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Sustainability in the Plastics Curriculum: Training for Improving Plastics Circularity

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Abstract

Sustainability has become a part of our everyday lives, and we are affected as members of the plastics industry as well as consumers. What can we do and what has been done to minimize or recycle plastic waste? Plastics have garnered a negative reputation over recent years due to the growing rate of plastic waste found in the environment.

This paper will focus on how faculty from the Plastics Engineering Technology program will be developing modules throughout the curriculum to focus on sustainability at each stage of the product's life cycle. Materials, part and mold design, testing and processing courses will include content that brings awareness to the importance of creating a sustainable mindset. This initiative is part of the Training for Improving Plastics Circularity grant received from the National Institute of Standards and Technology (NIST) through the Department of Commerce.

The plastic product lifecycle can no longer be sustained as a linear process. The days of blindly designing a product without putting serious thought into the endgame has become a reckless practice and needs to change. Thoughtful design and processes are continuing to evolve as part of the movement towards Plastics Circularity. The circular economy is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste and pollution (Ellen, n.d.). The importance of this initiative is being supported by the US Department of Commerce's National Institute of Standards and Technology (NIST). The Training for Improving Plastics Circularity (TIPC) Grant Program aims to develop the future workforce needed to grow a circular economy for plastics. A circular economy is one in which materials retain their value through repeated reuse, repair, and recycling, and are finally discarded only as a last resort (Hanacek, 2022). This paper will focus on the initial planning stages of introducing this concept into existing plastics curriculum of an engineering technology program as part of the Training for Plastics Circularity (TIPC) grant funded through NIST.

The PET program at Pittsburg State University

The Department of Engineering Technology (ETECH) is housed in the Kansas Technology Center on the Pittsburg State University campus. ETECH programs are comprised of technological elements requiring scientific and engineering knowledge plus the hands-on methods to provide practical skills in support of product producing industries, like plastics manufacturing. The Pittsburg State University Engineering Technology Programs are accredited by the Accreditation Board for Engineering and Technology (ABET). This accreditation provides assurance that our ETECH programs meet the quality standards of the profession for which that program prepares graduates.

Engineering and engineering technology are separate but closely related professional areas that differ in some areas (Thomas, n.d.). ETECH courses stress the application of technical knowledge and methods in the solution of practiced engineering problems. Engineering courses stress the underlying theory of the subject matter. In ETECH programs, laboratory activities are an integral component, including the study of practical design solutions, manufacturing techniques, and evaluation techniques for industrial type problems. In engineering programs, laboratory courses provide an intensive overview of experimental methods and related underlying theories of manufacturing. Upon program completion, the ETECH graduate and engineering graduate entering industry will likely have similar positions in design, process engineering, manufacturing, research and development, or technical sales and services. The ETECH graduate is prepared to immediately begin technical assignments in their specialty area since programs stress current industrial practices and design procedures. They “hit the ground running” in the words of many employers. The engineering graduate typically requires a period of internship since engineering programs stress fundamental concepts over applications.

PSU’s Plastics Engineering Technology (PET) program was started in 1969 and is one of three ABET-accredited PET programs in the United States. The PET program provides students with detailed technical knowledge and the ability to hone their skills on state-of-the-art equipment. The PET program emphasizes detailed technical knowledge and real-world problem solving and is the reason why PET graduates enjoy a near 100 percent placement rate after graduation. Our PET curriculum keeps pace with the technological changes and anticipated needs of the plastics industry. The PET program is a key component of the university’s Polymer Chemistry Initiative. Through this initiative students will be exposed to advanced foundation Polymer Chemistry courses, theory and application of plastic design, and the research-based opportunities at the Kansas Polymer Research Center and the National Institute for Materials Advancement, both housed within the Tyler Research Center at Pittsburg State University. The result is a well-rounded educational experience that provides students with the knowledge, skills, and contacts they need to become successful after graduation.

