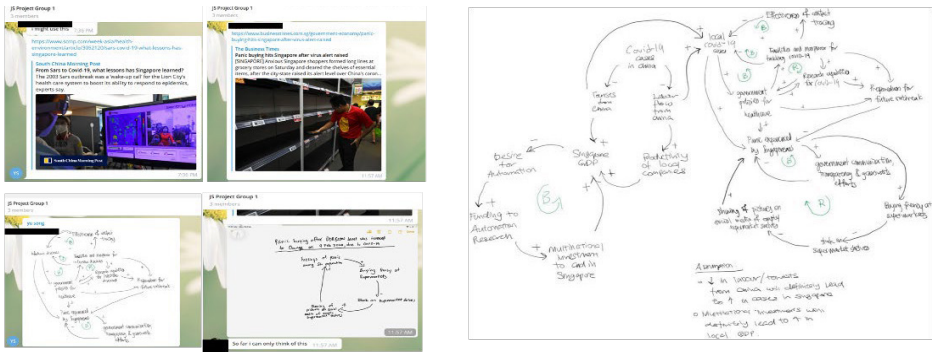
Since the pandemic situation resulted in extended lockdowns and stricter safe management measures, f2f module delivery has almost become impossible. Additionally, the lecturer of this module was stuck in overseas due to border restrictions. So, the module adopted 100% online learning mode in this pandemic. One of the conscious decisions that was made by the lecturer while designing the fully online learning mode was to facilitate students with the most effective tools (without making too many compromises), so that the students learning via fully online mode would achieve similar outcomes as that of f2f mode. This conscious decision inspired the lecturer to actively look for equivalent online learning tools as that of f2f learning for each stage of learning – as shown in Table 2.

Table 2. Conscious incorporation of face-to-face equivalent online learning tools

Stage	F2f delivery tools (pre-pandemic)	100% online delivery tools (pandemic)
1. Concept delivery (laying foundation)	Whiteboard with marker, slides	Zoom Whiteboardwith stylus, vote button/polling options in Zoom
2. Active learning in class via case study discussion and problem solving	Four to five mini groups using Whiteboard with marker, laptop	Zoom break-out rooms for Four to five mini group with laptop/Zoom whiteboard
3. Active learning outside class (peer-to-peer and peer-to-teacher)	Physical consultation slots	Telegram group chats with peers and teacher

In case of stage 1, concept delivery for fully online class was done using Zoom whiteboards with stylus pen. A sample of concept delivery in the online class using Zoom whiteboards is shown in Figure 1. The lecturer was able to almost mimic the f2f experience while explaining the concepts in steps using Zoom whiteboard. There could be a concern that in case of f2f delivery the teacher would be able to physically observe the class dynamics/ask questions to understand whether students understood the concepts.

Direct evidence on outside class learning via Telegram groups: Conceptualising current affairs into ST/SD models



(B) Student Testimonials on using Telegram groups for outside class learning

“Telegram was great, it allowed for quick and easy communication between everyone”

“Telegram group really helps in facilitating discussions and communication between students and also the (B) Student testimonials on using Telegram groups for outside class learning”

“It has helped me to interact with my group members more despite the current situation. It is great for keeping me engaged and active.”

Figure 7. Effectiveness of Telegram peer learning group chats in outside class learning

In all three scenarios (hybrid, fully online and partial hybrid), students completed an online survey adapted from Rovai’s Classroom Community Scale (CCS) (2002) on Microsoft forms at the end of the module, between weeks 12 to 14 of the semester. The approaches provide routes to the higher order thinking skills identified in Bloom’s taxonomy. Finally, a common survey is administered in order to gauge student reception of the strategies as well as to ascertain both the level of community experienced and whether there is a statistically significant difference in students’ perceptions regarding this sense of community in these three classes. The research question that the survey aims to answer is:

“What are students’ perceptions of connectedness and learning when a blend of online, asynchronous resources and face-to-face teaching strategies are used in the ST classroom?”

In addition to this main research question, this article explores the answers to the following three questions:

1. Are there statistically significant differences between student perceptions on the community scale between fully hybrid, partially hybrid, and fully online modes of learning?
2. Are there statistically significant differences between student perceptions on the connectedness sub-scale between fully hybrid, partially hybrid, and fully online modes of learning?

3. Are there statistically significant differences between student perceptions on the learning sub-scale between fully hybrid, partially hybrid, and fully online modes of learning?

