Paper ID #49282

Practical Approaches to Hybrid/HyFlex Delivery for Manufacturing and Automation-Rela Courses to Accommodate Work-Study Internships

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Abstract

HyFlex course delivery preserves in-person active learning opportunities while simultaneously offering online learning alternatives for students who cannot attend in person or have other reasons for finding the flexibility of asynchronous opportunities helpful to their life situations and learning goals.

Engineering and Engineering Technology programs face difficulties offering online learning due to the desirability of hands-on learning and lab equipment access. In manufacturing and automation education, experience with industry-relevant equipment is required. Post-COVID student appreciation for a return to experiential learning validates the need for in-person experiences. These same students benefit from work-study industry internships, which offer an additional layer of experiential opportunities. However, work scheduling requirements often conflict with class attendance.

The Engineering Technology program at Kansas State University Salina Campus balances these competing objectives through partial HyFlex course delivery and lab scheduling options. Challenges to the instructor include (1) developing and managing both in-person and online learning opportunities within the same class section with quality and sustainability and (2) scheduling and integrating appropriate experiential learning and equipment access. We review standards in HyFlex instruction and recent examples in the engineering education literature. Instructors of manufacturing and automation courses offer case examples of hybrid/HyFlex approaches to accommodate students with scheduling conflicts caused by industrial internships or other co-curricular activities. Solutions emphasize the adaptation of existing course materials, techniques, and technologies to work for both in-person and asynchronous online engagement. Assessments and feedback from students indicate successes and improvement opportunities. Additionally, non-internship students gained advantages from HyFlex options.

Keywords

hybrid learning, HyFlex course design, online instruction, internships, manufacturing education, automation education

Introduction

According to 2024 findings by Kelly Services, the global Industrial Automation market is expected to continue to grow annually at a compound annual growth rate of 8%, demanding a workforce with skills to leverage these advanced technologies [1]. A December 2023 report by Boston Consulting Group analysts compiled data from the U.S. Bureau of Labor Statistics, the National Science Foundation, ASEE, and the U.S. Citizen and Immigration Services to demonstrate that 33% of new engineering roles go unfulfilled annually [2]. The National

Association of Manufacturers (NAM) 2024 First Quarter found that "more than 65% of manufacturers cited the inability to attract and retain employees as their top primary challenge" [3].

Industry representatives on Advisory Boards for the Engineering Technology programs at Kansas State University Salina affirm an ongoing urgency for more manufacturing and automation engineering graduates. Local manufacturing employers particularly value local or regional students who are more likely to want to stay to work in the region after graduation. These companies are stepping up to offer internship incentives to employ and train student interns concurrent with their engineering technology studies.

In this paper, the term "work-study internship" refers to employment in the workplace related to the student's field of study, scheduled concurrent to semesters the student participates in academic coursework. At Kansas State University Salina, both the employer and the university agree to meet each other halfway on flexibility: The internship employer allows the student time in the workweek to attend some in-person classes (particularly labs that require hands-on experience with equipment), but the university commits to making flexibility for the student to be at the workplace some days in the week. Because student intern schedules may differ according to the needs of the employer, engineering technology programs accommodate flexibility through HyFlex course offerings, which allow students the choice of attending classes online or in-person "lecture" sessions.

HyFlex class sessions require the instructor to plan for the same learning objectives to be satisfied by the students either during the in-person class meeting or through online course activity [4], [5]. For time feasibility, the instructor must adopt strategies to offer both in-person and online asynchronous modalities in ways that minimize extra work on the instructor's part.[5] This paper explores HyFlex teaching approaches employed by instructors in manufacturing and automation courses based on the adaptation of existing course materials, techniques, and technologies.

Terminology related to HyFlex, hybrid, and fully online courses can vary by institution. "HyFlex" (short for "Hybrid Flexible") generally refers to a course in which a student has, theoretically, 100% choice of either an in-person or online modality at any time [4]. In this paper, we will refer to courses that have in-person lab components, but the "lecture" meetings provide HyFlex options. We will call the overall course "hybrid/HyFlex" but refer to the lecture component as HyFlex. For a deeper look at various flavors and alternate terms associated with HyFlex courses, see the chapter "1.1 Beginnings: Where Does Hybrid-Flexible Come From" in Brian J. Beatty's free eBook *Hybrid-Flexible Course Design*. [4]

Engineering and Engineering Technology programs face challenges when attempting to offer an option for 100% online course experiences:

- In manufacturing and automation education, experience with industry-relevant equipment is required.

- Engineering and engineering technology students tend to learn better with hands-on experiences.

Challenges to the instructor implementing HyFlex options include:

1. Developing and managing both in-person and online learning opportunities within the same class section with quality and sustainability.
2. Scheduling and integrating appropriate experiential learning and equipment access.

Table 1 provides an overview of how Engineering Technology programs at Kansas State University Salina address these challenges from a programmatic level.