Current Facility and Equipment Information

The PET program has extensive plastics processing and testing equipment in our student laboratories. The PET processing lab has two all-electric injection molders: a 90-ton PX 81-100 Krauss-Maffei injection molder with a robotic sprue picker and conveyer, an 85-ton eMotion 85 Engel Injection Molder a robotic sprue picker and conveyer, and a hydraulic, 55-ton Arburg injection molder with iMFLUX injection controls. Blow molding equipment includes a Kautex KEB-01 extrusion blow molder with an MC Molds in-line dome trimmer. A new Sidel SBO-1 stretch blow molder has recently been acquired and will be installed over the summer and fall of 2022. The PET program’s extrusion capability includes two single-screw extruders (Yelllowjacket and Milacron SMV-150) a twin-screw extruder (LabTech TE20-44), and several pieces of downstream equipment: a blown film tower (LabTech LF-400), a 300 mm coat Hanger flat die (LabTech LCR-300) with chill roller attachment (LabTech), a vacuum sizing tank (LabTech L2.5), an extrusion water bath (LabTech LW100), a haul-off puller (LabTech LCAT), and 4” Berlyn strand pelletizer. Our labs also have thermoforming capability in the form of a larger APM Integrity SFS/DP thermoformer and a smaller Formtech 508FS thermoformer. We have an additional Brabender puller/winder that is most often used with the Yellowjacket single-screw extruder. We have a four-chamber Plastrac gravimetric feeder that can be used with the LabTech twin-screw extrude to compound a variety of materials. We can also rotational mold using the Roto-Lab Model 30 rotational molder. Our processing efforts are supported by a

Rotogran 8x8 granulator, a Foremost 10x10 granulator, and a SRS SR1013 screenless granulator. We have an AEC Whitlock drier and a Novatec MCD 3000 drier for materials that require drying prior to processing.

The Plastics Testing Lab has recently been completely refurbished. Our testing lab has two Instron frames (models 34TM-30 and 4467), both with 30 kN load cells; a CEAST melt flow rheometer, a BYK-Gardner byko spetra-pro light booth, BYK-Gardner spectro2guide 45/0 spectrophotometer, a QUV accelerated weathering tester, a TMI Izod Impact tester, and TMI notching cutter. The Testing Lab also has a PET-dedicated computer lab with three computer loaded with Solidworks design software and Sigmasoft mold flow simulation sofware. We also have access to several 3D-printers including two Anycubic printers, three Creality Ender 3 Pro printers, and a Stratasys F170 fused deposition molder.

The Polymer Research Center (KPRC) is housed in the Tyler Research Center at PSU and is a leading center in the development of new bio-based polymer materials. KPRC is an internationally recognized center for chemistry and materials science with a specialization in vegetable oil-based polymer research and development. KPRC engages the academic community at PSU through research projects and other educational activities for faculty and students. Each PET-185 General Plastics cohort tours Tyler Research Center to learn about its analytical capabilities. Since 2018, KPRC has supported PET-586/687 (Senior Project I/II) students by providing access to key instrumentation for polymer analysis including: differential scanning calorimetry, thermogravimetric analysis, Fourier-transform infrared spectroscopy, tensile testing, and scanning electron microscopy. With the establishment of the National Institute for Materials Advancement, this analytical capability has expanded to include thermogravimetric analysis with mass spectrometry, a more powerful scanning electron microscope, and greater X-ray diffraction capability. KPRC also gives PET students employment opportunities in a working lab environment while performing bio-based materials research as undergraduates.

Plastic Engineering Technology Curriculum

PET program graduates will have the following skills upon program completion: (1) an ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly-defined engineering problems appropriate to the discipline; (2) an ability to design systems, components, or processes meeting specified needs for broadly-defined engineering problems appropriate to the discipline; (3) an ability to apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature; (4) an ability to conduct standard tests, measurements, and experiments and to analyze and interpret the results to improve processes; and (5) an ability to function effectively as a member as well as a leader on technical teams. The courses detailed in Table 1 below are specifically designed to meet these objectives.

Table 1: Degree Options with Required and Elective Courses
for Plastics Engineering Technology at XXXXX University