Rovai's (2002) (CCS), which measures a sense of community (as a whole) via two subscales (learning and connectedness) is used as a basis for the survey. Unlike similar studies which have found a marked distinction between fully online and hybrid classrooms (Ritter et al., 2010), our project investigates whether this sense of community will be significantly different when strategies of active learning are employed across these three systems classrooms.

LITERATURE REVIEW

Historically the research and experience of teaching and teaching well has mostly been focused within the f2f environment, however starting around the 21st century and particularly in the present climate of the COVID-19 pandemic the ability to effectively wield online tools in digital education has moved irrevocably to the forefront. The concept of "Classroom Community" surfaced in 2002, when Rovai introduced the CCS, which measured the sense of community experienced by students via two constructs – their feelings of connectedness, as well as their perception that learning goals were being met. Rovai defines classroom community as:

A feeling that members have of belonging, a feeling that members matter to one another and to the group, that they have duties and obligations to each other and to the school, and that they possess shared expectations that members' educational needs will be met through their commitment to shared learning goals. (Rovai, 2002, p. 322)

Since his publication there have been multiple studies of classroom community in pedagogical research using Rovai's CCS, some in the f2f classroom (Ahmady et al., 2018; Petrillo et al., 2016; Vora & Kinney, 2014; Dawson, 2008), and a significant number in blended and online spaces (Kavrayici, 2021; Gilken & Johnson, 2019; Aydin & Gumus, 2016; Yilmaz, 2016).

There has been a documentation of evidence that students' sense of belonging in a college environment leads to persistence, which facilitates academic success and encourages degree completion (Karp et al., 2010; Hoffman et al., 2002; Barnett, 2011; Yorke, 2016).

The pandemic has exacerbated the need for this sense of belonging, as social distancing and other safety measures have created a general environment of isolation (Burtscher et al., 2020), and a migration to online modes of learning as a substitute for f2f interaction. There is scant research that measures classroom community across learning modes, Ritter's study is one of the few exceptions that do so (Ritter et al., 2010) and possibly the only one that

compares classroom community between hybrid and online modes. Nonetheless, much has improved in education technology since his publication particularly with the rise of the Zoom platform that allows for a seamless synchronous (or f2f) engagement online, and the new level of hybrid where students can be virtually projected into the physical classroom (Tan, 2020).

The principles that are adhered to when teaching at RC4 follow theories of constructivism and visible learning. Vygotsky's theories of constructivism place the student at the centre, emphasising the learners' active participation. His theories have been seen as a prominent departure from Piaget with the more dominant recognition given to the social nature of learning, and the insistence that cognitive development was influenced directly by the social environment (Vygotsky & Cole, 1978). The paradigm of social activity having an impact on the processes of the mind is one that underlies the importance of classroom community, as well as the intentional prioritising of collaborative group work at RC4. Hattie is a more recent and leading voice in impactful teaching. His Visible Learning Model is based on evidence from a synthesis of more than 1,200 meta-analyses (Hattie, 2009; 2012). The synthesis situated the various influences on student achievement along an underlying achievement continuum. Hattie's conclusion is that the most effective teachers as evaluators of their impact (2015, p. 89). He highlights the culture that encourages evaluation:

“Teachers as evaluators” adapt their teaching to maximize student learning. There needs to be a culture in departments and universities of seeking evidence to support interpretations about impact, having collective discussions about this impact, what the magnitude of this impact should be, and how pervasive is this impact on the students. (Hattie, 2015, pp. 89–90).

In the same article, Hattie also emphasises the value of the student voice in evaluating impact. One of the four components for successful evaluation in the “Visible learning Model” is the “use of student voice as part of the responses to interventions (i.e., listen to how students are understanding the teaching)” (Hattie, 2015, p. 81). Moreover, the critical place of the student voice is repeated in his argument that students “are very good evaluators of the impact of teaching on their learning.” Again, the evidence that this claim is based on is persuasive, with “seven meta-analyses of more than 141 studies on this topic and the overall average effect ($d = 0.47$) shows a high relation between their ratings and teacher effectiveness” (2015, p. 87). This article shows three examples of how we as educators can innovate by using contemporary online tools, while embracing the principles of good teaching, to best support our students in their learning.