For this study, we focus on challenge number one, above, which falls to the instructor: Sustainable development and execution of quality HyFlex teaching. Methods that enable instructors to offer student learning in both in-person and online modalities without excessive workload will remove barriers to education and increase student access to industry experiences. Ultimately, these efforts seek to boost the pipeline of skilled engineering professionals entering the workforce for our industry partners.

Literature Review

HyFlex Instruction Methods and Standards in Higher Education Literature. Dr. Brian Beatty is generally credited with originating the terms "Hybrid-Flexible" and "HyFlex." His "Four Principles of HyFlex Course Design" [4], [6] are commonly referenced (e.g., [7], [8], [9], etc.) to summarize key challenges to the instructor:

- **Learner Choice:** Provide meaningful alternative participation modes and enable students to choose between participation modes daily, weekly, or topically.
- **Equivalency:** Provide learning activities in all participation modes, which lead to equivalent learning outcomes.
- **Reusability:** Utilize artifacts from learning activities in each participation mode as "learning objects' for all students.
- **Accessibility:** Equip students with technology skills and equitable access to all participation modes.

The obvious challenge to an instructor is to prepare and deliver one course section in two (or three) modalities: (1) for students choosing to attend the in-person class meeting and (2) for students electing to follow the online alternatives, which could be either asynchronous or synchronous online [4], [11].

Unique courses call for unique solutions. Typical approaches to offering both in-person and online learning options simultaneously include [4]:

- **Streaming and/or recording the in-person class.** The in-person class session may or may not be required viewing for online students, but it serves as a resource for all students.

- **Alternative online engagement tasks are typically offered**. For example, online students may contribute to discussion boards or shared documents, or they may complete assignment sheets that replicate the in-person student activities.

- **Clear assignment instructions** and **support resources** for online students attempt to provide just-in-time support for students in place of immediate instructor assistance. These generally provide bonus support for in-person students as well.

Table 1. Approaches to Supporting Work-Study Internships for Engineering Technology students at Kansas State University Salina Campus.

	Challenge to Work-Study Student Support	Mitigating Strategies Employed
Timing Issues	Workplace scheduling needs are difficult to balance with a schedule of full-time class attendance.	• Classes offer **hybrid/HyFlex asynchronous online alternatives** to in-person participation in the scheduled class sessions. • The **workplace agrees to some reasonable flexibility** to allow the **intern to attend minimal in-person lab experiences.** In some cases, the industry has agreed to a schedule that consolidates intern work hours to two workdays per week, allowing the student to attend in-person on other days. This **allows the student some enjoyment of in-person experiential learning**, even if some of the class time must be attended online asynchronously.
Location	The **workplace usually needs to be within a reasonable commute**, unless distance participation can be arranged.	• Classes are offered HyFlex as much as possible, **allowing the student to perform much of the course participaton online** from a distance. • The university attempts to **consolidate the scheduling of required in-person lab sessions** such that the student only travels to the campus once per week or even less. This allows students to commute from longer distances.
Academic Load and Support	Students **must apply good time management** to maintain a full-time courseload while working the required number of internship hours. **Students must adapt to online learning** when not available to attend class in-person.	• The **campus provides support specific to work-study interns**, including a coordinator to ensure student advising, coordination with employers, and student support activities. Work-study students are given opportunity to network together for mutual support. • Faculty receive training and support to carry out **quality HyFlex course practices that offer feedback, support, and connection to the learning community.**

For instructors designing a class for the first time intended for HyFlex modality, it is often recommended to design for all-online students first, then build from those resources for the in-person class experience [4].

An accessibility and equivalency concern for Kansas State University Salina instructors is that students who choose all-online options are not left isolated from the support of a learning community. One example occurs in CAD-based classes which provide scheduled in-person class time in the CAD lab. The instructor is in the room to assist students who run into CAD difficulties, but students can also consult with their neighbors for assistance. Students with connections to other students may also consult with their peers when they get stuck during homework time outside of class. Online students may have greater difficulty connecting with their fellow students if the instructor does not encourage and facilitate connections. Although some students like to work alone, connections with their peers can help keep students mutually encouraged and spurred to timely activity. Instructors will use various means to connect online students with their peers. Common techniques include individual student introductions, team activities, discussion boards, shared document assignments, etc.