	Bachelor of Science in Engineering Technology (BSET): Plastics Engineering Technology	Associate of Applied Science Degree (AAS): Plastics Technology	Plastics Technology Minor
Degree Option	4-year degree	2-year degree	Minor for 4-year degree
Total Credits Required	120	64	21
Total Credits in Plastics/Polymer Courses	35	22	21
Required Plastics/Polymer Courses	PET-180 General Plastics Laboratory [a] PET-185 General Plastics PET-272 Plastics Processing I Laboratory [a] PET-273 Plastics Processing I PET-281 Plastics Testing Technology [c] PET-370 Thermoplastic Resins Laboratory [a] PET-371 Thermoplastic Resins PET-374 Thermoset Resins Laboratory [a] PET-375 Thermoset Resins PET-376 Plastic Processing II Laboratory [a] PET-377 Plastic Processing II PET-585 Part and Mold Design I PET-586 Senior Project I [a,c] PET-684 Part and Mold Design II PET-687 Senior Project II [b,c]	PET-180 General Plastics Laboratory [a] PET-185 General Plastics PET-272 Plastics Processing I Laboratory [a] PET-273 Plastics Processing I PET-370 Thermoplastic Resins Laboratory [a] PET-371 Thermoplastic Resins PET-585 Part and Mold Design I PET-376 Plastic Processing II Laboratory [a] PET-377 Plastic Processing II	PET-180 General Plastics Laboratory [a] PET-185 General Plastics PET-272 Plastics Processing I Laboratory [a] PET-273 Plastics Processing I PET-370 Thermoplastic Resins Laboratory [a] PET-371 Thermoplastic Resins PET-585 Part and Mold Design I
Elective Courses *BSET: 3 elective credit hours* *AAS: 3 elective credit hours* *Minor: 6 elective credit hours*	PET-673 Advanced Injection Molding [c] PET-685 Composites [c]	PET-281 Plastics Testing Technology [c] PET-673 Advanced Injection Molding [c] PET-685 Composites [c]	PET-281 Plastics Testing Technology [c] PET-370 Thermoplastic Resins Laboratory [a] PET-371 Thermoplastic Resins PET-376 Plastic Processing II Laboratory [a] PET-377 Plastic Processing II PET-673 Advanced Injection Molding [c] PET-684 Part and Mold Design II PET-685 Composites [c]

Notes:
[a] PET-586 Senior Project I and PET Laboratory courses are worth one credit hour.
[b] PET 687 is worth two credit hours.
[c] PET-281 Plastics Testing Technology, PET-586 Senior Project I, PET-673 Advanced Injection Molding, PET-685 Composites, and PET-687 Senior Project II are combination lecture/lab courses.
All other courses listed are worth three credit hours and follow a lecture format.

The following courses are required for each degree program or option: PET-180 General Plastics Laboratory: PET-185 General Plastics, PET-272 Plastics Processing I Laboratory, PET-273 Plastics Processing I, PET-370 Thermoplastic Resins Laboratory, PET-371 Thermoplastic Resins, PET-585 Part and Mold Design I.

The following courses will include a project or module that focuses on improving polymer circularity from the perspective of plastics engineering technology: PET-180 General Plastics Laboratory PET-185 General Plastics, PET-272 Plastics Processing I Laboratory, PET-273 Plastics Processing I, PET-281 Plastics Testing Technology, PET-370 Thermoplastic Resins Laboratory, PET-371 Thermoplastic Resins, PET-376 Plastic Processing II Laboratory, PET-377 Plastic Processing II, PET-585 Part and Mold Design I, PET-586 Senior Project I, and PET-687 Senior Project II. The Pittsburg State University catalog description of these courses is presented in Table 2 below. The details of each project or module that will be incorporated into these courses are also explained below.

Table 2: Plastics Courses, Credit Hours, and
Course Descriptions for Courses with Circularity Modules or Projects

