Learning Environments Research (2023) 26:271–289
https://doi.org/10.1007/s10984-022-09431-z

HyFlex environment: addressing students' basic psychological needs

Nathan Mentzer[1] · Bhawna Krishna[1] · Ankita Kotangale[1] · Lakshmy Mohandas[1]

Received: 7 August 2021 / Accepted: 19 September 2022 / Published online: 28 October 2022

Abstract
Active learning strategies engage students and promote student-centered learning environments. Implementing active learning in a HyFlex environment during the Fall of 2020 global pandemic was challenging. We describe the *Interactive Synchronous HyFlex* approach to teaching design thinking at the introductory college level and explore impacts on students' basic psychological needs, including autonomy, competence, and relatedness. Aligned with Self-Determination Theory, active learning has been shown to motivate students and increase performance and retention in science, engineering, and mathematics disciplines, among others (Freeman et al., 2014; Lo & Hew, 2019). In active environments, the predominant mode of instruction is not lecture based and it engages students through student–to–student interactions and student–to–instructor interactions. The flipped classroom is a pedagogical model in which the typical lecture and homework elements of a course are reversed. This model of instruction is ideal for our design thinking course used as a context for this study because students are challenged to learn by doing. In active learning courses, students engage in video-recorded lectures or talks, text-based materials and online quizzes, or other preparation activities before and in preparation for class (Bishop & Verleger, 2013; Lo et al., 2017; O'Flaherty & Phillips, 2015). Scheduled class meeting time is used for engagement and interaction between students informed by a social constructivist learning theory. Students challenge each other to apply what they have learned with guidance and support from the instructor.

Keywords Basic psychological needs · Design education · Design thinking · HyFlex

✉ Nathan Mentzer
nmentzer@purdue.edu

[1] Technology and Engineering Teacher Education, Purdue University, 155 S. Grant Street, 47907 West Lafayette, IN, USA

Introduction

Social constructivist learning

According to social constructivist theory, "learning concepts are transmitted by means of language, interpreted and understood by experience and interactions within a cultural setting" (Akpan et al., 2020, p. 50). This theory emphasizes peers and instructors as co-constructors of knowledge along with the student. Pedagogical strategies in our design thinking course leverage problem-based learning (Akpan et al., 2020) with teams of students being challenged to identify a problem, develop a deep understanding of the problem, brainstorm potential solutions, select a viable solution and test it as they engage in our social constructivist pedagogical approach to learning design. With this approach, students can share their design ideas with others and be challenged by their peers' varying perspectives and interpretations of what constitutes a problem or what solution is the 'best' for a given context (Wright, 2011). The instructor's role is more aptly described as a 'facilitator' and involves guiding student groups by providing appropriate prompts and using questioning techniques that lead to achieving their objectives (Pedersen & Liu, 2003). Basic psychological needs inform this collaborative approach to learning including autonomy, competence, and relatedness. Further, collaborative learning has been shown to directly increase student relatedness, which is critical for a sense of community and retention (Laux et al., 2016). Student-centered learning settings enhance students' learning desires and students' quest for understanding while providing an engaging pedagogical strategy (Land & Hannafin, 1996). The goals of student-centered learning include encouraging students to be responsible and make decisions to generate responses for the problems.

Self-determination theory

Human motivation is the main focus of Self-Determination Theory (SDT) (Deci & Ryan, 2008). Within SDT, individuals are active, determined to their personal growth, seeking opportunities to address the challenges in their surroundings and embracing their potential and capability (Ryan & Deci, 2002). SDT provides a structure for understanding motivation and understanding the learner's personality traits, which is why it is ideal for our study of face-to-face and remote learners (Audet, Levine, Metin, et al., 2021). The engagement of a person on a task within a particular environment also depends on whether the environment is flexible, so that the student has autonomy rather than being closely controlled (Audet, Levine, Holding, et al., 2021). According to SDT, many factors influence student motivations, including peer–teacher communication. Support from the instructor is an important factor that keeps the students motivated (Chiu, 2021). Student motivation is essential for learning and even more critical in an online environment (Chiu, 2021).

SDT is a general theory that has a few specific instantiations. Basic Psychological Need Theory (BPNT) is one of six narrowly-focused variations of SDT (Deci & Ryan, 1985; Ryan & Deci, 2000). BPNT states that humans have three universal and basic needs: autonomy, competence and relatedness. The satisfaction of these needs is essential for human development and well-being. Ryan and Deci's (2017) Proposition II states that autonomy support plays a critical role in creating a supportive environment and actively satisfying people's needs. "When there is support for autonomy, people are more able to seek out and find sat-

isfaction for both competence and relatedness as well" (Ryan & Deci, 2017, p. 247). Each of the three psychological needs is important and are interrelated, which directly impacts people's wellness and mental health (Ryan & Deci, 2017) Chen et al., (2015) suggested that the satisfaction and frustration component of each of the three needs is an important predictor of human well-being. Hence, in our study, we looked to these measures as a barometer to measure the success of the HyFlex model and its impact on students' psychological needs.

Among the three needs, the first need of Autonomy is defined as freedom of choice that should not be misconstrued as being independent (Levesque-Bristol et al., 2010). The students can have the freedom to make their own decisions often through choices provided by the instructors. Choices are posited to enhance students' perceptions of autonomy and to build a positive learning environment (Levesque-Bristol et al., 2010). When the students feel satisfied, they feel freedom to make decisions based on their interest in the course. In addition, they also can feel a sense of frustration if they feel pressured and forced against their will to engage in learning activities that they do not prefer. Competence refers to one's capability to effectively fulfill what is required through classroom expectations (Levesque-Bristol et al., 2010) and is established when students feel capable and confident that they can achieve their goals in the course. They experience frustration related to competence when they feel disappointment and insecurity, which lead to lower grades. Levesque-Bristol et al., (2010) found that students feel competent if they can fulfill course expectations and achieve good grades in a course. The third need is Relatedness which signifies connectedness among students when they collaboratively work together and have engaging interactions with their instructors (Fedesco et al., 2019). Fedesco et al. emphasized that, in the field of education, when students are involved in discussions and are allowed to interact with each other freely, there is created an ideal learning atmosphere in which they feel intellectually and emotionally connected, and this enhances their sense of relatedness.