METHODOLOGY

Participants

The participants in this study ($n = 104$) were all undergraduates of the National University of Singapore and enrolled in RC4. RC4 delivers a living and learning experience and a curriculum called the Utown College Programme (UTCP). The UTCP maps onto the compulsory General Education modules that students take at faculty. The students were mostly in their first year, DH ($n = 32$) and DR ($n = 48$) are “Junior Seminars” in the first tier of the UTCP, while CCW ($n = 24$) is a “Senior Seminar” in the second tier comprised offirst and second year students. Students typically take Junior Seminars before they study the Senior Seminars. The majority of students are Singaporean, with some students hailing from the surrounding region in Asia (China, India, Indonesia, Korea and Vietnam). The students have a multidisciplinary background, and those taking the Junior Seminars are encountering ST for the first time. The following section considers the three modes of delivery in descending order of the amount of time that students spend in the traditional space of the f2f classroom.

Procedure

To address the main and sub research questions, a modified application of Rovai’s CCS (Rovai, 2022) was used to examine students’ experiences with face-to-face, online and hybrid learning within the systems classroom. The undergraduate resident students completed these surveys on Microsoft Forms at the end of the second semester in academic year 2019–2020. Their participation was voluntary and anonymous. The quantitative survey data was analysed using ANOVA and the Bonferroni method.

Measure

Rovai’s CCS (2002) was validated as a reliable measure of students’ sense of classroom community based on two constructs, their experience of connectedness and their perception that learning goals are being met. Rovai definition of classroom community is thus a combination of students’ perception of connectedness and learning. For sense of connectedness, Rovai explains that this is a “feeling of belonging and acceptance” and “bonding relationships” while perception of learning refers to “the feeling that knowledge and meaning” are “actively constructed”, enhanced, and that “the learning needs of its members are being satisfied” (Rovai, 2002, p. 322).

We adapted the CCS to measure the students’ sense of community across these three learning modes and used a Likert scale of 0 to 4, with 0 signaling strong disagreement, and 4 its opposite, strong agreement. Each of the two constructs, perception of connectedness and perception of learning, was made up of four items. Examples of these items are “I feel that I can rely on others in this module” (connectedness construct) and “I feel that I am given ample opportunities to learn” (learning construct). Rovai’s CCS was selected with the

COVID-19 pandemic in mind as the sense of community (coupled with the challenge of meeting learning goals) was topmost in the pressing concerns that educators in residential colleges within higher education (Inkelas, 2016) faced.

RESULTS

Internal Consistency of Survey Instrument

The reliability and internal consistency of CCS instrument used in this study was first calculated using Cronbach's alpha coefficients. This study used a reduced version of CCS questions with eight questions for community scale; five questions were related to connectedness sub-scale and three questions were related to learning sub-scale. The Cronbach's alpha coefficient values for the questions used in this study are presented in Table 3. The Cronbach's alpha coefficients for community, connectedness and learning are greater than 0.75, which is an indication of good reliability of CCS instrument used in this study.

Table 3. Cronbach's alpha coefficients

Groups	Cronbach's alpha
Community	0.97
Connectedness	0.87
Learning	0.77

Descriptive Statistics of Collected Survey Responses

A summary of descriptive statistics of survey responses collected from 85 students is presented in Table 4. Ritter et al. (2010) presented the average and standard deviation values of their study which compared the online, hybrid and f2f classes. Comparing the average values of fully online and fullyhybrid classes between Ritter et al., the current study shows better performances in both the delivery modes. On the other hand, it is also important to analyse and understand whether there are statistically significant differences between three learning modes investigated in this study.

Table 4. Descriptive statistics of collected survey responses

Learning modes	Responses	Average	SD
Community			
Partially hybrid	31	2.98	0.54
Fully hybrid	24	3.39 (2.98)*	0.41 (0.48)*
Fully online	30	3.41 (2.58)*	0.48 (0.66)8

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Tabel 4 (continued)

Learning modes	Responses	Average	SD
Connectedness			
Partially hybrid	31	2.87	0.64
Fully hybrid	24	3.39 (3.04) *	0.41 (0.6) *
Fully online	30	3.35 (2.4) *	0.51 (0.67) *
Learning			
Partially hybrid	31	3.17	0.45
Fully hybrid	24	3.47 (2.92) *	0.45 (0.57) *
Fully online	30	3.51 (2.77) *	0.49 (0.88) *

Note: * values within bracket are the literature values for fully online mode of delivery taken from Ritter et al. (2010).