Course	Credit Hours	Course Description
PET-185 General Plastics	3	Introductory plastics course including topics in polymers and applications, processing and fabrication methods, tooling and molds, and testing.
PET-180 General Plastics Laboratory	1	Laboratory experiments involving plastic materials and processes used in plastics industry.
PET-273 Plastics Processing I	3	Processing techniques for polymers including; extrusion, injection molding, blow molding, thermoforming, rotational molding, compression molding, transfer molding, casting, and fabrication.
PET-272 Plastics Processing I Laboratory	1	Safety, economics, set-up, and production with extrusion, injection molding, blow molding, thermoforming, rotational molding, compression molding, transfer molding, casting, and fabrication.
PET-281 Plastics Testing Technology	3	Theories and practical aspects of industrial and scientific testing and characterization procedures of plastics. Understanding of properties, testing, identification, characterization, specification, and standardization of polymers.
PET-371 Thermoplastic Resins	3	Study of thermoplastic materials that are commercially available for the plastics industry. Review of the manufacture, properties and applications of widely utilized resins with a focus on chemical structure/property relationships (crystallinity, morphology, copolymerization, molecular weight, and physical properties).
PET-370 Thermoplastic Resins Laboratory	1	Techniques and procedures used for the testing, evaluation, and selection of thermoplastic resins.
PET-377 Plastic Processing II	3	Study of the more prevalent industry processing methods (extrusion, injection molding, blow molding, thermoforming, and others) focusing on optimization, quality, automation, maintenance, and safety. Overall manufacturing enterprise and costing strategies will be included.
PET-376 Plastic Processing II Laboratory	1	Focused on safety, set-up, optimization, and automation with extrusion, injection molding, blow molding, thermoforming and other processing methods.
PET-585 Part and Mold Design I	3	Methods and systems used in the development of plastic products, from concept development, material selection, CAD design, CAE analysis, cost analysis, and prototyping, through molds/tooling used for production. Focus is placed on the design process using standard industry practices.
PET-586 Senior Project I	1	Part I of the capstone plastics course incorporating functional part/process selection and design, technical and processing analysis, and suitable polymeric material selection.
PET-687 Senior Project II	2	Part II of this capstone course will continue with the initial efforts of PET 586 and is based on sound design, costing and quality, testing and evaluation with the culminating efforts in producing a prototype and/or enhancement of a process.

Proposed Project Approach and Execution Plan to Improve Plastic Circularity Training in the Undergraduate PET Curriculum

Improving plastics circularity in the training in the PET undergraduate curriculum will combine modules and learning activities within all levels of existing coursework, from freshman to seniors; new coursework focused on the incorporation of plastics circularity concepts at an advanced level; SPE student activities that combine service activities, social interaction, and improved awareness of the ways students can reduce plastics in waste streams and manufacture useful products; summer undergraduate internships to develop, trouble-shoot, and fine-tune undergraduate lab activities used during the fall and spring, and faculty and student travel to conferences that serve the plastics industry and focus on recycling and sustainability.

Proposed learning activities for PET-185 General Plastics and PET-180 General Plastics Laboratory

Students that enroll in PET-185/180 are generally students in their first semester of the PET program. Face-to-face and online classes will include lectures that compare the recyclability of parts made from thermoplastics versus parts made from thermoset plastics. Face-to-face and hybrid labs will include field trips to two local manufacturers that incorporate regrind into their products and a field trip to the local recycling facility to familiarize students with the real-world process of collecting plastics for recycling.

Proposed learning activities for PET-273 Plastics Processing I & PET-272 Plastics Processing I

Students that enroll in PET-273/272 are generally students in their second or third semester of the PET program. Face-to-face lecture material on post-consumer collection, handling, cleaning, separating, and sorting for plastics recycling will be presented to enhance student understanding of the challenges that post-consumer plastics present when they are considered as a material resource for manufacturing new plastics parts or products. Plastic size reduction techniques, like granulation, and the challenges associated with size reduction to result in a viable material for processing will also be presented in lecture, as well as operation of granulators and driers with regrind material. The lecture will also address reprocessing of co-mingled plastics material streams versus segregated material streams when considering post-consumer content for plastics applications.

Face-to-face laboratory activities will reinforce the lecture material through hands-on activities with the twin-screw extruder and downstream pulling/winding equipment and pelletizing equipment. Lab activities will also utilize a volumetric four-hopper feeding blender and modification of blender parameters to vary PCR and/or other additive content for plastics processing via twin-screw extrusion. Students will then examine the effect that the incorporation of different ratios of PCR to virgin material has on the resulting extruded material.

Proposed learning activities for PET-281 Plastics Testing Technology

Students that enroll in PET-281 are generally students in their second, third, or fourth semester of the PET program. In this face-to-face lab/lecture course, students learn the analytical techniques necessary to develop a material data sheet for a given plastic material. Students learn how to measure tensile strength, tensile modulus, flexural strength, Izod impact properties, melt flow and Shore hardness. Students also calculate material density. Measurement techniques are discussed in lecture material and reinforced with hands-on laboratory activities.