Some of the extra preparation which may be required of an instructor teaching HyFlex includes [4]:

- Providing asynchronous options with self-guided resources and self-guided learning activities to compensate for lack of time in-person with ready instructor guidance.
- Providing clear instructions for options (in-person, synchronous, asynchronous).
- Ensuring engagement for students in multiple modalities.
- Ensuring formative feedback for students in multiple modalities (with particular attention to online students who may miss formative feedback from interaction with the instructor during in-person class meetings, if that applies).
- Arrangements for assessments.
- Extending flexible instructor-student interactions outside of scheduled class meetings.
-

Literature Review of HyFlex Instructional Design in Engineering Education. Little has been written in the manufacturing and automation engineering domain concerning HyFlex teaching and learning methods, possibly because of the highly hands-on nature of these technologies and the difficulty of replicating them in an online alternative. Credit must be given to Fidan et al. [12] for their 2022 discussion of flipped classroom techniques that offered online options for manufacturing courses during COVID-19 conditions. The Engineering Technology faculty from Tennessee Technological University and the University of Alabama Huntsville compiled flipped classroom course design strategies and observations from various manufacturing-related courses, all offered either HyFlex or online. Their courses leaned heavily on project-based learning during the classroom or classroom alternative portions of the course. Course design descriptions suggest various methods to spur student preparation, activity, and collaboration which proved successful in engaging students.

Morse [13] of Kansas State University Salina Campus in 2024 expanded on Fidan et al., reporting on the ease of offering HyFlex options to manufacturing and automation courses by employing existing flipped classroom exercises and resources.

Also representing manufacturing and automation students, Yoshikubo et al. from Shibaura Institute of Technology, Japan, in 2023 [14] reported on efforts to use the platform Slack to encourage engagement and accountability of international team members in HyFlex problems-based learning in an Interdisciplinary Robotics Workshop. Their instructor team was pleased by the rich data they could obtain by observing workshop participant team interactions and believed that when coupled with meaningful scoring models, it should provide a route to increased student motivation.

Becklinger of the University of Southern Indiana [15] tracked student perceptions of HyFlex course offerings following the COVID pandemic. Two Manufacturing Technology classes were included in the study. Although the offerings apparently emphasized synchronous online attendance, the student responses valued the posting of class recordings for later viewing as useful to mitigate absence due to conflicts and illness or for later review.

In the broader engineering education community, a team from Purdue (Mohandas et al.) [16] 2024 compiled findings from eleven HyFlex studies, emphasizing synchronous HyFlex options. While only one of the studies under review was from engineering, others had STEM connections. The team found repeating themes emphasizing the inclusivity and flexibility that HyFlex course design presented. Clear communication surfaced as a key course design need. The study noted that many students are inexperienced with this type of learning opportunity and may need coaching in team collaboration in a HyFlex environment.

In 2023, Mohandas et al. [17] studied the self-regulation of learning goals by students choosing the online environment. Their findings dispel a myth that students who choose remote learning do so because they are less motivated.

In all, eight paper presentations containing the keyword "HyFlex" were presented at the 2024 ASEE Annual Conference, representing about nine universities.

<u>Identification of gaps in the literature</u>. This paper builds onto the foundations by Fidan et al. [2] and Morse [3] of quality HyFlex instructional applications to manufacturing and automation course needs, focusing on ease of implementation and instructor time economy.

Methodology

The objective of this study was to develop and implement effective strategies to provide both in-person and online options for a manufacturing or automation-related course by adapting existing, familiar teaching tools and techniques.

This study draws from the real implementation experience of six different manufacturing and automation-related engineering technology courses implemented in 2024 by two faculty members.

Anticipated measures of success included:

- **Successful completion of course learning outcomes** by students attending primarily online.
- **Comparable learning outcome performance of online students** compared to in-person students
- **Instructor self-reporting of ease of development and implementation** within the expected teaching load.

In order to support work-study internship students taking manufacturing and automation classes, instructors at Kansas State University Salina developed HyFlex strategies appropriate to the needs of particular classes.

Whenever practical, instructors developed alternative asynchronous learning activities that allow students to work toward the desired student learning outcomes on their own schedule. These are the “HyFlex" portions of these classes. Some classes, such as CAD-based Mechanical Detailing, allow students to pursue the entire course online asynchronously, while other courses have a portion of the class meetings that can be performed online.

When first accommodating students who need to attend asynchronously, faculty found ways to draw from already-familiar techniques and technologies. Examples include:

- **Zoom recordings** of the in-person class.
- **Flexible presentation technologies** that enable and capture interactivity in the classroom.
- **In-class activity worksheets** that could be easily adapted for asynchronous online student use.
- **Existing flipped-classroom assignments and resources** that already support student learning outside of the class meeting time.
- **Resources for self-help and review** posted and easily navigable assist both in-person and asynchronous students.

Table 2 provides examples of some of these techniques applied to specific manufacturing and automation courses.

Zoom Recordings. Since the HyFlex class includes an in-person option, the ability to make Zoom recordings of the live session offers a fairly low investment of time to provide access to the same content for online asynchronous students. However, it may not be the most engaging solution. Instructors are encouraged to break up the recordings into smaller videos, but having multiple videos for a class session somewhat complicates and extends the instructor time investment necessary to post the videos online with appropriate annotations, links to related resources and assignments, etc.

Flexible presentation technologies help make the in-person class experience more interactive while also presenting and recording it for online student participation. Some instructors were often already using these techniques before students could attend asynchronously, as the video record became helpful when posted in an online archive for review purposes.

Table 2. Strategies for Manufacturing and Automation Course Support for HyFlex (Asynchronous) Students (continued on next page).

Course	Lab Attendance Arrangements	HyFlex Course Strategies	Existing Methods and Technologies Adapted for HyFlex Delivery

Manufacturing Methods (1st year)
 	
One course requiring both a lab component and a lecture component.
	2 credit hours (4 clock hours) per week is scheduled in-person time in the manufacturing lab. This is usually not a problem, since this class typically occurs their first semester on campus, before they begin working their internship. Non-traditional students work out attendance with their employer.	• The lecture session is offered HyFlex to accommodate special student needs.
		• A Zoom recording is made of the in-person class meeting.
		• In-person "lecture" class time strives to involve small groups in active-learning activities. Usual types of activities:
		  ○ Hands-on activities with parts and equipment
		  ○ Worksheets leading student conclusions and notes on new content based on resources
		Asynchronous students are generally provided the same activity sheets.
		• This course has a flipped-classroom strategy for all students, expecting students to do preparation using SME Tooling U online learning modules or alternative media and learning quizzes developed by the instructor.
			• Flipped-classroom activities and support resources, such as:
			  ○ SME Tooling U modules
			  ○ Videos and study guides
			  ○ Other online references
			  ○ Self-check quizzes
			• Existing in-person class activities

CNC Machining Processes
 	
One course designated as all lab time.
	The class is designated as 2 credit hours, provided as two 2-hour lab sessions per week. We can't get all students on the CNC equipment at one time, anyway, so we schedule the interns to have CNC equipment time on one day a week when they can be available on-campus.	• All students (in-person or asynchronous) use one 2-hour lab day per week as a prep day. Whether working in the lab or remotely, students have access to necessary software to do toolpath planning, programming, and simulation.	• Flipped-classroom activities and support resources, such as:
			  ○ SME Tooling U modules
			  ○ Videos and study guides
			  ○ Instructor-made teaching videos
			  ○ Instructor-made practice problems and worksheets
			• Free CNC simulation software

Table 2. Strategies for Manufacturing and Automation Course Support for HyFlex (Asynchronous) Students (continued).

Course	Lab Attendance Arrangements	HyFlex Course Strategies	Existing Methods and Technologies Adapted for HyFlex Delivery
Automated Manufacturing Systems I ($1^{st}/2^{nd}$ Year) One course requiring both a lab component and a lecture component.	The course is largely driven by weekly lab activities. We schedule 2 hours of class time one hour of "lecture" back-to-back to provide one 3-hour session in the lab on a day that the intern can be available in-person.	• For the second 1-hour "lecture" session, students are given a small group study project. It usually involves a worksheet or study quiz to accompany provided online resources. Occasionally there is a simulation project activity. ○ In-person students have a classroom where they can meet, or may choose another place or time, or they may choose to work independently. If they have questions, they can come to the lab room to discuss with the instructor. ○ Asynchronous students can similarly work the assignment in their own time and space, or team with other students asynchronously, either meeting or using online collaboration.	• Existing flipped-classroom resources, assignment worksheets, and practice quizzes help students prepare outside of class.
Mechanical Design Modeling & Detailing (1^{st} Year) One course designated as all lab time.	The course is scheduled as two 3-hour lab sessions. Students may choose to participate asynchronously at any or all times, with the exception of three exam sessions. Asynchronous students may arrange with the instructor if the scheduled exam time is not feasible.	• Any in-person presentation or activities of interest to asynchronous students is recorded via Zoom recordings. Instructor breaks up the recordings by topic for ease of reference (both for asynchronous students and for review for in-person students). • Tutorial textbooks for self-paced learning of CAD techniques. • Instructor requests one-on-one appointments (either in-person or screenshare videoconference) with students not regularly attending in-person at least once every two weeks. This provides opportunity to share and discuss CAD, answer questions, and discuss study strategies moving forward.	• CAD tutorial textbooks for flipped-classroom instruction. • CAD screen sharing over Zoom videoconferencing (for both the class recording and communication with asynchronous students). • Document camera and pen-enabled laptop to capture interactive demonstrations and discussion.

Table 2. Strategies for Manufacturing and Automation Course Support for HyFlex (Asynchronous) Students (continued).

Course	Lab Attendance Arrangements	HyFlex Course Strategies	Existing Methods and Technologies Adapted for HyFlex Delivery
Electric Power and Devices (3rd Year) and **Instrumentation and Controls** (3rd Year) Each course requires both a lab component and a lecture component.	Two-hour in-person lab session per week, scheduled to accommodate intern student availability.	• Highly interactive in-person lecture and problem-solving is recorded for asynchronous student participation. • Posting of the interactive session becomes a reference for both asynchronous and in-person students.	• Document camera connected to laptop allows flexibility between prepared PowerPoint and interactive activities. • Zoom recording captures the session for online posting for all students (asynchronous participation or in-person student review).

An example of flexible presentation technologies is demonstrated in the Electrical Power and Devices and Instrumentation and Controls Classes. The instructor creates lecture handouts that summarize the topic and present example exercises. Similar to PowerPoints, the lecture handouts are highly structured and contain sections, subsections, definitions, summaries, etc. However, unlike traditional slides, they are highly interactive, because using them as paper documents with the document camera, the instructor can work along with the students in real time, circling or underlining the important concepts, drawing plots, boxing in equations. The document camera is directly connected to the instructor laptop for ready reference to data sheets, various web content, and specialty software programs that might be required for a particular lecture.

Activity worksheets and resources. Worksheets and resources already created to support classes typically translate well into the online environment—perhaps with some additions to make up for the absence of a real-time explanation from a live instructor. Conversely, support references and resources created for asynchronous students who cannot consult the instructor in real time also make great study support resources for in-person students. Thus, these promote the HyFlex principle of "reusability;" whatever resources support one modality are likely an excellent support for all modalities.

Flipped classroom assignments and resources. Flipped classroom resources translate well to the HyFlex class since they expect the student to prepare on their own outside of the class meeting, regardless of their modality selection. Flipped classroom resources already present resources and instruction designed for student reference on their own, as needed. Course in Manufacturing Methods, Automated Manufacturing Systems I, and CNC Machining Processes already required students to learn content using SME’s Tooling U modules outside of class, so there was no change for asynchronous students.

However, the flipped classroom design leaves the expectation of an activity-based in-person class meeting, which may or may not translate well when including students attending asynchronously. In some cases, the instructor can provide the asynchronous students with the same group activity worksheets and resources, but the asynchronous student may work independently rather than with a group. (In the future, we hope to connect asynchronous students with the possibility of working together if that suits their learning needs.)

In some cases within the Manufacturing Methods class, the in-person active-learning session involves using equipment such as micrometers or other equipment that remote students do not have. To substitute for the lack of equipment, the instructor has prepared online worksheets in a self-check quiz format, as shown in Figure 4. The multi-take quiz questions provide links to video demonstrations (to be watched on an as-needed basis) for asynchronous students who need assistance—or for any student who needs a review.

Resources for self-help and review. The self-check quiz is an example of self-assessment and review. It is especially helpful for early formative assessment, and it also serves as a low-stakes, early motivator to help keep students engaged and moving forward with the course material and activities.

Figure 5 presents an example from the Automated Manufacturing Systems I class. The online learning activity worksheet presents a case example of a simple PLC program for students who have never seen a PLC program before. They apply their previous knowledge of pneumatic systems and relay logic to narrow down the correct interpretation of the PLC ladder diagram presented by the self-check quiz question.

Results

Data was collected from assessments of student work representative of the learning outcomes supported by the HyFlex delivery methods of the six manufacturing and automation courses in 2024. Student performance scores were compiled from instruments such as exam scores, project or lab rubrics, and in some cases overall course grades that come from a combination of these instruments. Data was collected using the same standards the programs apply to program assessment.

To ensure the anonymity of individuals involved in the study, outcomes reporting averaged scores across students and anonymized class names. A simple analysis compares the average performance of in-person students to students who attended "mostly online" or, in some cases, "sporadically online," as judged by the instructor. The summary also tracks how many students in each modality meet or exceed the baseline outcome of 70%.

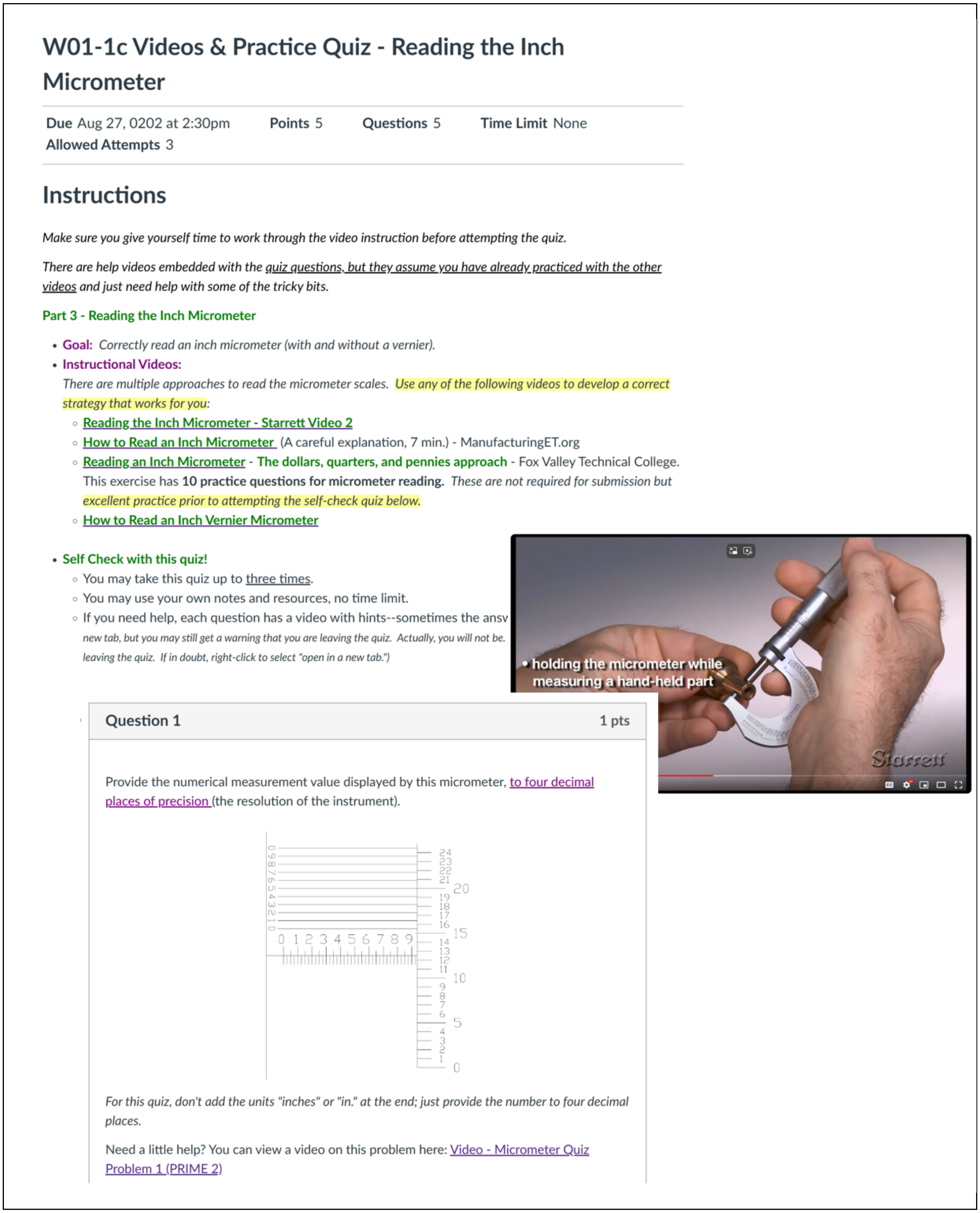
Table 3 presents the summary data of student performance from the six manufacturing and automation courses. In summary, in Courses A, B, and D, the online students performed better on average than the in-person students. In Course C, the in-person students performed, on average, 6.6 points better but still in the same letter grade category.

In four of the six classes, all of the student, regardless of modality, met baseline requirements. In the other two (Courses E and F), one mostly-online student (the same student in both classes) did not meet baseline expectations of 70% or better. This was primarily due to the student not engaging in the online learning activities and resources. The instructor was concerned going into HyFlex that online students would neglect classwork when no longer forced to prepare for scheduled meetings. The fact that only one online student from these six classes performed below baseline due to neglect of work was a better outcome than expected. Course F additionally had two in-person students who did not meet baseline expectations.

For the courses where online students surpassed the performance of the in-person students, the instructor postulates that some students choosing to do online work may be more diligent or confident than in-person students. These students are more likely to re-watch lectures, review material before exams, ask questions if they do not understand something, and therefore do well on exams.

The clear success of online students in three of the courses indicates the effectiveness that can be achieved with even simple online instructional solutions.

Additionally, the instructors self-reported ease of implementation and satisfaction with these strategies.



W01-1c Videos & Practice Quiz - Reading the Inch Micrometer

Due Aug 27, 0202 at 2:30pm **Points** 5 **Questions** 5 **Time Limit** None
Allowed Attempts 3

Instructions

Make sure you give yourself time to work through the video instruction before attempting the quiz.

There are help videos embedded with the quiz questions, but they assume you have already practiced with the other videos and just need help with some of the tricky bits.

Part 3 - Reading the Inch Micrometer

- **Goal:** *Correctly read an inch micrometer (with and without a vernier).*
- **Instructional Videos:**
  There are multiple approaches to read the micrometer scales. Use any of the following videos to develop a correct strategy that works for you:
  - Reading the Inch Micrometer - Starrett Video 2
  - How to Read an Inch Micrometer (A careful explanation, 7 min.) - ManufacturingET.org
  - Reading an Inch Micrometer - **The dollars, quarters, and pennies approach** - Fox Valley Technical College. This exercise has **10 practice questions for micrometer reading.** *These are not required for submission but excellent practice prior to attempting the self-check quiz below.*
  - How to Read an Inch Vernier Micrometer

- **Self Check with this quiz!**
  - You may take this quiz up to three times.
  - You may use your own notes and resources, no time limit.
  - If you need help, each question has a video with hints--sometimes the ansv
    new tab, but you may still get a warning that you are leaving the quiz. Actually, you will not be. leaving the quiz. If in doubt, right-click to select "open in a new tab.")

Question 1 1 pts

Provide the numerical measurement value displayed by this micrometer, to four decimal places of precision (the resolution of the instrument).

For this quiz, don't add the units "inches" or "in." at the end; just provide the number to four decimal places.

Need a little help? You can view a video on this problem here: Video - Micrometer Quiz Problem 1 (PRIME 2)

Figure 4. Example of flipped classroom teaching resource with self-check quiz for the Manufacturing Methods course. The quiz provides links to instructor-made videos of step-by-step solutions to each problem.

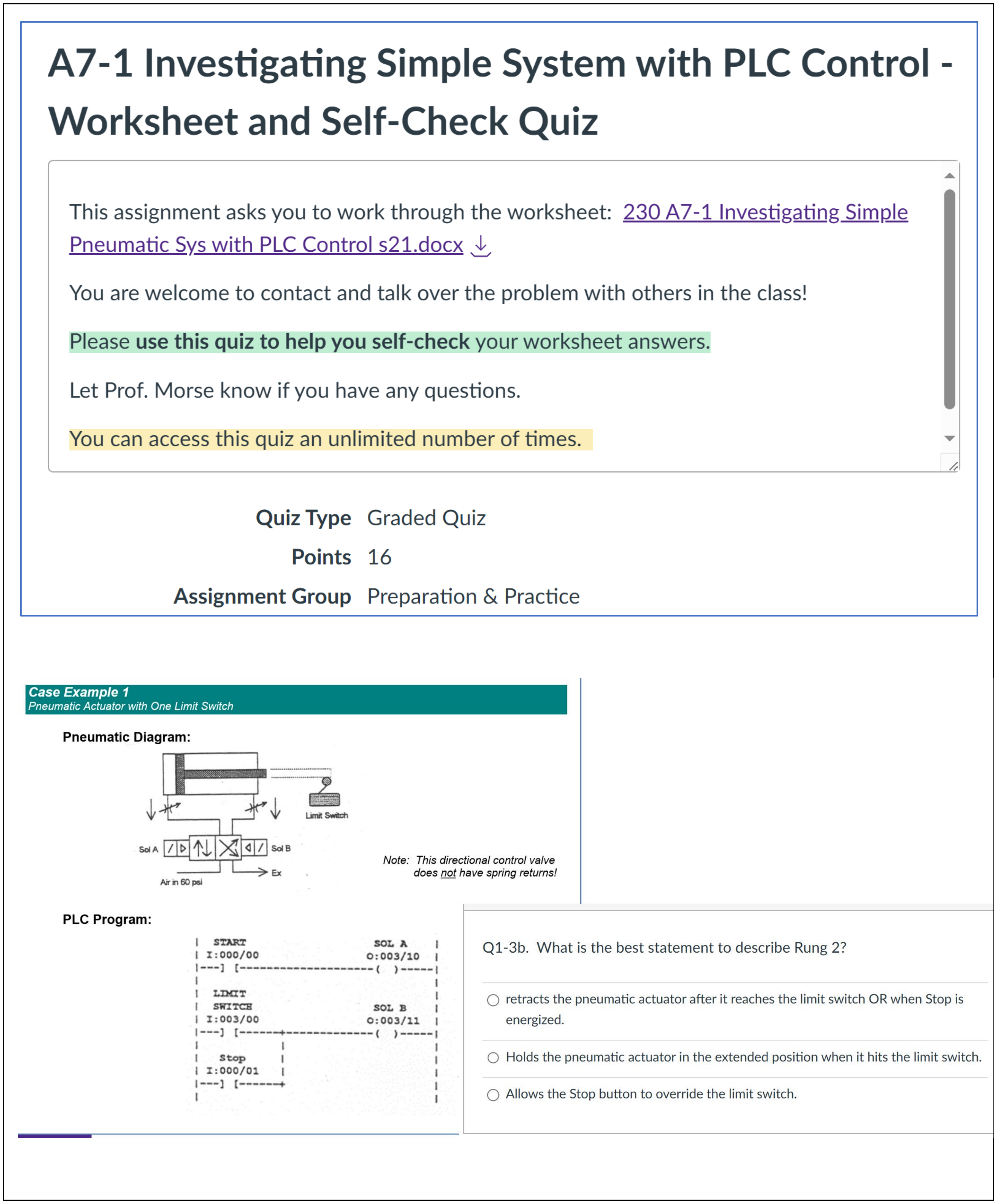


Figure 5. Example of a self-learning case example activity for Automated Manufacturing Systems 1 course. The self-check quiz questions help students narrow down correct interpretation and check their hypotheses.

Table 3. Student Performance Comparison Data for In-Person and Online Modalities in HyFlex Manufacturing and Automation Courses

			Students participating primarily **In-Person**			Students participating primarily **Online** (for the HyFlex course component)			Students participating **Mixed In-Person and Online** (for the HyFlex course component)		
Manufacturing or Automation Course	Performance measure	Instrument	Number (percent)	Average Performance	Percent performing 70% or better	Number (percent)	Average Performance	Percent performing 70% or better	Number (percent)	Average Performance	Percent performing 70% or better
A	Final exam score	Rubric scoring levels for design problems	12 (60%)	86.8	100%	2 (10%)	88.0	100%	6 (30%)	88.2	100%
B	Final exam score	Rubric scoring levels for design problems	10 (55.5%)	86.4	100%	3 (16.7%)	95.3	100%	5 (27.8%)	93.4	100%
C	Overall course grade	Lab performance evaluations, Exam problem rubrics, multiple choice scores	19 (95%)	89.1	100%	1 (5.0%)	82.5	100%	-	-	-
D	Overall course grade	Lab/Project performance evaluations, Exam problem rubrics, multiple choice scores	14 (73.7)	91.6	100%	4 (21.1%)	92.8	100%	1 (5.3%)	70.1	100%
E	Student Exam Average	Exam problem rubric, multiple choice scores	15 (65.2%)	90.7	100%	8 (34.8%)	81.6*	75%	-	-	-
F	Student Exam Average	Exam problem rubric, multiple choice scores	16 (80%)	80.5	87.5%	2 (10%)	63.6%**	50%	2 (10%)	87.8%	100%

**Average of passing students was 88.1%*
***Average of passing student was 72.8%*

The success of our work-study internship students in these classes so far testifies to the effectiveness of these approaches. In this past academic year of work-study internships with a specific employer, only one student has dropped out, not because of academic performance issues, but because of a change in interest by the student. (In a way, that is a success, since the workplace experience gave the student an early indication of the career mismatch.)

Instructors implementing HyFlex opportunities in their classes frequently noted advantages the HyFlex resources and options offered to all students, not just those involved in internships:

- Improved ease of accommodation for students with illness.
- Student flexibility to miss classes to attend career enrichment opportunities (such as conferences, trade shows, or campus events).
- Student flexibility to be more involved in campus and community events that might conflict with scheduled classes.
- Ease for students to attend to family responsibilities such as to assist family with health concerns or to attend funerals, weddings and special events, etc., without adversely affecting their course performance.
- Improved opportunities for students who fall behind to catch up.
- Improved study materials and resources for all students.

Individual students express their appreciation for the rich techniques, interactivity, accessibility, and flexibility afforded by HyFlex courses:

- Students appreciate the "semi-normal way" they can access courses remotely if needed.
- A student experiencing the flexible in-class problem-solving technologies stated, "I cannot wait to have more classes with [this instructor]. The way he teaches with lecture notes and problem [solving] is an amazing way to learn." Additional positive comments echo this theme.

Conclusions

The overall aspiration of this paper was to share and present effective methods to improve engagement strategies for asynchronous learners through improved peer-to-peer support, instructor interactions, and course instructional resources.

There is a high demand for engineering graduates, particularly in the manufacturing and automation industries. Innovative approaches to recruiting and retaining engineering students are necessary to satisfy the rising demand. One of these approaches is the HyFlex course delivery method.

The HyFlex course delivery preserves in-person active learning opportunities while simultaneously offering online learning alternatives for students who cannot attend in person or have other reasons for finding the flexibility of asynchronous opportunities helpful to their life situations and learning goals.

One of the challenges engineering students face is reconciling work schedules and class schedules. In manufacturing and automation education, experience with industry-relevant equipment is required. Therefore, many students enroll in work-study industry internships which offer experiential learning opportunities in real industrial settings. However, work scheduling requirements often conflict with class attendance.

The Engineering Technology program at Kansas State University Salina Campus attempts to balance these competing objectives through partial HyFlex course delivery and lab scheduling options. In this paper, instructors present hybrid/HyFlex innovative approaches in six manufacturing and automation courses, which allow them to accommodate students with scheduling conflicts caused by industrial internships or other co-curricular activities.

The presented solutions emphasize the adaptation of existing course materials, techniques, and technologies to work for both in-person and asynchronous online students. Challenges and opportunities of the implemented HyFlex methods are discussed, and advantages and disadvantages of in-person as well as asynchronous students are compared and contrasted.

Student assessments and teaching evaluation feedback demonstrate student satisfaction and appreciation for added resources and accessibility offered by hybrid/HyFlex options. Instructors at Kansas State University Salina have been somewhat surprised with the amount of asynchronous student support materials and techniques which they had already developed. With some modifications and the assistance of in-person classroom recordings, asynchronous students have been able to join in and meet outcomes with success on par with their in-person counterparts—or even better.

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