Implementation of HyFlex learning in a design thinking course

The spring of 2020 emergency transition to online teaching happened almost overnight (Adedoyin & Soykan, 2020). However, establishing healthy and productive online programming that fits the needs of students can take years. This transition came with many challenges for both students and instructors, from technical to psychological, including issues such as login problems, audio and video problems, and software downloading. Many students were restricted to a home environment where they balanced their academic demands with work and family, which in many cases led to a lack of concentration on their studies (Dhawan, 2020). According to Dhawan (2020), students lacked two-way communication and opportunities to practise what they were learning, had difficulty understanding the instructional goals and struggled with a severely-limited sense of community with their peers and instructors. Further, the instructors and students faced psychological challenges such as stress, anxiety, depression, and lack of concentration (Dhawan, 2020).

Our design thinking course resumed face-to-face instruction during the summer of 2020. To meet and accommodate the changing demands and uncertainties of the pandemic such as being sick and quarantine requirements (García-Morales et al., 2021), we developed and implemented a specific version of HyFlex to meet the needs of our course and learning climate. HyFlex is a general term for learning environments that blend face-to-face and online learning modalities in a course setting where students choose how they want to engage in

the course (Beatty, 2019). HyFlex gives a platform for instructors to provide the learning material online as well as face-to-face (Abdelmalak & Parra, 2016). Coordinators of the Tech 12000, Design Thinking in Technology course at Purdue University in the Polytechnic adopted and implemented a specific approach to HyFlex learning environment that they named the Interactive Synchronous HyFlex in an attempt to provide high-quality, uninterrupted education to their students during the turbulent fall of 2020. We define the Interactive Synchronous HyFlex model as an instructional model that provides an interactive, engaging, and equitable classroom experience for students regardless of whether they choose to join each class meeting face-to-face or remote synchronously. The Tech 12000 course used Microsoft Teams software as an online platform for face-to-face and online students to connect to their peers and instructor during each regularly-scheduled class session. Students could choose daily whether to attend face-to-face or online according to their needs. The instructors of each section were provided with wireless headsets so that they were audible to the students who were face-to-face and online during the sessions. The face-to-face students were expected to connect to the university's network and keep Microsoft Teams open on their laptops so that the online students could communicate with their peers. There was an appropriate physical distance between the students and the class sizes were slightly reduced to meet university protocol. Although there was space in the classroom for everyone enrolled, students participated remotely or face-to-face as needed.

We hypothesize that our Interactive Synchronous HyFlex model would meet the basic psychological needs of our students. Students had choices in their participation daily in that they could decide, with no advanced notice or permission, if they wanted to be in the classroom or remote, which aligns with students' needs for autonomy (Reis et al., 2000). In the HyFlex model, both the online and face-to-face students were provided with the same instructional material, assignments, and same support from instructors and peers in group work, thereby providing support for their sense of competence (Reis et al., 2000). The course was synchronously online and therefore the online and face-to-face students were connected to the instructor and their peers, maintaining the student–student and student–teacher relationship. Because both online and face-to-face students received interaction and support from their instructor, the need for relatedness was addressed (Masland, 2021). We conducted this research to investigate the extent to which our Interactive Synchronous HyFlex model met students' basic psychological needs relative to the traditional experience. Further, we parsed HyFlex students into two categories: those who choose to participate remotely in one or more class meetings (we called them 'remote' students); and those who were not remote (they were in the classroom face-to-face or absent). We compared their basic psychological needs based on two research questions:

1. How does the Interactive Synchronous HyFlex approach to learning meet students' basic psychological needs compared with a traditional face-to-face environment?
2. In a HyFlex environment, are the basic psychological needs met equally well for remote and face-to-face learners?

Course context

The Purdue Polytechnic has a culture of design and innovation. Tech 12000, Design Thinking in Technology, is the leading course in the Design and Innovation Minor as an introductory design course for freshmen required for graduation by all Purdue Polytechnic graduates. Approximately 1344 students enrolled in the course during the Fall of 2019 and the Fall of 2020 combined. The key learning outcomes in the course are aligned with key design thinking processes such as problem definition, brainstorming, benchmarking, decision making, prototyping, and communicating results.

The course has been an active learning flipped course since 2012 with support from the Purdue University Center for Instructional Excellence. Students engage in three design projects as opportunities to apply what they are learning in a context that is relevant and engaging. The first design project spans about a week and is used to hook students into the course during the second week of classes. This project challenges students to interview each other to identify an opportunity to improve something with which a peer is struggling (typically time management, getting enough sleep/exercise, navigating campus, etc.) and this becomes the context for course content as well as a focus for reflection throughout the semester. The second project begins around the fourth week and runs for about four weeks. Students are grouped by major and challenged to identify an opportunity (problem) within their field related to safety and to develop a solution to it. As an example, students in construction-related majors might consider communicating and enforcing safety protocols on jobsites. Aviation majors could consider reducing aircraft noise for people living near airports or for airport employees. Students learn more about ethnographic data collection and begin to make models or prototypes that might not completely function, but demonstrate proof of concept. This project also provides a chance to work with peers in a longer-term group project which helps students to realize the challenges of group work in a collegiate setting as well as course-based supports such as assessments of peer contribution to hold peers accountable.

The third and final project spans the last eight weeks of the course and engages student teams in addressing a grand global engineering challenge (National Academy of Engineering, 2021). Students are scaffolded to identify an area of interest and then self-assemble in teams based on their shared interests and willingness to work together. After teams are established, the curriculum structures students through the now familiar design process from problem definition including observations, interviews and literature research to developing a solution to communicating results in a persuasive presentation. Students iteratively revise their problem statement as they learn more, engage in benchmarking to understand what currently exists, and develop working prototypes that demonstrate one or more key features of their concept. The top five of the culminating presentations are shared in a panel of expert judges to determine which two receive prize money to support their continued development.

Tech 12000 is administered in small sections of about 40 students each in a room with flexible chairs and tables, whiteboards for every team and chromebooks. Instructors are typically graduate students with an interest in teaching (either former secondary technology and engineering education teachers or future university faculty). Two coordinators (one associate professor and one senior lecturer) provide oversight and teach sections as well. The coordinators provide professional development for the instructors during the week prior to classes starting and each week during two-hour meetings throughout the semester. The

teaching team is generally experienced with graduate instructors typically teaching in the program for 2–5 years depending on what degree they are pursuing.

Study design and variables

For the purposes of this study, Fall 2020 was considered the treatment year as it was administered in a HyFlex model because of the global COVID-19 pandemic. This challenging time forced an overhaul of how participation in classroom activities was defined and became an opportunity to study student experiences. Data from the HyFlex approach (Fall 2020) is compared with the traditional approach which was most recently experienced in Fall 2019 in this quasi-experimental study. Specifically, this study used a pretest–posttest design with nonequivalent groups. SAT scores served as a proxy pretest in our design to ensure groups were not different academically.

There were four key variables in this study. SAT scores were used as a pretest to confirm that student groups were similar prior to the treatment experiences. Demographics were used to further investigate similarities between groups of students as evidence that groups were similar at the onset of the experiences. Each research question has its own pair of groups. Two pairs of groups were in this study: HyFlex vs. traditional experiences; and HyFlex students participating in person and HyFlex students who participated once or more remotely. Attendance data were available from 14 of the 19 sections, but unavailable from 5 sections, at the time of analysis. The outcome measure was adapted from the Basic Psychological Needs and Frustration Scale (Fedesco et al., 2019). All data were collected with University IRB approval.

SAT scores were collected by the research team from the University's application database. Most students in the course were in their first year in the Purdue Polytechnic. The SAT is a relatively-recent and standard measure of academic preparation and therefore a reasonable measure to use to measure academic similarities between groups. While most students recently took the SAT examination, a few students took the previous version of the SAT. Additionally, some students took the ACT examination. Further, some students took the SAT multiple times and/or both current SAT and previous SAT or ACT. Published concordance tables (The College Board, 2009) were used to convert previous SAT and ACT scores to equivalent current SAT scores. If students took multiple examinations, the highest of the SAT or SAT equivalent score available for each student was used in this study and is referenced hereafter as the 'SAT score'.

Demographics were also collected by the research team from the University's application database for analysis, including gender, ethnicity and residency. Class rank was obtained from the University's database as well. Gender was only available from the database as a binary measure (male vs. female). Non-responses were not considered in the analysis. Ethnicity was collapsed into White and Non-White as research in the STEM fields frequently uses this distinction for under-represented minorities vs. over-represented groups. Residency for this analysis was categorised as domestic or international. Class rank was measured by credit hours earned per student. While 0–30 credits typically cover the freshman year and each additional 30 credits is the transition point of the next rank, these numbers include transfer credits from other colleges at Purdue University, colleges outside of

Purdue University, and dual-credit high school and test-out programs. Thus, sophomores by class rank actually could be in their first year in our college.

The first research question involved potential differences between the traditional experience and the HyFlex experience. The grouping variable was the semester enrolled. Students in the Fall 2019 semester were the traditional group while students enrolled in Fall 2020 were the HyFlex group. All students in the HyFlex group knowingly signed up for a face-to-face experience, but some students were remote for one or more class days because of sickness (Covid or not) or other reasons (overslept, flat car tire, etc.). While students were encouraged to be face-to-face if possible, students were not held accountable to be face-to-face and had the autonomy to choose how they preferred to participate on any given day without providing documentation justifying their remote participation. For the second research question, students in the HyFlex experience were divided into two groups for comparison based on attendance records kept by instructors. Students who were remote for one or more meetings while their peers were in the classroom were considered 'Remote' students for purposes of analysis. Students who never participated remotely were considered 'face-to-face' students. Neither the actual number of days remote (if it was greater than 1) nor the number of days absent from class was considered in this analysis. The University calendar was modified so that all students were remote from Thanksgiving break to the conclusion of the term (2 weeks or 4 meetings). These 'remote' participating days for everyone were ignored from the determination to classify a student as 'remote' or 'face-to-face' so that we could identify students who were choosing to participate remotely for comparison against those who were not. Aligned with this decision, the measures of basic psychological needs were administered at the end of the face-to-face period just prior to transitioning everyone online.

To measure basic psychological needs, we chose an instrument derived from the Basic Psychological Needs Theory (BPNT) and adapted to fit the needs of our University's Center for Instructional Excellence IMPACT program. The IMPACT program supports course transformations towards a more student-centered active learning environment to increase student engagement, competence and learning gains. BPNT was operationalized into an instrument called the Basic Psychological Needs Scale (BPNS) by Deci and Ryan (2000) to measure the satisfaction of three psychological needs: autonomy, competence and relatedness. Chen et al., (2015) introduced a variation of the original instrument called the Basic Psychological Needs Satisfaction and Frustration Scale (BPNSFS) to parse needs satisfaction from needs frustration. This scale consists of 24 items in six subscales, each consisting of four items. Fedesco et al., (2019) found that the basic psychological need of relatedness was multidimensional in educational settings. Because of the critical and different relationships between a student and their peers and a student and their instructor, Fedesco split the relatedness construct into two elements to measure peer relatedness and instructor relatedness. Her research suggested that the satisfaction and frustration scales for these two additional dimensions were not necessary for classroom use. For purposes of this study, we used the BPNSFS as modified by Fedesco in 2019 with the IMPACT program. The six subscales of this instrument are autonomy satisfaction, autonomy frustration, competence satisfaction, competence frustration, relatedness to instructor and relatedness to peer. The reliability and validity of each of the subscales is shown in Table 1 with a sample question for each. Participants responded to each item on a 7-point Likert-type scale to indicate their extent of

Table 1 Reliability of subscales

Construct	No. of questions	Cronbach α reliability	Sample question
Autonomy satisfaction	4	0.81	I feel a sense of choice and freedom in the things I undertake in this course.
Autonomy frustration	4	0.71	Most of the things I do feel like "I have to" in this course.
Competence satisfaction	4	0.88	I feel confident that I can do things well in this course.
Competence frustration	4	0.86	I have serious doubts about whether I can do things well in this course.
Relatedness to instructor	5	0.86	I get along with the instructor(s) in this course.
Relatedness to peers	5	0.80	I really like the other students in this course.

Table 2 Traditional and HyFlex semester student numbers

Data source	Traditional experience (Fall 2019, $n=686$)	HyFlex experience (Fall 2020, $n=658$)
SAT data	584	579
Basic Psychological Needs Scale	392	192
Demographics	645	616
Attendance data	N/A	483

satisfaction and frustration of psychological needs from 1 (strongly disagree) to 7 (strongly agree). Refer to the Appendix for the complete instrument.

Data analysis and results

Table 2 shows what data were available. The university had SAT data (from the SAT or converted from the older SAT or ACT) from about 85% of our students. Basic Psychological Needs data were collected by a voluntary survey to which students were incentivized with extra credit. Just over one-half of the students responded during Fall 2019 while just under one-third responded during Fall 2020. During Fall 2020, the survey was administered at about the time when the university transitioned to online-only instruction at the end of the term which could account for why fewer students responded because they were in the process of moving away from campus at a peak point in the pandemic.

Table 3 shows that the instructional team had similarities during both semesters with about half the instructors being the same during both semesters. One instructor from each term had previous teaching experience and was a graduate of a teacher preparation program. Two experienced instructors from the traditional semester were replaced by three new instructors in the HyFlex semester. Thus, while just over half the instructors were very comparable, the HyFlex semester's instructional team was less experienced.

Prior to analysis, the two pairs of groups (Traditional semester, Fall 2019 vs. HyFlex semester, Fall 2020 and face-to-face students, Fall 2020 vs. Remote students, Fall 2020) were pretested for comparability to establish the extent to which they were similar at the onset of the terms. Demographic data were compared between the two sets of groups and

Table 3 Instructor information for traditional and HyFlex semester

Instructor	Traditional experience (Fall 2019)	HyFlex experience (Fall 2020)
Instructor 1*	Teacher prep, Previous public school teaching experience, Previous experience teaching this course	
Instructor 2*	Teacher prep	
Instructor 3*	Previous experience teaching this course	
Instructor 4*	Previous experience teaching this course	
Instructor 5	Teacher prep, Previous public school teaching experience	Teacher prep, Previous public school teaching experience
Instructor 6	Teacher prep, Previous public school teaching experience	New to teaching
Instructor 7	Previous public school teaching experience, Previous experience teaching this course	New to teaching
Instructor 8	None	New to teaching

* *Note* – Same instructor both years/semesters/groups

Table 4 Pearson χ^2 of demographics in 2019 and 2020 Semester

Demographic variable		Traditional experience (Fall 2019) Number of students (%)	HyFlex experience (Fall 2020) Number of students (%)	Pearson χ^2
Class rank	Freshman	378 (68%)	421 (67%)	$\chi^2(4)=15.331$
	Sophomore	175 (27%)	132 (21%)	$p=.004$
	Junior	68 (11%)	40 (7%)	
	Senior	24 (4%)	22 (4%)	
Gender	Female	142 (22%)	141 (23%)	$\chi^2(2)=0.391$
	Male	503 (78%)	475 (77%)	$p=.823$
Ethnicity	White	430 (68%)	461 (75%)	$\chi^2(3)=15.688$
	Non-White	210 (33%)	142 (23%)	$p=.001$
	Unknown	5 (1%)	10 (2%)	
Residency	Domestic	566 (88%)	598 (97%)	$\chi^2(2)=38.840$
	International	79 (12%)	18 (3%)	$p<.001$

Note: Percent (%) based on numbers of students from whom data were available

Table 5 Independent *t* test for SAT score in 2019 and 2020 semester

Dependent variable	Traditional experience (Fall 2019, $n=584$)		HyFlex experience (Fall 2020, $n=579$)		*t*	*p*
	M	*SD*	*M*	*SD*		
SAT score	1263.72	123.91	1258.34	127.72	0.728	0.467

are shown in Tables 4, 5, 6 and 7. Student distribution across class rank, ethnicity and residency were significantly different when compared across the traditional experience (Fall 2019) and the HyFlex experience (Fall 2020). During the HyFlex semester, the only significant difference between students who were consistently face-to-face and those who were remote once or more was their residency status. These differences should be considered as results are generalized to other settings. Importantly, the SAT measure of academic preparation was not significantly different for either of the pairs of groups.

Table 6 Pearson χ^2 for demographics for Fall 2020 Face-to-Face and Remote

Demographic variable		Face-to-Face (%)	Remote (%)	Pearson χ^2
Class rank	Freshman	102 (74%)	209 (67%)	$\chi^2(4)=9.006$
	Sophomore	26 (19%)	68 (22%)	$p=.061$
	Junior	6 (4%)	23 (7%)	
	Senior	3 (2%)	10 (3%)	
Gender	Female	34 (25%)	76 (24%)	$\chi^2(2)=5.768$
	Male	103 (75%)	235 (76%)	$p=.056$
Ethnicity	White	109 (67%)	238 (67%)	$\chi^2(3)=7.240$
	Non-White	24 (18%)	68 (22%)	$p=.065$
	Unknown	3 (2%)	3 (1%)	
Residency	Domestic	135 (99%)	301 (97%)	$\chi^2(2)=6.915$
	International	2 (1%)	10 (3%)	$p=.032$

Note: Percent (%) based on numbers of students from whom data were available.

Table 7 Independent *t* test for SAT score in 2020 semester Face-to-Face and Remote

Dependent variable	Face-to-Face ($n=130$)		Remote ($n=295$)		*t*	*p*
	M	*SD*	*M*	*SD*		
SAT score	1269.46	134.58	1263.93	126.95	0.406	0.685

Table 8 Fall 2019 Traditional experience and Fall 2020 HyFlex experience test for normality

Construct	Fall 2019 Traditional Shapiro-Wilks			Fall 2020 HyFlex Shapiro-Wilks		
	Statistic	df	Sig.	Statistic	df	Sig.
Autonomy satisfaction	0.983	392	<001	0.974	192	0.001
Autonomy frustration	0.982	392	<0.001	0.988	192	0.096
Competence satisfaction	0.946	392	<0.001	0.901	192	<0.001
Competence frustration	0.946	392	<0.001	0.936	192	<0.001
Relatedness to instructor	0.968	392	<0.001	0.962	192	<0.001
Relatedness to peer	0.987	392	<0.001	0.986	192	0.059

Table 9 HyFlex Face-to-Face vs. Remote Participation test for normality

Construct	Face-to-Face Shapiro-Wilks			Remote Shapiro-Wilks		
	Statistic	df	Sig.	Statistic	df	Sig.
Autonomy satisfaction	0.941	45	0.023	0.981	91	0.199
Autonomy frustration	0.977	45	0.509	0.987	91	0.513
Competence satisfaction	0.910	45	0.002	0.952	91	0.002
Competence frustration	0.942	45	0.026	0.952	91	0.002
Relatedness to instructor	0.949	45	0.048	0.976	91	0.098
Relatedness to peer	0.972	45	0.347	0.979	91	0.145

A Shaprio-Wilks test for normality indicated that distribution of some variables deviated significantly from a normal distribution as shown in Tables 8 and 9. As a result, both parametric (*t* tests) and non-parametric (Mann-Whitney *U* tests) were run and results compared. Results for Fall 2019 Traditional vs. Fall 2020 HyFlex are shown in Table 10 as parametric *t* tests. These results were confirmed by the Mann-Whitney *U* test and represent a large

Table 10 Independent Samples *t*-test comparing Traditional vs. HyFlex experiences

Basic Psychological Need	Traditional Experience (Fall 2019, $n=392$)		HyFlex Experience (Fall 2020, $n=192$)		t	df	*p*	*d*
	M	SD	M	SD				
Autonomy satisfaction	4.53	1.25	4.69	1.18	-1.52	582	0.129	0.13
Autonomy frustration	4.68	1.28	4.32	1.22	3.22	397	0.001**	0.28
Competence satisfaction	5.39	1.06	5.51	0.95	-1.30	418	0.194	0.11
Competence frustration	3.03	1.40	2.68	1.14	3.20	455	0.002**	0.27
Relatedness instructor	5.22	1.05	5.31	0.94	-1.05	421	0.290	0.09
Relatedness peer	4.91	0.94	4.92	0.87	-0.11	582	0.914	0.01

Note: Levene's test indicated equality of variances for all tests. *p < .05, **p < .01

Table 11 Mann-Whitney *U* Test for Face-to-Face vs. Remote Experiences

Basic Psychological Need	Face-to-Face ($n=45$)	Remote ($N=91$)	*u*	*p*	*r*
	Mean Rank	Mean Rank			
Autonomy satisfaction	76.06	64.76	1707.50	0.115	0.14
Autonomy frustration	62.17	71.63	1762.50	0.187	0.11
Competence satisfaction	70.24	67.64	1969.00	0.714	0.03
Competence frustration	64.08	70.69	1848.50	0.356	0.08
Relatedness to instructor	72.67	66.44	1860.00	0.384	0.07
Relatedness to peers	78.54	63.53	1595.50	0.036*	0.18

Note: *p < .05, **p < .01

sample size which is more tolerant of deviations from normality. Results of the face-to-face and remote experience comparisons are shown in Table 11 with non-parametric Mann-Whitney *U* tests as these results are likely to be more reasonable than *t* test results because of concerns with deviation from normal distribution associated with smaller sample size (Anderson, 2010; Field, 2009).

Independent samples t tests were used to determine whether the traditional format was different from the HyFlex environment with respect to the key variables. The results shown in Table 10; Fig. 1 indicated that autonomy frustration and competence frustration were significantly lower for the HyFlex experience than for the traditional experience. Effect size was measured with Cohen's *d* which is appropriate for larger samples. A Cohen's *d* value between 0.15 and 0.40 is considered a small effect, while values between 0.40 and 0.75 are medium effects, and a large effect is above 0.75 (Cohen, 1992). Therefore, while significantly different, the effect sizes associated with differences were small.

In the similar way, we used Mann-Whitney *U* tests to examine the difference between the two experiences in HyFlex 2020 when students had the choice of attending classes face-to-face or remotely on any given day. The results in Table 11; Fig. 2 indicate no significant difference on five of the six measures. Relatedness to peers was significantly higher for face-to-face students than for those who participated remotely one or more times. Effect sizes are reported as a rank biserial correlation and interpreted in much the same way as Cohen's *d*. While differences were significant, effect sizes were small.

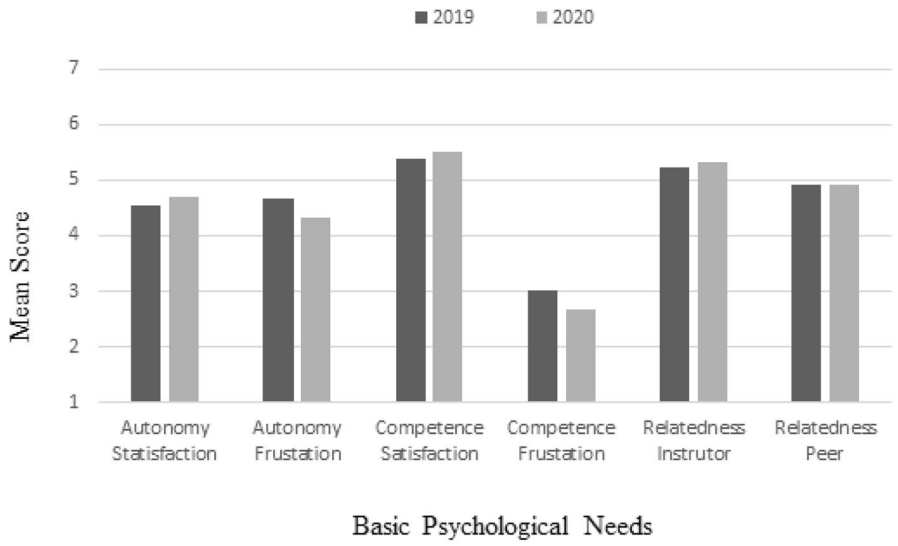

Fig. 1 Mean Basic Psychological Needs scores for 2019 (Traditional learning environment) vs. 2020 (HyFlex learning environment)

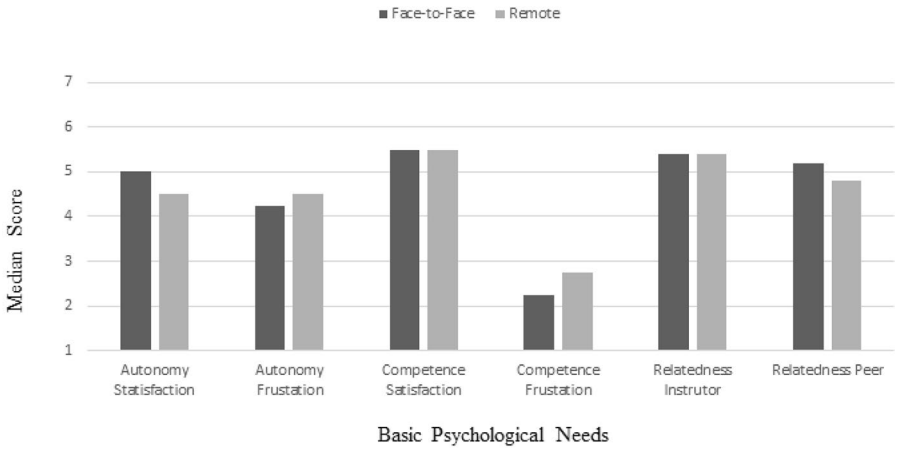

Fig. 2 Median Basic Psychological Needs scores for Face-to-Face vs. Remote students

Discussion

Our study shows that the Interactive Synchronous HyFlex model had an overall positive impact on Basic Psychological Needs. Students in the HyFlex version of our Design Thinking course had very similar autonomy satisfaction, competence satisfaction and relatedness with peers and instructor compared with students in the traditional design thinking class. Students in the HyFlex design thinking course had lower levels of autonomy frustration

Table 12 Summary table of results

Outcome variable	Subscale	Traditional (2019) vs. HyFlex (2020)	Face-to-Face vs. Remote (Fall 2020)
Autonomy	Satisfaction	Traditional = HyFlex	Face-to-Face = Remote
	Frustration	Traditional > HyFlex**	Face-to-Face = Remote
Competence	Satisfaction	Traditional = HyFlex	Face-to-Face = Remote
	Frustration	Traditional > HyFlex**	Face-to-Face = Remote
Relatedness	Instructor	Traditional = HyFlex	Face-to-Face = Remote
	Peer	Traditional = HyFlex	Face-to-Face > Remote*

*p > .05, **p > .01

and competence frustration compared with the students in the traditional design thinking class and only slightly lower levels of peer to peer relationships. Table 12 summarizes the statistically-significant results from the two comparisons for the six outcome variables.

Students felt a similar autonomy satisfaction level in both the traditional and HyFlex instructional approaches, and also this did not differ if they were always participating in the HyFlex course Face-to-Face or remotely. Their level of autonomy satisfaction ranged from 4.53 to 4.82 which is somewhere between "neither agree nor disagree" (4) and "somewhat agree" (5) to a statement such as "I feel a sense of choice and freedom in the things I undertake in this course". While not significant, this score was highest among the HyFlex students and, among them, highest for the students who participated face-to-face, which makes sense because the HyFlex option gave students the autonomy to choose how to participate on a daily basis and because students who were face-to-face could have had both the benefits of being in the classroom with their peers and instructor and the freedom to have chosen to be there.

Students felt significantly-lower autonomy frustration in the HyFlex instructional approach with an effect size on the high end of the small range. There was no significant difference in autonomy frustration for students participating in the HyFlex approach face-to-face vs. remotely. Scores ranged from 4.14 (face-to-face students within the HyFlex approach) to 4.58 (traditional approach). A score of 4 represented "neither agree nor disagree" (4) and "somewhat agree" (5) to a statement such as "Most of the things I do feel like "I have to" in this course." Thus students felt significantly less forced to do "things" related to the course in the HyFlex approach and slightly less so if they were participating Face-to-Face.

Competence satisfaction and competence frustration followed a pattern similar to autonomy satisfaction and autonomy frustration. Competence satisfaction differed neither between the traditional and HyFlex approaches nor between face-to-face or remote experiences within the HyFlex model. Scores ranged from 5.39 to 5.44 which is between "somewhat agree" and "agree" to statements such as "I feel confident that I can do things well in this course." We celebrate this success because literature suggests that many students and instructors struggled with the emergency transition to online learning forced by the Covid pandemic during Fall 2020. With a less-experienced instructional team and during a pandemic, our students felt equally competent in their abilities to be successful in class regardless of the participation mode.

Competence frustration scores dropped significantly for the HyFlex approach but did not differ between face-to-face participation and remote participation in the HyFlex semester.

In the traditional semester, students responded with "somewhat disagree" to prompts similar to "I have serious doubts about whether I can do things well in this course" whereas, in the HyFlex semester, students' level of disagreement rose significantly to about halfway between "disagree" and "somewhat disagree". This indicates that, with the HyFlex approach, students have less doubt about their ability to do the things expected in the course which could be related to students knowing that they can attend class regardless of their physical location. If they are sick or away from campus or unable to find a parking spot, they can still participate in class.

Peer and Instructor relatedness were not significantly different in the traditional vs. HyFlex comparison, thus indicating that students feel equally well connected to their peers and instructors. Relatedness to peers was significantly higher for face-to-face students vs. remote students, while relatedness to their instructor was not different. This too is a celebration as literature suggested Fall 2020 devastated the sense of community in many contexts including education. Scores ranged from 5.22 to 5.40 for relatedness to instructor with the slightly-higher score being for face-to-face students in the HyFlex environment, which can be interpreted as between "somewhat agree" (5) and "agree" (6) that students "get along with the instructor(s) in this course". Scores for relatedness to peers ranged from 4.88 to 5.15 with the highest score also being from face-to-face students in the HyFlex environment, indicating that students typically "somewhat agree" that "I really like the other students in this course".

To situate our findings in the context of related literature, we note that this approach addressed issues that other models of emergency remote teaching struggled to address and extended our understanding of HyFlex in the context of active learning, whereas many previous students were in lecture-based environments. Adedoyin & Soykan (2020) anticipated that online and hybrid online learning environments could become more sustainable post pandemic as technology and our culture changes. These results support the Interactive Synchronous HyFlex approach as a specific instantiation of Hybrid learning as a model that meets students' basic psychological needs. While born in the context of emergency remote teaching, this model demonstrates success when other models might have struggled. Our model addressed the challenges illuminated by Dhawan (2020) related to students struggling to engage in two-way communication and limited sense of community. This model also provides a method to address ubiquitous attendance uncertainties as we never can be sure that every student will be in class at our next session, which was exacerbated during the pandemic (García-Morales et al., 2021). Further, most previous literature exploring the HyFlex model was situated in lecture-based environments where active project-based learning was not a central pedagogical strategy. In our course, we engage in active learning that is team based and project based, which is often found in STEM and other learning environments.

This study could have implications for the classroom beyond the global pandemic. While students were absent from the classroom at much higher levels during the pandemic, it was not uncommon for students to miss class for a variety of reasons including normal seasonal illnesses, transportation issues and travel for university-sponsored events or personal reasons. Offering the HyFlex environment did place a burden on the instructor and face-to-face classmates including configuring a video conferencing software (Microsoft Teams) and using headsets both in the classroom and for remote students. As instructors prepare for future course offerings, they need to balance the benefits of HyFlex participation in terms of

reduced autonomy frustration and reduced competence frustration with the costs of setting up the video conference concurrently with 'normal' classroom routines. Further, the actual impact of offering a HyFlex environment might have been more dramatic if the instructional team had more comparable levels of experience. Three new instructors, who were new to teaching and did not have any teacher preparation coursework, joined the HyFlex semester to replace two instructors from the comparison who were experienced teachers and graduates of a teacher preparation program.

Future researchers could parse out differences in remote participation in the HyFlex environment. As an instructional team, our intuition is that remote participation was beneficial to students who legitimately could not make it to class but wanted to continue participation. However, we suspect that students who might want to disengage in the traditional classroom are kept attentive by peer and instructor pressure. For example, students who might be distracted could be brought back on track by an instructor's eye contact or proximity. Remote participation could facilitate disengagement as students might not feel the same levels of pressure to be alert and attentive. Additional investigation might identify if and to what extent engagement can be bifurcated among remote students so that perhaps it works better for some but worse for others. For purposes of this research, we drew a line between face-to-face students and remote students in the HyFlex environment by categorizing 'remote' students as those who were remote one or more times by choice. Further research might categorize remote students differently so that two or more days remotely define a remote learner or a more-complex regression analysis to identify trends between the number of days remote and the experience of the student and their teammates. Additional research might review the attendance patterns of remote learners. In reviewing our data, a few patterns of potential interest emerged such as students who were face-to-face all semester except for a two-week remote experience which might have been a Covid-related quarantine. Some students began the term participating face-to-face but transitioned to remote participation at some point. Other students might have begun remote and transitioned to face-to-face. Still, other students seemed to be remote on occasion at random or in a pattern such as frequently on a particular day of the week.

Because of the complexity of understanding students' attendance choices and HIPPA regulations related to Covid or non-Covid related illness, the extent to which students participated remotely in the HyFlex instructional approach due directly to the pandemic is unclear. Thus, findings from our study could have some generalizability to future semesters regardless of Covid and a global pandemic. We anticipate for the foreseeable future continuing to offer the HyFlex approach to accommodate students who are unable to be in the classroom physically, but we worry that remote students in the HyFlex model experience slightly-less autonomy and competence satisfaction, slightly-more autonomy and competence frustration, slightly-less relatedness to their instructions, and significantly-lower relatedness to their peers. These slight differences could be by chance and chance alone or an early warning signal that small differences do exist. If these represent actual differences, we are unable to detect if they are correlational or cause-and-effect. It is possible that students who are less interested in engaging with the course chose remote participation as a way of being harder to notice. While we appreciate increased participation and fewer justifiable 'absences' with the HyFlex approach, we are cautious that the HyFlex option might tempt some students to participate remotely even if they are able to participate face-to-face. Further research is needed to understand why students might choose one participation method over another, as

well as whether all students experience similar impacts on their educational experience or if the impacts vary depending on the student.

Appendix

Adapted Basic Psychological Needs and Frustration Scale (Fedesco et al., 2019).

Question Text: Your Overall Experience. The following questions concern your feelings about your experience in *Course Number: Course Name*. Please indicate how true each of the following statements is for you given your specific experiences with *Course Number: Course Name* thus far.

All items measured on a 7-point, Likert-type scale ranging from strongly agree to strongly disagree.

Answer Responses

1. Strongly Disagree.
2. Disagree.
3. Somewhat Disagree.
4. Neither Agree nor Disagree.
5. Somewhat Agree.
6. Agree.
7. Strongly Agree.

Individual Items

1. Autonomy.

    a. Satisfaction:

        i. I feel a sense of choice and freedom in the things I undertake in this course.
        ii. I feel that my decisions reflect what I really want in this course.
        iii. I feel my choices express who I really am in this course.
        iv. I feel I have been doing what really interests me in this course.

    b. Frustration.

        i. Most of the things I do feel like "I have to" in this course.
        ii. I feel forced to do many things I wouldn't choose to do in this course.
        iii. I feel pressured to do too many things in this course.
        iv. My daily activities feel like a chain of obligations in this course.

    2. Competence.

a. Satisfaction.

i. I feel confident that I can do things well in this course.
ii. I feel capable at what I do in this course.
iii. I feel competent to achieve my goals in this course.
iv. I feel I can successfully complete difficult tasks in this course.

b. Frustration.

i. I have serious doubts about whether I can do things well in this course.
ii. I feel disappointed with many of my performances in this course.
iii. I feel insecure about my abilities in this course.
iv. I feel like a failure because of the mistakes I make in this course.

3. Relatedness.

a. Instructor.

i. I get along with the instructor(s) in this course.
ii. I really like the instructor(s) in this course.
iii. The instructor(s) in this course care(s) about me.
iv. I am not close to the instructor(s) in this course.
v. The instructor(s) in this course do(es) not seem to like me much.

b. Peer.

i. I really like the other students in this course.
ii. I get along with other students in this course.
iii. The other students in this course do not seem to like me much.
iv. The other students in this course care about me.
v. There are not many students in this course that I am close to.

Acknowledgements This material is based on work supported by Purdue University Provost's Office and the National Science Foundation under Grant Number 2110799.

References

Abdelmalak, M. M. M., & Parra, J. L. (2016). Expanding learning opportunities for graduate students with HyFlex course design. *International Journal of Online Pedagogy and Course Design (IJOPCD)*, *6*(4), 19–37. https://doi.org/10.4018/IJOPCD.2016100102

Adedoyin, O. B., & Soykan, E. (2020). Covid-19 pandemic and online learning: The challenges and opportunities. *Interactive Learning Environments*, 1–13. https://doi.org/10.1080/10494820.2020.1813180

Akpan, D. V. I., Igwe, D. U. A., Blessing, I., Mpamah, I., & Okoro, C. O. (2020). Social Constructivism: Implications on teaching and learning. *British Journal of Education*, *8*(8), 49–56

Anderson, C. J. (2010). Central limit theorem. *The Corsini Encyclopedia of Psychology* (pp. 1–2). American Cancer Society. https://doi.org/10.1002/9780470479216.corpsy0160

Audet, É. C., Levine, S. L., Holding, A. C., Powers, T. A., & Koestner, R. (2021). Navigating the ups and downs: Peer and family autonomy support during personal goals and crises on identity development. *Self and Identity*, 1–18. https://doi.org/10.1080/15298868.2021.1939772

Audet, É. C., Levine, S., Metin, E., Koestner, S., & Barcan, S. (2021). Zooming their way through university: Which Big 5 traits facilitated students' adjustment to online courses during the COVID-19 pandemic. *Personality and Individual Differences*, *180*, 110969. https://doi.org/10.1016/j.paid.2021.110969

Beatty, B. (Ed.). (2019). *H ybrid-Flexible course design: Implementing student-directed hybrid classes*. EdTech Books. https://edtechbooks.org/hyflex

Bishop, J., & Verleger, M. (2013). *The flipped classroom: A survey of the research*. 120th ASEE Annual Conference & Exposition, Atlanta, GA

Chen, B., Vansteenkiste, M., Beyers, W., Boone, L., Deci, E. L., Van der Kaap-Deeder, J., Duriez, B., Lens, W., Matos, L., Mouratidis, A., Ryan, R. M., Sheldon, K. M., Soenens, B., Van Petegem, S., & Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. *Motivation and Emotion*, *39*(2), 216–236. https://doi.org/10.1007/s11031-014-9450-1

Chiu, T. K. F. (2021). Applying the self-determination theory (SDT) to explain student engagement in online learning during the COVID-19 pandemic. *Journal of Research on Technology in Education*, 1–17. https://doi.org/10.1080/15391523.2021.1891998

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037//0033-2909.112.1.155

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Springer. https://doi.org/10.1007/978-1-4899-2271-7

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology/Psychologie Canadienne*, *49*(3), 182–185. https://doi.org/10.1037/a0012801

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of Educational Technology Systems*, *49*(1), 5–22. https://doi.org/10.1177/0047239520934018

Fedesco, H. N., Bonem, E. M., Wang, C., & Henares, R. (2019). Connections in the classroom: Separating the effects of instructor and peer relatedness in the basic needs satisfaction scale. *Motivation and Emotion*, *43*(5), 758–770. https://doi.org/10.1007/s11031-019-09765-x

Field, A. (2009). *Discovering statistics using SPSS*. SAGE Publications

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*. (Published ahead of print May 12, 2014). https://doi.org/10.1073/pnas.1319030111

García-Morales, V. J., Garrido-Moreno, A., & Martín-Rojas, R. (2021). The transformation of higher education after the COVID disruption: Emerging challenges in an online learning scenario. *Frontiers in Psychology*, *12*, 616059. https://doi.org/10.3389/fpsyg.2021.616059

Land, S. M., & Hannafin, M. J. (1996). *Student-centered learning environments: Foundations, assumptions, and implications*. https://ERIC.ed.gov/?id=ED397810

Laux, D., Luse, A., & Mennecke, B. E. (2016). Collaboration, connectedness, and community: An examination of the factors influencing student persistence in virtual communities. *Computers in Human Behavior*, *57*, 452–464. https://doi.org/10.1016/j.chb.2015.12.046

Levesque-Bristol, C., Knapp, T. D., & Fisher, B. J. (2010). The effectiveness of service-learning: It's not always what you think. *Journal of Experiential Education*, *33*(3), 208–224. https://doi.org/10.5193/JEE33.3.208

Lo, C., & Hew, K. (2019). The impact of flipped classrooms on student achievement in engineering education: A meta-analysis of 10 years of research. *Journal of Engineering Education*, *108*(4), https://doi.org/10.1002/jee.20293

Lo, C., Hew, K., & Chen, G. (2017). Toward a set of design principles for mathematics flipped classrooms: A synthesis of research in mathematics education. *Educational Research Review*, *22*, 50–73. https://doi.org/10.1016/j.edurev.2017.08.002

Masland, L. (2021). Chapter 1- Resilient pedagogy and self-determination: Unlocking student engagement in uncertain times.Resilient Pedagogy,13–36

National Academy of Engineering (2021). *NAE grand challenges for Engineering*. http://www.engineeringchallenges.org/challenges.aspx

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *Internet and Higher Education*, *25*, 85–95. https://doi.org/10.1016/j.iheduc.2015.02.002

Pedersen, S., & Liu, M. (2003). Teachers' beliefs about issues in the implementation of a student-centered learning environment. *Educational Technology Research and Development*, *51*(2), 57–76. https://doi.org/10.1007/BF02504526

Reis, H. T., Sheldon, K. M., Gable, S. L., Roscoe, J., & Ryan, R. M. (2000). Daily well-being: The role of autonomy, competence, and relatedness. *Personality and Social Psychology Bulletin*, *26*(4), 419–435. https://doi.org/10.1177/0146167200266002

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Ryan, R. M., & Deci, E. L. (2002). Overview of self-determination theory: An organismic-dialectical perspective. *Handbook of self-determination research* (pp. 3–33). University of Rochester Press

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness* (pp. xii, 756). The Guilford Press. https://doi.org/10.1521/978.14625/28806

The College Board (2009). *ACT and SAT concordance tables*: *Things you should know about flipped classrooms*. (2012). Educause. https://library.educause.edu/resources/2012/2/7-things-you-should-know-about-flipped-classrooms

Wright, G. B. (2011). Student-centered learning in higher education. *International Journal of Teaching and Learning in Higher Education*, *23*(1), 92–97