A module will be created that compares material properties among the same base polymer with different levels of material handling typical of a commodity plastic used in consumer packaging. The proposed plastics are virgin polypropylene, PCR polypropylene, 20/80 virgin/PCR polypropylene blend, 50/50 virgin/PCR polypropylene blend, and ocean-sourced polypropylene. Test bars from each material will be injection molded and analyzed for tensile strength, tensile modulus, flexural strength, Izod impact properties, melt flow, Shore hardness, and material density. Students will be required to generate a report on each material analyzed. Students will be able to see the effects of types of material handling and treatment on material properties that are directly relevant to plastics processing with a focus on comparison between virgin plastic and plastic sourced to keep plastic out of the waste stream.

Proposed learning activities for PET-371 Thermoplastic Resins and PET-370 Thermoplastic Resins Laboratory

Students that enroll in PET-371/370 are generally students in their fifth or seventh semester of the PET program. Face-to-face and online lectures will identify the role of plastics in the environment through the considerations of energy input during production, transportation, land usage, and recycling of plastic materials versus traditional materials like aluminum, glass, cotton or wool for comparable products like shopping bags, beverage containers, or textiles. Lectures will also highlight the prevalence of recycling facilities and the reuse or repurposing of plastic items in day-to-day life. The lectures highlight the benefits of plastics on reduced fuel consumption during transportation and energy input when sourcing raw materials, producing comparable packaging, and recycling post-consumer products. Recycling symbols used in post-consumer recycling facilities will also be presented in conjunction with the typical plastics that are used and recycled by consumers in typical packaging applications. The lecture will also define the differences between post-industrial and post-consumer plastics.

Face-to-face and lab activities will require students to identify several different items of unique packaging they use in their day-to-day lives, the plastic from which the packaging is made, and the recycling capability of that type of packaging. Students will also be required to evaluate their access to recycling facilities in their university community compared to recycling facilities in their hometowns. They will also be required to report the degree to which they recycle on a routine basis as a way of highlighting the role that individual involvement and municipal facilities play in keeping plastic packaging out of landfills and waterways.

Face-to-face and online lab activities will also require students to use data generated from polymer analytical techniques to identify unknown polymers. Students will be presented with two test bars that are identical in physical appearance and two sets of data from differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), Fourier-transform infrared spectroscopy (FT-IR), tensile testing, and Izod impact testing. Using their knowledge of polymer structure/property relationships, they will identify the test bar made from virgin material and the test bar made from PCR or ocean-sourced material. They will be required to generate a report that highlights the key pieces of data that supported their conclusions, and the data that was similar for each unknown plastic. Students will become more familiar with standard polymer analytical techniques; this activity will give them more insight into the viability of PCR or ocean-sourced material into plastics products by specifically highlighting thermal and mechanical properties relevant to plastics processing.

Proposed learning activities for PET-377 Plastic Processing II and PET-376 Plastic Processing II Laboratory

Students that enroll in PET-377/376 are generally students in their fifth or sixth semester of the PET program. Students will examine the screws, reconfigure the screws, and operate the twin-screw extruder using varied operating parameters to understand the effects of machine parameters, screw design, and type of material on plastic in the melt and final extruded product. Topics related to screw design will include screw design parameters of mixing sections, non-compression sections, kneading sections, and how screw configuration can be modified to affect twin-screw extrusion processing parameters and resulting products. Information included in lecture presentations will include twin-screw extruder operating basics and twin-screw screw design basics with a focus on screw geometry and the effect of screw geometry modification. Different pelletizing techniques of extruded filament and their advantages and disadvantages will also be presented. The main types that will be discussed are strand chopping versus underwater pelletizing.

Face-to-face laboratory activities will reinforce the lecture material through hands-on activities with the twin-screw extruder and downstream pulling/winding equipment and pelletizing equipment. Students will examine the effects that screw configuration and design have on the extruded filament as modifications to screw geometry are applied in the laboratory. In both the lecture and hands-on laboratory activities, there will be an emphasis on how incorporation of different materials including ocean plastics, post-consumer regrind (PCR), and bio-based thermoplastics affect processing parameters and the quality of the final products produced by twin-screw extrusion to assess viability of the increased use of these materials using standard processing equipment.

Proposed learning activities for PET-585 Part and Mold Design I

Students that enroll in PET-585 are generally students in their seventh semester of the PET program. Solidworks design software is used to design and modify plastic parts and molds in this course. Solidworks offers sustainability features as part of the software package, and each student will earn Solidworks sustainability certification. Upon earning a score of 80% or greater, students with this certification will understand the principles of environmental assessment and sustainable design. The Sustainability exam features theory-based questions of the following: sustainability and sustainable business introductory concepts, sustainable design concepts, stages of a product life cycle, considerations for setting up an environmental assessment study, variables for an environmental assessment study, tools for performing environmental assessments, steps for performing a life cycle assessment study, interpreting results of a product environmental assessment, universal strategies for sustainable design, and communication of environmental assessment results, and use of environmental marketing claims.

Students will also be required to incorporate sustainability parameters in their part designs and report on the impact that design parameters have on the overall carbon footprint of their part, as well as what factors contribute to that carbon footprint including material, manufacturing, transportation, use, and end of life. Figures 1 and 2 show how Solidworks incorporates sustainability in part design.

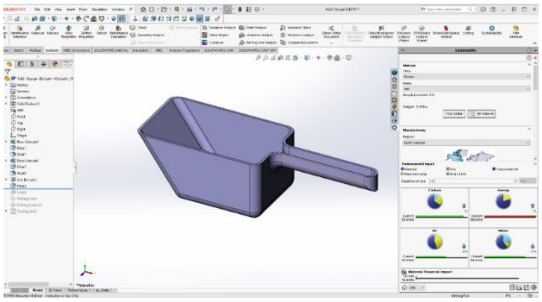

Figure 1. Solidworks part design of a scoop with sustainability factors shown.

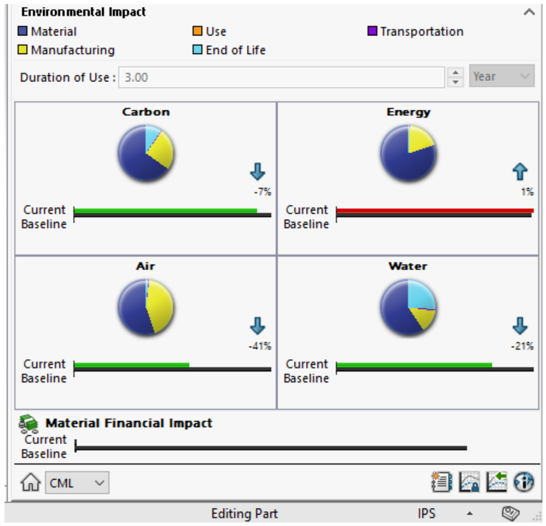

Figure 2: Sustainability factors considered in a Solidworks part design: carbon, energy, air, and water.

Proposed projects for PET-586 Senior Project I and PET-687 Senior Project II

Students that enroll in PET-586/687 are generally students in their seventh and eighth semester of the PET program. Students take PET 586 and PET 687 in sequence as Senior students that will be finishing their degree eminently. Students spend most of their time engaged in hands-on activities designed to meet the deliverables of their specific projects. Senior Projects vary depending on collaborative efforts and support from industry but have historically focused on investigating the role of bio-plastics and PCR. Table 3 details these projects.

Table 3: Senior Projects with Sustainability Focus 2018 - 2021

Year	Project Title
2020 - 2021	Investigation of Post-Consumer Regrind Content in ABS and Polystyrene for Consumer Packaging Applications
2020 - 2021	Investigation of Post-Consumer Regrind Content in Polyethylene and Polypropylene for Consumer Packaging Applications
2019 - 2020	The Effects of Environmentally-Friendly Plastic Resins on Color of Injection-Molded Plastic Parts
2019 - 2020	Development of Bioplastics for Consumer Applications
2019 - 2020	The Effects of Post-Consumer Regrind on Physical Properties of Plastic Products
2018 - 2019	Comparison of Bioplastics with Conventional Thermoplastics for Consumer Applications

The faculty plan to maintain this focus with the support of Green Dot Bioplastics and other industrial partners. We have been communicating with PSU alumni at iMFLUX in order to modify a test bar mold for the Arburg injection molder. The modification will allow pressure sensors for iMFLUX Automatic Viscosity Adjustment (AVA) technology to be introduced into the mold. AVA technology can then adjust parameters to maintain consistent production with varied materials including PCR and bioplastics. Our capstone course gives students the ability to work in teams with one focused project over the course of two semesters, allowing them to learn about the details of their project at a much greater depth than shorter-term laboratory or classroom learning activities.

Proposed new coursework (PET 690-Additives Formulation & Compounding)
A senior-level elective lab/lecture course focused on additives, formulation, and compounding PET 690-Additives Formulation & Compounding will be legislated and added to the PET program curriculum. The course will focus on the synergy between thermoplastics formulation and thermoplastic processing with a more in-depth analysis of how and why commercial thermoplastics are formulated. A face-to-face lecture module will examine how and why different types of regrind is used, how regrind can be used in different applications to different extents, and how regrind content can be optimized before part performance is compromised, and the categories of material properties that are affected by regrind including melt rheology, tensile strength, flexibility, impact resistance, heat resistance, chemical resistance, part color, and overall part appearance.

Face-to-face lab activities will use our compounding capability and gravimetric feeder to modify the material feed and processing parameters to illustrate changes in melt rheology and part performance as the feed of material is changed during compounding and blending. Pelletizing and reprocessing into test parts will examine the effect of multiple reprocessing cycles on tensile strength, flexibility, impact resistance, heat resistance, chemical resistance, part color, and overall part appearance. These lab activities will underscore the challenges and opportunities that regrind presents in processing and manufacturing of viable plastic parts.

Society of Plastics Engineers Student Chapter activities
In addition to circularity concepts in PET program coursework, students are encouraged to participate in the PSU student chapter of the Society of Plastics Engineers (SPE). For the past five years, PET has produced 1000 – 1500 “Gorilla Bottles” from post-industrial polyethylene waste produced in our processing labs. Students blow mold, injection mold, trim, flame treat, print, and assemble bottles at SPE Production Parties held weekly. Gorilla Bottles (Figure 3) are distributed by the PSU Admissions to prospective students and families touring the campus. The PSU Carnie Smith Stadium recently underwent renovation that included the removal of all stadium seats and cup holders. We have granulated the discarded cup holders into useable feedstock for gorilla keychains (Figure 3). Keychains are also used as promotional items by PSU Admissions. The demand for these promotional items continues to grow, so our students will continue bottle and key chain production.

Figure 3: Left: A) Blow-molded bottle with screen printed decoration, B) Injection molded bottle lid, and C) Gorilla keychain made from discarded cup holders. Right: Students at a PET Production Party.

Proposed undergraduate summer internship

The use of graduate teaching assistants in PET during the academic year is limited to only one student. Modification and addition of new learning activities and modules will require development and creation of new lab procedures, plastics samples, and course documents. Two students will be employed as PET Curriculum Development interns at $15 per hour for 40 hours per week over the course of the twelve weeks to assist PET faculty in processing, testing, and analytical lab development, procedure troubleshooting, sample production, and lab dissemination documents in new and existing coursework focused on lab learning activities.

Proposed faculty and student travel

Faculty members and undergraduate students will attend the Plastics Industry Association Re|Focus Sustainability & Recycling Summit Annual Conference. Conference topics include three tracks: sustainable business, sustainable manufacturing, and Operation Clean Sweep. The sustainable manufacturing track includes actionable strategies that can be applied to improving sustainable manufacturing, including advanced recycling technologies, utilizing alternative materials, and integrating recycled content into products (Richardson, 2022). This conference track will provide students with the greatest immediate insight into areas of the plastics industry that they are already familiar with, but with a focus on sustainable current plastics industry practices and immediate next steps to improve the sustainability of the plastics industry.

Proposed Equipment to Support Learning Activities

To support our ability to measure plastic parts, several pieces of analytical equipment will be added to our Plastics Testing Lab. The ability to quantify moisture in materials prior to processing will be improved with a Sartorius Mark3 HP Moisture Analyzer. Students will gain the ability to determine thermal properties of their materials in-house with a Discovery DSC 250 differential scanning calorimeter with Discovery Refrigerated RC S90 cooling system and a Discovery TGA 550 thermogravimetric analyzer, both from TA Instruments. An upgrade to our current melt flow capability will be accomplished with a CEAST MF20 Versatile Melt Flow

Tester from Instron. The ability to quantify the impact strength of plastic parts will be greatly enhanced by an upgrade to our Izod impact testing equipment and pendulum impact notcher. We will also have greater impact testing versatility by adding Charpy capability. With new film production capability from the cast film die and blown film tower, our ability to test film will be improved by the acquisition of a Magna-Mike 8600 Hall effect thickness gauge with internal data logger, and a film puncture fixture for the Instron 4467 tensile frame. Harvard Factory Automation Inc. Reversing Conveyor for the Arburg injection molder will be added to complement the iMFLUX AVA technology so that parts can be automatically sorted into in-spec parts and rejected parts. A Rotogran WO-1418 Medium Duty Granulator with evacuation system will allow our students to use regrind more efficiently and will sort out small particles that have been problematic in the past and caused burned areas of parts. An additional computer with Solidworks and Sigmasoft software will also be added to the Plastics Testing Simulation lab for greater student access to this modeling and simulation software. The equipment mentioned here will be discussed in greater detail in the Budget Narrative.

Dissemination and Communication Plan

To quantify student learning and assess that plastics circularity concepts are being successfully integrated into the PET program at Pittsburg State University and are actively being learned by PET undergraduate students, we first identify specific quantifiable performance indicators and assessment tools in each course that incorporates circularity learning activities. Table 4 outlines the course, performance indicator, assessment method, and target performance for plastics circularity-focused learning activities. Assessments will be reported on a yearly cycle. If performance targets are not met, an action plan will be presented to improve student learning performance and modification will be made to the learning activity accordingly.

Table 4: Courses, Performance Indicators,Assessment Methods, and Target Performance for PET Learning Activities

Course	Performance Indicator	Assessment Method	Target Performance	Actual Performance
PET-185/180 General Plastics and Lab	Identify how plastics are recycled locally	Field Trip Attendance	85% of students attend all field trips	Year 1 – Year 2 – Year 3 –
PET-273/272 Plastics Processing I and Lab	Identify the challenges that size reduction and sorting of regrind can have on plastic parts	Lecture Quiz	80% of students will score at least 80% on the quiz	Year 1 – Year 2 – Year 3 –
PET-281 Plastics Testing Technology	Compare and contrast the properties of virgin vs. sustainable plastics	Lab Report	75% of students will correctly identify the materials studied with the data collected	Year 1 – Year 2 – Year 3 –
PET-371/370 Thermoplastic Resins and Lab	Compare and contrast the properties of virgin vs. sustainable plastics	Lab Report	75% of students will correctly identify the materials studied with the data collected	Year 1 – Year 2 – Year 3 –
PET-377/376 Plastic Processing II And Lab	Predict how screw design and configuration can be used to extrude PCR and bioplastics	Lecture Quiz	80% of students will score at least 80% on the quiz	Year 1 – Year 2 – Year 3 –
PET-585 Part and Mold Design I	Review how sustainability can be applied to the plastic part design process	Certification Exam	75% of students will successfully complete the Solidworks Sustainability certification	Year 1 – Year 2 – Year 3 –
PET-586/687 Senior Project I and II	Hypothesize and review the effects of bioplastics and PCR on parts and properties	Research Poster	100% of students will present posters at the PSU Research Colloquium	Year 1 – Year 2 – Year 3 –

As part of ABET accreditation requirements, the Plastics Engineering Technology Advisory Council (PETAC) meets twice a year to discuss program goals with members of the plastics industry to keep the PET program up to date with the needs and immediate future directions of the plastics industry. PETAC attendees consist of PSU PET alumni in the plastic industry, plastics industry members that have non-PSU alma maters, current PET faculty, former PET faculty, and current PET students for an average attendance of 25 attendees. Given the history of the PET program, PETAC attendees have between one and over thirty years of industry experience from companies including, but not limited to, BD Medical, Chevron Phillips, Fabrick Molding, Rehrig Pacific, Silgan Dispensing and Packaging, Yanfeng Automotive Interiors. The results of the learning activities detailed in the Project Execution Plan and quantified in Table X will be shared with the PETAC attendees as we report on our efforts to improve training in plastics circularity to them in line with the overall goals of this project. We will solicit their feedback on the learning activities and take their recommendations into consideration when improving or expanding these activities in future coursework.

The PET program will advertise on the PSU campus to recruit interns for the summer curriculum development internship positions. Advertisement will emphasize the importance of supporting learning in areas that make the plastics industry more sustainable and economically viable for years to come by learning how to develop hands-on learning methods for future PET students. In addition to operating processing equipment with PCR or bioplastic materials, recording parameters, and making changes to parameters to successfully process samples, student interns will assist in writing lab procedures, work instructions, and worksheets. