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Addressing and resolving issues with hybrid flexible/dual mode teaching and technology in learning spaces: the 2 × n matrix model

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Abstract
Hybrid flexible learning is a mechanism for providing flexible learning to both online and on-campus students. Synchronous HyFlex teaching uses both technology and pedagogy to connect both groups within the same cohort. It is gaining popularity in higher educational institutions, but it also can create challenges associated with pedagogy, including technology, acoustics, and logistics. Finding solutions to these challenges is an organisational imperative for institutions aiming to address them. This article provides an overview of a mechanism for reviewing and problem solving as it relates to hybrid flexible teaching. A conceptual overview is detailed, building on previous literature; and experience from implementation, and rooted in a learning environments context, is described. The unique contribution of the study is demonstrated through the framework for resolving and understanding problems to provide solutions within the specific example of hybrid learning, which has not been analysed or considered in this way before. Example case studies are provided and considered, with an emphasis on practical real-world solutions (rooted in literature and evidence) that are likely to be useful to fellow practitioners.

Keywords Dual mode · HyFlex · Hybrid learning · Pedagogy · Problem solving

Introduction

Hybrid flexible (HyFlex) or dual mode teaching is a relatively novel form of teaching. The approach of synchronous seminar delivery to a hybrid cohort was first used in the UK in 2020 at King's College London (Detyna et al., 2022; Sanchez-Pizani et al., 2022) but had previously been introduced as a mechanism for asynchronous learning in the US by Beatty (2019), and now, there is a wider international interest in this approach (e.g. Howell (2022)). This article is based on a specific implementation, with the conceptual framework that arose from analysis of this implementation perhaps having broader uses. Here, we are

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using HyFlex to mean synchronous seminar delivery for a mixed cohort, both online and on-campus. HyFlex is analogous to but distinct from blended learning for which online or on-campus delivery is usually at different times or is asynchronous because both cohorts are learning at the same time fully synchronously. This approach has been detailed in previous papers and is summarised in Fig. 1, but essentially, the system consists of professional technical equipment used to provide a sense of presence for online students, so that both online and on-campus students feel that they are all in the same learning environment. While there is an emerging literature on evaluating it as a teaching approach (e.g. Binnewies & Wang, 2019; Raes et al., 2019), there is not a great deal of writing focusing on the practical challenges of this approach and how to deal with them.

One question that can be considered is why the field of learning environment research needs to address challenges of HyFlex specifically. The rationale for this is that, because HyFlex is a novel form of learning environment, understanding all the aspects in situ (combining the technical, the pedagogical and the physical estate) is best done from a learning environment perspective. There are already several examples in the learning environment literature of how to deal with the learning environment challenges of the pandemic and distance learning (e.g. Doz et al., 2023) and how learning spaces can be extended beyond the standard physical environment (e.g. Connolly et al., 2023). Mateo-Canedo et al. (2023) have also written about how challenges such as learning and health security have been dealt with from a learning environment perspective, and how HyFlex could help in dealing with these.

When implementing such a system, there are a number of problems or challenges. Technical equipment might not function as expected or be difficult to set up (Raes, 2019). Lecturers could struggle with ensuring learner engagement (Binnewies, 2019). Students might have difficulties with audio or connection, their sense of belonging to the class, or the physical environment (Detyna, 2023). These challenges highlight the need for a comprehensive approach to effectively manage and optimise HyFlex learning environments. This article conceptualises and develops a model to find such solutions.

Within our approach to HyFlex, we facilitate the ability to see online students in-class by using a large screen displaying the face and facial expressions of the online students.

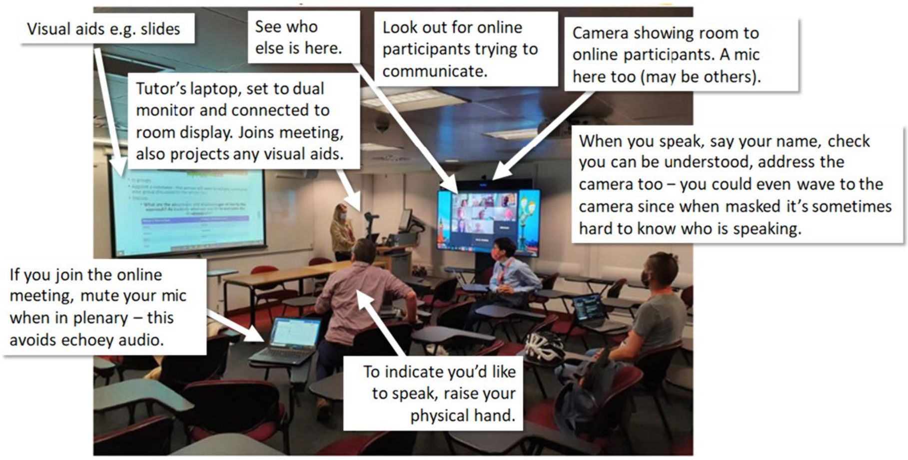

Fig. 1 Outline of the King's HyFlex system from guidance material (Image credit: Mira Vogel)