ANOVA and Post-hoc Tests

Like Ritter et al. (2010), in addition to the main research question, this article explores the answers to the following three questions:

1. Are there statistically significant differences between student perceptions on the community scale between fully hybrid, partially hybrid, and fully online modes of learning?
2. Are there statistically significant differences between student perceptions on the connectedness sub-scale between fully hybrid, partially hybrid, and fully online modes of learning?
3. Are there statistically significant differences between student perceptions on the learning sub- scale between fully hybrid, partially hybrid, and fully online modes of learning?

First, one-way ANOVA was performed to find out whether there was a significant difference between the three modes of learning for the above-mentioned three questions and the results can be found in Table 5. The F -value ($F > F_{crit}$) and p -value ($p < 0.05$) for all the three questions confirm that there is a statistically significant difference between the three modes of learning for the community scale, connectedness sub-scale and learning sub-scale.

Table 5. ANOVA without correction

Source of variation	SS	Df	MS	F	p -value	F_{crit}
Community						
Between groups	3.42	2	1.71	7.18	0.0013	3.11
Within groups	19.53	82	0.24			
Total	22.95	84				

(continue on next page)

Figure 5 (continued)

Source of variation	SS	Df	MS	<i>F</i>	<i>p</i> -value	Fcrit
Connectedness						
Between groups	4.86	2	2.43	8.46	0.00046	3.11
Within groups	23.54	82	0.29			
Total	28.40	84				
Learning						
Between groups	2.059393	2	1.029696	4.78	0.0109	3.12
Within groups	17.67133	82	0.215504			
Total	19.73072	84				

Table 6. ANOVA post-hoc analysis and Bonferroni correction

ANOVA post-hoc analysis		
Groups	<i>p</i> -value (<i>t</i> -test)	Significant
1. Community		
Fully online vs. partially hybrid	0.002	Yes
Partially hybrid vs. fully hybrid	0.004	Yes
Fully hybrid vs. fully online	0.89	No
2. Connectedness		
Fully online vs. partially hybrid	0.002	Yes
Partially hybrid vs. fully hybrid	0.001	Yes
Fully hybrid vs. fully online	0.73	No
3. Learning		
Fully online vs. partially hybrid	0.007	Yes
Partially hybrid vs. fully hybrid	0.013	Yes
Fully hybrid vs. fully online	0.89	No
Bonferroni correction test	Alpha	
ANOVA	0.05	
Bonferroni corrected α	0.017	

However, the one-way ANOVA results in Table 5 are not sufficient to specifically conclude which of these three-delivery mode(s) show statistically significant differences from another. Hence, post-hoc analysis was performed using the Bonferroni method to analyse the pairwise differences for the community scale, connectedness and learning sub-scales and the results are presented in Table 6. Since three new statistical tests had to be performed to know which learning modes show statistically significant differences from one other, ANOVA α -value was corrected to Bonferroni corrected α -value of 0.017 and the significance of three learning modes were obtained based on the corrected Bonferroni α . ANOVA post-hoc results in Table 6 signify that two pairs of learning modes show statistically significant differences:

- (1) Fully online and partially hybrid ($p = 0.002$; $p < 0.017$, i.e., $p\text{-val} < \text{Bonferroni corrected } \alpha$).
- (2) Partially hybrid and fully hybrid ($p = 0.004$; $p\text{-val} < 0.017$, $p < \text{Bonferroni corrected } \alpha$) for the community scale, connectedness sub-scale and learning sub-scale as their p -values are less than Bonferroni corrected α -value.

DISCUSSION

The aim of this study was to investigate students' perceptions of connectedness and learning when a blend of online, asynchronous resources and f2f teaching strategies are used in the ST classroom. The robust scores in all three modes, particularly in the fully online classroom signals those recent advancements in technology, when used appropriately, can now match and replace the sense of community that is derived in the physical classroom.

The average scores for community, connectedness and learning in Table 4 shows that all three modes of delivery had a positive impact on students – it was above 3 (above “Agree” or “Strongly agree”) for all three modes of delivery except that it was above 2.5 (which was also close to “Agree”) for community and connectedness in partially hybrid mode. From Table 4 it can also be seen that the fully hybrid and fully online modes now exceed comparable scores from Ritter's study in 2010. On a scale of 0 to 4, with the overall sense of community construct, the earlier study indicated 2.98 for hybrid delivery and 2.58 for online delivery, however this is not only amplified but reversed in this study with 3.39 for hybrid delivery and 3.41 for online delivery. The earlier relationship however is preserved for the sub-construct of connectedness where the previous study scored 3.04 for the hybrid mode (3.39 in this study) and 2.4 for the online mode (3.35 in this study). The sub-construct of learning again reverses the scoring of the earlier study, with 2.92 for the hybrid mode in Ritter's example (3.47 in this study) and 2.77 for the online mode (3.51 in this study). Ritter's study has no corresponding mode for what we have identified as the partially hybrid classroom – however while it appears that the less f2f contact that student have in the physical classroom would explain the lower scores when compared to the fully hybrid classroom, that logic does not hold when its scores are compared to that of the fully online classroom.

There are two possible reasons for this departure from the earlier study. The first is the improvements in technology that have elapsed since 2010 when Ritter et al conducted their research. RC4 is known for innovative teaching methods and faculty are keen to experiment with the latest viable strategies that educational technology has to offer. In the fully online mode or hybrid modes faculty intentionally creating learning environments that incorporated active learning principles, using tools such as gamification, the breakout rooms in Zoom, social media platforms such as Telegram, as well as coming up with a new version of hybrid environment that combined successful traditional practices (f2f) and technological advancements, such as Zoom. The employment of technological improvements at NUS had an impact on learning that cannot be understated. Unlike online learning in

the past that had minimal f2f contact and thus a lack of sense of community amongst students and between students and the educator, technological improvements in the last decade (as well as the Zoom platform which ostensibly facilitated seamless synchronous f2f lessons) enhanced the social connection between students and with the educator. Faculty from NUS were also greatly supported in their use of educational technology via the Centre for Development of Teaching and Learning at NUS, which provided numerous workshops that were highly effective in enabling the adept use of these tools for teaching.

The second reason is linked to the context of RC4 where ST is the focus of the curriculum. Students at RC4 are encountering ST for the first time and they are drawn from a multi-disciplinary background. There is also an impetus at RC4 to provide an interdisciplinary education, where students from various disciplines grow in knowledge of the disciplines outside of their core areas. The push to make ST accessible to students at RC4 as well as the concurrent emphasis on a sense of community that is at the heart of residential colleges, pushes faculty to be creative and to adapt quickly to new technologies for engaging students. This push was intensified with the onset of the COVID-19 pandemic which threw up a formidable barrier to traditional f2f classes and their associated teaching strategies. Whether in the traditional classroom or the new fully online, fully hybrid or partially hybrid classrooms what can be seen is the centrality of the student. The social construction of knowledge advocated by Vygotsky is adhered to in the careful facilitation of student/student and student/faculty interaction within each mode with the application of knowledge and creation that typifies the higher order thinking skills in Bloom's taxonomy. In this study it is also evidenced that faculty are aligned with Hattie's culture where faculty are evaluators of their learning who place a high emphasis on the student voice.

The statistically differences (that are shown in Table 6) between students' perception on the community scale, connectedness sub-scale and learning sub-scale for two pairs of learning modes – partially hybrid and fully online; partially hybrid and fully hybrid show that the students are more comfortable with either fully online or fully hybrid mode throughout the semester. Since partially hybrid involves a mix of fully online and fully hybrid mode classes in different weeks of semester, students may find difficult to adjust the changing learning environments within the same semester. No significant statistical difference between the fully online and fully hybrid learning mode pair for community, connectedness and learning could be attributed to the fact that a high level of classroom community formation can happen outside of the traditional f2f class. Ritter et al. also made a similar observation in their study. Formation of learning communities outside the classroom in a living-learning environment like RC4 is not a difficult aspect.

There are limitations to this study – the fully hybrid classroom, unlike the partially hybrid and fully online classrooms was a second level module, whilst the others are first year modules. There were also 24 participants for the fully hybrid mode, while the partially hybrid had 31, and the fully online had 30.

Nonetheless as Table 3 shows, Cronbach's alpha for this study was robust. Since the completion of this study, a more extensive comparison of learning modes (online, hybrid and f2f) involving over 200 participants has been initiated.

CONCLUSION

The importance of adhering to principles of effective teaching cannot be overemphasised. In each of the learning modes, fully hybrid, partially hybrid or fully online, technology was not used for its own sake. Students were placed at the centre and engaged in active learning processes that utilised higher order thinking skills. The study also shows that online learning requires as much if not more effort in thought, preparation and delivery for the instructor as compared to the f2f class. The implications for teaching during and post-pandemic are significant. This study has shown that when coupled with active learning strategies, hybrid and online platforms can now equally, if not more effectively, produce as robust a sense of community in the classroom as the f2f environment.

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