This allows a virtual space whereby online and on-campus students can see and hear each other. As well as the technical implementation, an induction programme was implemented to ensure that staff were acquainted with the technology, including micro-teaching opportunities to ensure that staff could consider the pedagogy of the space. This article provides an overview of some of the implementational challenges of this approach, particularly how such challenges can be overcome. The elements of learning environments being studied in this paper are the pedagogy, space, and technology (Radcliffe, 2009) related to synchronous HyFlex learning.

In this article, we seek to answer the research question: "How does one understand and resolve the teaching and technical challenges inherent in synchronous hybrid flexible teaching?" In doing so, this work uniquely provides reflections and discussion of methodological issues, specifically around resolving problems within synchronous HyFlex environments. It defines and explains the approach, gives a case study of how it has been implemented, and analyses and details methods for finding solutions to challenges. Specifically, what is novel in this paper is that it seeks a conceptual model for understanding, and a general approach for considering and finding solutions to issues. This can be of great use for creating effective strategies for practitioners and enhancing the student experience in HyFlex learning environments.

Literature

This article is primarily aimed at those currently using HyFlex and intended to conceptualise and resolve issues with their approach. Nonetheless, a short introduction to the literature is important. We should also clarify what literature we are covering here and why. Firstly, we cover literature on how to consider the general case – any technology in a learning space – and how the literature (e.g. Roberts, 2009) suggests that we should conceptualise that. Secondly, we look at the literature more specifically about hybrid learning, particularly the debate about adoption. Thirdly, we focus on existing methodologies for dealing with issues on this subject.

Setting the scene – conceptualising technology in learning spaces

Before we go further, it is important to provide a clear conceptual lens for understanding the issues. Radcliffe (2009) suggests that any technology in a learning space should be considered with three inter-connecting elements: pedagogy, space, and technology. Each of these three areas interacts with and affects the others, and needs to be considered to ensure an effective learning environment. Additionally, when considering technology in a learning space, we should be aware of Mishra and Koehler's (2006) TPACK framework in which technology, pedagogy, and content knowledge all are important forms of understanding, and with institutional understanding at the intersection of all three being important to ensure that effective technology enhanced learning occurs. Our research focused primarily on technology and space, but additional work could focus more on content-based knowledge. Further, we should understand that hybrid flexible learning – fully synchronous learning with a mixed cohort of students both online and on-campus – builds on previous techniques and approaches. In particular, it is worth considering previous approaches such as blended learning, as described by Castro (2019).

Overview of HyFlex

The first UK implementations of fully synchronous HyFlex were outlined by Sanchez-Piziani et al. (2022) and Detyna et al. (2022). These built on previous approaches that were not always fully synchronous, such as Beatty's (2019) approach which also included asynchronous teaching. One of the most detailed literature reviews on the subject by Raes et al. (2020) details understanding of the area and current gaps in the literature, one being technical problem solving which this article hopes to help to resolve. Further points include managing the technical complexity of multi-modal instruction, time, workload, and administrative processing. Shek et al. (2022) and Mentzer (2022) have written on student perceptions, the former describing overall satisfaction with the lecture and the latter focusing on it being an effective model and providing flexibility, sense of community, and challenges including technology and online non-contributors.

International context

Taking a broader international perspective, researchers in other countries have previously adopted the approach including in Netherlands (Raes, 2019), France (Gobeil-Proulx, 2019), and Australia (Binniweis, 2019). Following COVID and the UK implementation, a number of other countries have directly made reference and connection to the King's approach including Malaysia, Ireland (O'Ceallaigh, 2023), and China (Wong, 2023), among others (e.g. Mentzer et al., 2023). In an international longitudinal study, Wong (2023) has shown that institutional support, teacher understanding, and appropriate use of technology are critical for success.

The synchronous HyFlex approach (adopted at King's and in the UK more generally) contributes to our knowledge and practice of teaching and learning in several ways. For example, Mentzer et al, (2023) have shown that there is much greater grade distribution, with some students learning synchronous HyFlex gaining more As and more Fs than those learning only face-to-face.

Existing mechanisms for ensuring that technical and other issues can be solved

As stated, there are issues with pedagogy, space, and technology that need to be addressed. Issues with the space can be further broken down into areas such as safety-related issues (particularly relevant given how the set up at our institution was organised during the pandemic), and areas around acoustics. Acoustics in this context have been covered in detail by Sanchez-Pizani et al. (2022), who analysed the relationship between room acoustics and audio quality, noting both human perception of sound quality, as well as mechanisms to reduce noise, have a social component.

When considering pedagogy, there already is an emerging body of literature. Wong (2023) found that the interaction in HyFlex allowed students to become responsible, proactive, and autonomous towards their own learning. Gobeil-Proulx (2019) argues that "there are several factors that can impact a Hybrid course" and that "the classroom, the quality of teaching and competence of teachers in using technology may have a greater effect on satisfaction with a co-modal course than the course format itself". When looking at the pedagogy, we should note that specific tools (such as Flipgrid) have been shown to be beneficial from a student perspective (Keiper et al., 2021).

Synchronous HyFlex and student learning outcomes

There is an emerging literature on the subject of synchronous HyFlex and student outcomes. With respect to student focus, Raes (2021) found both online and on-campus students gained comparable grades in terms of conceptual understanding. As well as this, in-person students had greater levels of affective engagement. By contrast, Boylan et al. (2022) stated that student engagement was also highlighted as a challenge, but the majority of the students asked felt that the academic quality was equal to that of in-room delivery. Rhoads (2020) found a positive relationship between course attendance flexibility and student satisfaction, but no significant difference between mode of course delivery in their impact on final grade average. Mentzer et al (2023) also found no mean grade differences but a greater spread of higher and lower grades with the same average, suggesting that HyFlex is an appropriate mode of teaching in terms of student learning outcomes. Of course, as with any educational situation, the effectiveness of teaching should be borne in mind, and Maulana et al. (2023) provide some insights into international perspectives and methodological practices in effective teaching more generally.

Because Park et al. (2007) found evidence of disparate student opinions on blended learning, we should be mindful of that when considering the related approach of HyFlex. Maloney et al. (2020) considered ways to adopt the HyFlex approach, and Cilliers et al. (2020) found that, when using online teaching, additional technical support was needed to meet educational outcomes. Zydney et al. (2019) found a number of effective practices, including simplifying the technology set up, providing upfront training for educators, and involving students in troubleshooting and facilitating the technology. This last approach was also used, considered, and adopted to some extent independently at this institution. Overall, then, it is clear that challenges exist with any adoption of HyFlex, including a gap in the literature concerning an effective problem-solving approach to address these challenges.

Methodology

Our methodology was suited to answering the research question concerning how one understands and resolves the teaching and technical challenges inherent in synchronous hybrid flexible teaching. Developing a conceptual model requires a systematic methodology to ensure that it comprehensively represents the system of interest. The first step in developing the conceptual model was to define the problem or system to be modelled, including identifying the key components of the system, their relationships, and any constraints or assumptions that need to be taken into account. Next, a literature review was conducted to gather information about similar systems or previous research that can inform the model's development. The key research question that we hoped to answer was: "When using a synchronous hybrid flexible learning approach, how can one conceptualise and resolve issues to ensure good student experience?" Nõuaka et al. (2023) also have written about the specific problems with HyFlex learning, again noting that considering problems is the first step towards finding a solution.

The main step involved experiential learning, as initially defined by Kolb (2014). Additionally, Roberts (2018) has described how experiential learning can be used to inform and create research in higher education, explaining how it can be used to research and create conceptual models based on practitioners' own experience. This was the key approach to developing the conceptual model of the problem-solving approach defined later. Once a sufficient understanding of the system had been obtained, the conceptual model and approach could be formulated and then described in writing. Separately, we recommend that the model should be tested and validated through simulations or other means to ensure that it accurately represents the system. Finally, we recommend that the model should be continuously refined and updated as new information or insights become available.

In outlining the methodology for problem solving, we started with understanding of the nature of the problems and gathering concerns and potential problems. Once these were outlined, one could work with a range of potential tools to find appropriate solutions. Some aspects of this approach build on research by Guenther (2013) who proposes a methodology with seven phases of work. Kim et al. (2018) argue that problem solving as a skill is important for innovative behaviour (such as the innovative learning environments in this situation).

The method for developing the problem-solving approach is based on ideas from Creswell (1994). Specifically, the initial stages of the research involved gathering information from the literature and building an understanding from that. As stated, the conceptual model results from lived experience of using this specific combination of technology and learning space. We suggest that this model can be further evaluated and assessed against relevant data in a subsequent paper to confirm its validity.

Developing the problem-solving approach

Our problem-solving approach has the following three specific stages based on the previous research outlined above.

Understanding the nature of the problems

One of the key steps in addressing problems is understanding the initial problem. One simple way to conceptualise the larger nexus of interlinked problems is to break it into smaller issues. Dailio (2017) argues that the key steps with identifying a problem are to: quickly

Table 1 Example 2 × n matrix problem

Challenge	Solution
Teaching issue 1[a]: Lack of student engagement of online students	[To be considered through mechanism below]
Teaching issue 2: Concerns around online/on-campus student interplay	
Space issue 1: Concern over reverberation causing noise and consequent audio quality issue	
[Additional issues to be added here]	

These are labelled as teaching issues but could also be considered as technological mediation interfering with a conducive learning environment, and how to address this inventory all the core problems; then scrutinise problems from relevant areas; and not focus on rare events or trivial problems. He also argues that one should initially focus on understanding and conceptualising the problem or problems before attempting to find any resolutions. Examples of this are listed in Table 1. We should also note we use the word “issues" throughout, but other terminology (e.g. “hygiene factors" in education, meaning those factors which are necessary for people to work) could also be used.

Gathering concerns and potential problems

Rhodes (1999) discusses Murphy’s law in the context of its originator Edward Murphy, an acclaimed aerospace engineer. The notion that “anything that can go wrong will go wrong" can be seen as negative but, in the context of aerospace engineering, considering every possible problem and finding a solution for it in advance can help save lives. Equally, more broadly with technology in an educational setting, it is important to pre-emptively gather potential problems and find solutions for them. This can be accomplished through a number of mechanisms, including group discussion and self-reflection.

Once the system and approach are in general use, there is a range of ways of gathering additional concerns and problems. Feedback is regularly given by academics using HyFlex teaching. King’s College Audio Visual (AV) staff are regularly told about potential or current problems, as are IT staff and other academics. In-room assistants were also hired on a temporary basis (as a solution to deal with the surge of demand and lack of academic experience at the start of term), and they were also a source of information on specific problems.

Organising the problems into appropriate areas

As previously mentioned, Radcliffe (2009) suggests that any technology in a learning space should be considered with three inter-connecting elements: pedagogy, space, and technology. The pedagogical aspect can be broken down further into staff and student challenges. As noted previously, we should be particularly attuned to issues of learner engagement. Space challenges relate to the room and environment. Technological issues can be audiovisual or related to the software and technology and its interplay with education (also known as technology enhanced learning). So, each of the three areas of pedagogy, space, and technology can be dealt with separately. Breaking down larger problems into a series of smaller challenges, and then organising them appropriately, helps to resolve them.

The key point here is to organise a $2\times n$ matrix (where n is the number of potential issues). Each problem can be listed and then organised by group (for example, into pedagogy, space, and technology, staff and student challenges). At this point, we have the beginning of a problem-solving matrix and then need to consider mechanisms for finding solutions.

Mechanisms for finding solutions

There are a number of mechanisms for finding solutions to challenges, including:

1. Self-reflection
2. Peer discussion
3. Connecting to the literature

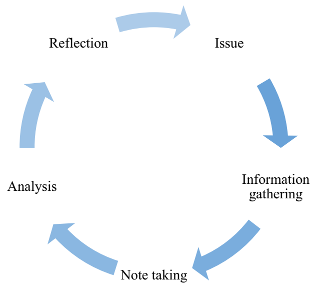

Fig. 2 A potential cycle of reflection and analysis, starting with a specific issue

4. Relevant subject matter experts
5. Using common sense
6. Learning through experience and teaching
7. Experimenting with potential solutions

It's worth noting that, because some challenges cannot be resolved immediately, they need to be reflected upon further, often through an iterative method of trial and improvement.

Self-reflection

In considering how to resolve challenges, Dalio (2017) suggests that you should remember to reflect when you experience pain, arguing that this process of calm self-reflection after an issue is crucial to helping to resolve it in future. Self-reflection is used in many disciplines, but Bengtsson (1995) argues that it can be a key benefit to educators, and indeed, the Professional Standards Framework for HE in the UK (HEA) regards it as a key skill. The experience of the authors of this paper is that nearly all solutions to major problems came about through pausing and self-reflecting on specific aspects of challenges.

The cycle in Fig. 2 builds to some extent on work by Guenther (2013) who proposed a framework of seven steps: prepare, discover, define, ideate, validate, implement, and deliver. However, it is worth describing the method of defining and ideation (detailed in Fig. 2). Delivery can be considered as a separate area. The reflective cycle in Fig. 2 considers in more detail how to reflect, starting with an issue and then gathering information and using it to make notes on the problem. Taking time to analyse and reflect will then help in coming to a solution. Analysis consists of taking time to examine and understand an issue, while self-reflection can be used to consider possible solutions. If finding answers individually is not leading to answers, another option is to consider discussion with peers.

Peer discussion

Rubin et al. (2006) provide examples of how peer discussion and collaboration can help in resolving issues in the context of child development, and this is equally true here. Cheng et al. (2011) build on this in a workplace context, arguing that their results show the beneficial effects of support for promoting a norm of cooperation on employees; and this has certainly been the experience in this project. Peer discussion and collaboration can help in finding solutions and consider issues from a different perspective.

Connecting to the literature

Relevant existing evidence can help in understanding how to conceptualise a problem and consider addressing it. It is rarely the case that there is a ready-made solution to a specific problem. However, by understanding how others have encountered challenges in the past, one can obtain a sense of the scale and nature of the problem which, combined with self-reflection, can help in finding solutions. One clear example is the problem of cognitive load – that is, when lecturers engage with teaching, students, names, and learning objectives but must also think about technical set up, audio, cameras, etc., they can become overwhelmed with cognitive effort. The literature highlights this as a problem, particularly Binneweis et al. (2019) and Raes (2019) suggest that writing down specific issues on a page is one possible start to a solution. While having an issue written down clearly isn't the same as resolving it, having a sense of the scale of the issue and the language used to describe it can help in understanding it further and prompt further reflection on specific solutions.

Consulting with relevant subject matter experts

With this project, there are specific professional services and academic departments that could help to provide ideas and solutions. Specifically, there is a concentration of expertise around pedagogy in the King's Academy department, pedagogy, and digital technology in our Center for Technology Enhanced Learning, and AV design in the AV solutions team. Specific staff can be called upon to consider and try to help to find solutions to, specific problems. Frequently, this involves some combination of previously named approaches, including existing literature and self-reflection, alongside utilising their expertise.

Using common sense

While this might seem like an obvious point, sometimes, one can miss the wood for the trees, and what might seem to be a very conceptually difficult or technically challenging problem can be addressed through common-sense solutions. Flach et al. (2016) describe the benefits of using common sense in connection with cognitive science and technology. Often, simple, straightforward and non-technical approaches can help to resolve issues. An example of this would be the additional noise in the HyFlex environment. While acoustic noise can be dealt with through different types and positions of microphones, Artificial Intelligence (AI) to help with noise cancellation and other technical solutions, it can also be resolved through more basic approaches (e.g. good classroom management protocols and students keeping quiet to ensure that in-room noise is minimized without a technical solution).

Learning through experience and teaching

Learning about and understanding problems through teaching about them are an approach that can be adopted. In fact, Koh et al. (2018) found that the notion that teachers learn through teaching is not just an idea, but it also has good evidence as a basis. This approach has involved teaching and inducting hundreds of academics into this method. Questions, queries, concerns, and discussions through this process have helped to crystalise procedures for finding appropriate solutions (e.g. finding approaches to deal with the challenge of cognitive overload for academics). Through the experience of engaging with teaching, we can also gauge the extent to which potential problems are genuine issues in the real world.

Experimenting with potential solutions

The scientific method is a powerful tool for reviewing and researching educational technical tools. As Wainer (2011) noted, Feynman (1963) has argued: “It doesn’t matter how beautiful your theory is. If it doesn’t agree with experiment, it’s wrong”; one needs reasonable evidence. Experimentation, with the understanding that the approach tested might be wrong, is key to this. Crucial to the scientific method is the notion of putting forward a hypothesis and then testing it. This hypothesis can be quite speculative, so long as it is subsequently tested through experimentation.

Testing can be used to consider different software options, and for in-room hardware tools, specific metrics can be used against a range of possible tools to consider their efficacy. This has been used to verify if potential digital tools are worthwhile (e.g. specific digital collaboration tool being tested in situ to confirm that it is appropriate; Detyna & Dommett, 2020) and further specific acoustic solutions have been tested to see how well they perform in practice.

Beyond the classroom: organisational strategy and implementation

As well as issues around problem solving, it is also worth considering the area of change management and support.

Induction

In addition to overall implementation, a complete guidance website with details on our virtual learning environments was created. There was also a range of induction opportunities which paired a webinar together with face-to-face training. The webinar provided the opportunity for self-reflection and providing those moments with leading questions proved beneficial in creating a problem-solving mindset. Because we should be mindful of upskill fatigue, as White (2021) mentions, and so there was a range of options for staff to engage with this approach to make it easier to implement.

Practical training

There also were practical opportunities offered to staff, including in-person training and the testing room. Academics were given an opportunity to micro-teach colleagues for a few minutes in an informal sandbox setting and experience the space as both a “student" and an educator. This allowed a more practical understanding, with relevant technical support being provided for this.

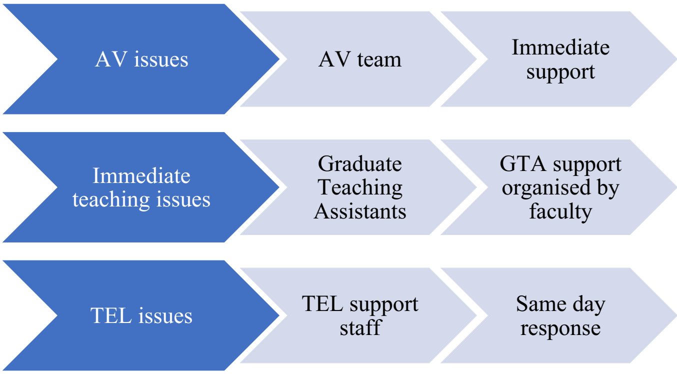

Fig. 3 Support model for in-classroom issues

Practical support

In order to provide support for staff with issues in-class, there was developed a support system so that issues with AV equipment, technology, or teaching could all be resolved appropriately (see Fig. 3). One of the issues was that support for different issues might have different response times, and additional surge support was given at certain times of year.

Because there would be a surge in support queries, a number of additional temporary staff (primarily recent graduates) were recruited at the start of the year and at the start of term. These staff were inducted and trained in technology, pedagogy, and customer service to ensure that they felt calm, ready, and supported. This helped to ensure a smoother start and better engagement. Feedback from participants and staff was positive. This comment from a recent graduate support worker was typical: “I know you don’t want me to be falsely positive, but I have genuinely had a fabulous experience working here. It has really helped put lecturers at ease and made them feel more relaxed at solving issues themselves.”

Oversight and local support

In addition, there were a number of mechanisms for oversight at our institution, including a main institutional board to create a sense of community and sharing ideas of HyFlex uses and best practice. This allowed frequent feedback and peer-to-peer support. Additionally, each of the faculties was advised to provide support locally with members focused on teaching, technology, and coordination.

Iterative improvement

Additionally, through feedback, comments, and advice, iterative improvements were able to be made. New technical approaches were used; new support mechanisms were tried out and included. Once the implementation was live, numerous challenges and problems were encountered, and the $2 \times n$ matrix method was introduced to address them.

Table 2 Examples of potential problems and solutions related to in-room classroom management and technology and teaching issues

Challenge	*Solution*
1 The lecturer is a few minutes late starting the online session, and online students are left unclear what to do.	Recommend having a graduate teaching assistant (GTA) to provide a spark for discussion and to welcome students. Give clear instructions on the Virtual Leaning Environment (VLE) or verbally for this circumstance.
2 Not knowing the technology.	Recommend lecturers have already completed training in Teams, and to try out everything, they want to do with a member of the AV team in the room review guidance, practice ahead of time, and ask for help from local digital education team.
3 Teaching issues: Students not feeling engaged online and face-to-face.	Welcome all students and try to aim for smooth transitions between sections. Try to ensure their eyes look at the camera and the students in the room to ensure equity for all students. Consider vocalising their actions to clarify what you are doing to online students. Consider getting a GTA/student volunteer to state words to the effect of "Please bear with us" if there are technical issues. Ensure only one person in the room speaks at a time.
4 Technical issues: audio quality poor, or video issues.	Recommend staff repeat statements made by students at the back of the room, and staff are aware of where the camera faces and does not face, and where you can/cannot be seen. Students should have their microphones off in the room. Larger rooms (with space greater than 49 square metres) will have a second microphone at the back to make hearing students easier.
5 Lack of clarity for students in the session.	Plan out the session appropriately with relevant pace and allowing time to complete all tasks. Advise them to be patient. Recognise that things may not work perfectly initially**.** Signposting to students to use relevant guidance.
6 Lecturers feeling overwhelmed.	Lecturers advised to try not to do too much too quickly. We recommend preparing the session well ahead of time and preparing yourself mentally. Be aware that this approach is not for everyone and look at other methods (e.g. fully online) if this is not the approach for you.
7 Safety concerns.	All staff and students were recommended to wear a face covering during the pandemic. We recommend that staff are aware of institutional guidance on Coronavirus safety and advice on staying safe on-campus.
8 Recording students without consent.	Recommend lecturers are familiar with the relevant policy stating that recording of seminars "is not permitted without obtaining opt-in consent at the beginning of such activities of the lecturer and all participants". The camera by default should be facing the lecturer. Ensure you get consent from any students if you're thinking of recording the session.
9 Lecturer wants to move around the room.	Advise lecturers to be aware of where the camera is facing and adjust if appropriate.

Table 2 (continued)

Challenge	*Solution*
10 Students online feeling ignored.	Make a point of welcoming students and talking to online students throughout the session.
11 Students online finding it difficult to hear because of cross talk.	Recommend one only one person in the room speaks at a time.
12 Lecturer not being confident with software.	Recommend staff review guidance, practice ahead of time, and ask for help from their local digital education team.
13 Sharing with video through Teams without sharing "computer audio" and students online cannot hear.	If you are sharing audio content online on Teams, share with "computer audio" so students online can hear.
14 Students online do not see slides.	Make sure you're confident with how to share slides in Teams and remember half the students are online.

Results

This section provides some case studies of application of the problem-solving framework (Table 2).

Table 3 Examples of potential problems and solutions related to organisational issues

Challenge	Solution
1 There is no one in a faculty to provide HyFlex technical training,	Building up capacity in a relevant faculty via a small group who really understand the technology and can pass that on to others.
2 There is no one in a faculty with a clear understanding of the teaching of HyFlex to deliver induction.	Ensure working with relevant departments to build up that knowledge, understanding and that capacity to help deliver training.
3 Induction is not properly organised in a given faculty.	Faculty to ensure there is proper induction and the people to provide it. Specifically, as well as webinar guidance, there are specific people assigned for in-room support.
4 There is inadequate support in-room.	Build up mechanisms for in-room support.
5 Staff members in a faculty feel they do not have enough support with their teaching.	Ensure there is a base of knowledge understanding with an academic champion prepared to listen, give guidance and support, and who really understands the space, technology, and teaching requirements.
6 Graduate teaching assistant (GTA) support—there is no one organising, training, or supporting GTAs.	A staff member needs to plan for both coordinating and managing—who is working with them and organising the logistics of the times they'll be there.
7 Students don't know what HyFlex is, don't know what to do, and haven't read guidance.	Make sure (a) students have a clear sense of what HyFlex is, (b) students have read HyFlex guidance, (c) you communicate this to the right audience – only inform the students that need to know.

Examples of challenges and solutions on mitigation

As well as at classroom level, there are also wider organisational and faculty issues. Wider organisational issues are detailed in Table 3.

Examples of school and faculty-based issues and solutions.

Inducting staff

It is recommended that faculties ensure that there is a clear mechanism for inducting new staff. This will only work if there are capacity and knowledge in the faculty regarding the areas detailed above, as well as plans to build that knowledge further. It is also recommended that there is regular communication with staff members explaining what HyFlex is, how it works and how it's being coordinated, including making sure that both students and staff know what guidance and support mechanisms are available within the faculty. Teaching fully online or teaching fully face-to-face are a lot easier for lecturers, whereas attempting to do both simultaneously and teach and use technology does have its challenges, although they are not insurmountable. HyFlex was rated more highly than fully online teaching in the staff feedback.

Student equity issues

By definition, there are going to be two groups in every HyFlex session: one half online and another half in the room. Ensuring parity of experience is important. We have suggested a few ideas (e.g. maintaining eye contact; alternating between in-room and online students) to help address this challenge. This is an issue that came up a lot in the feedback. Staff need to be aware of this challenge and be proactive in finding solutions.

Discussion

Overall, this research provides a clear model for understanding and conceptualising the nature of problems and issues in hybrid flexible learning, as well as for addressing them. Some of the techniques here build on those described by Zydney et al. (2019) and Raes et al. (2019), particularly understanding the interplay between technology and teaching and how they cannot be seen in isolation.

It is important to understand the importance of the TPACK framework of Mishra and Koehler (2006) for both providing induction and understanding the nature of challenges. Technology and pedagogy both interplay with content knowledge, with each of those areas being important. Challenges in a number of areas of Mishra et al.'s framework have come up and been addressed or at least mitigated using the $2 \times n$ matrix approach. There is a large variety of challenges which are encountered when using HyFlex teaching, and this methodology works best when issues are categorised appropriately. We should be mindful though that, while the bulk of the examples in the cases studies of the framework illuminate teachers' (and teacher-educators') "technological knowledge" dimension of TPACK comprehensively and well, the other areas could be further developed. We should also be mindful that, while technical issues are no less important than pedagogical issues, all could be considered further. In the future, pedagogical issues around what kinds of subjects or teaching strategies are amenable to HyFlex, and around how these might be variously taught, could be addressed. This would also involve the study of psychosocial and material issues of how students can be enabled to connect with each other and participate fully without deficit.

Analysing the overall methodology, it is important to consider how different approaches can all be relevant and beneficial for finding solutions. In an academic setting, reflective cycles and using the academic literature are familiar to many, while simpler solutions such as using basic common sense can often be overlooked, as Flach et al. (2016) argue. Further, reflecting in an appropriate way is crucial – the Gibbs reflective cycle is fully appropriate for analysing teaching, but different forms of reflective cycles need to be considered to fully understand and resolve teaching technology challenges.

The work builds on Raes and Zydney (2019), but rather than just describing existing approaches, it sets out a methodology to resolve and consider new issues going forward. One of its potential benefits is that it can continue to be adapted and be used in the future. Further, this work builds on some of the ideas expressed by Binnewies et al. (2019), but it is broader and addresses not just teaching approaches, but technical and learning environment areas as well.

The results suggest that problem solving can be understood as a set of approaches which can be defined and improved upon. In addition, these problem-solving approaches can be taught to others and disseminated more broadly. Reviewing this study critically, we recognise that it used the analysis of issues to describe a methodology. It is therefore a declarative approach, showing a methodology and its potential benefits. The key point is that, because this is an example of the framework applied in one setting, this would need to be applied to other settings and evaluated for effectiveness. To enhance the rigour of this approach, it would be necessary to conduct a thorough review.

Also, it is important to consider some broader issues related to teaching support. It is important for universities to build in mechanisms within faculties to allow staff to voice problems and be provided with support. Because HyFlex is a cognitively challenging approach, staff want to feel supported (Raes, 2021). There are benefits for students in terms of flexibility, as Zydney et al. (2019) noted. In general, feedback from the institution has been that HyFlex is better than online teaching. Student feedback is more positive, but it is also mixed. Lecturers need to reflect on this and consider how to ensure that students have a positive learning experience.

The learning environment literature has a number of authors who describe challenges and problems with HyFlex (e.g. Binnewies 2019; O'Ceallaigh, 2023). But the challenges are rarely fully addressed, and what is lacking is a clear mechanism and structure to resolve issues with it. It is hoped that this paper sets out a clear approach to fund such resolutions and thus makes a unique contribution to research, but more importantly directly to practice.

The approach detailed here could be broadened to a number of other circumstances related to technology in learning spaces or more generally with technology. Problem solving more generally clearly has wider applicability in education as an assessment instrument. Teaching problem-solving skills has long been known to benefit students as Wood et al. (1975) and Kim et al. (2018) have argued. The $2 \times n$ matrix methodology could well be used in a broader set of circumstances. Future research could test to what extent this model is valid, and in what circumstances. This research describes a model and process for finding solutions via hybrid teaching technology and this teaching approach. As Feynman states in Wainer (2011), it is important to recognise based on evidence if an approach is working, and further research could be done. Future research could assess the extent to which this approach provides optimum solutions, as well as considering other approaches.

Conclusions

In conclusion, a model for finding solutions and resolving issues with hybrid flexible learning environments has been described and discussed. This could have wider application across universities post-pandemic. Conceptualising and resolving this are in a learning environments that context is crucial to resolve these issues altogether, rather than in isolation. A mechanism and approach for conceptualising problems and codifying them have been considered. Further, a potential approach for finding solutions has been outlined and reviewed. Applying these approaches to this relatively new form of teaching has produced a clear methodology – the $2 \times n$ matrix methodology. Future work could build on this research and focus and incorporate it more into the pedagogical content knowledge of the TPACK framework. This allows relevant stakeholders to provide input and ensure a positive outcome. It works well in resolving issues in digital education, and future research could involve further evaluation to assess its broader application.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or relationships that would have influenced the work reported in this paper.

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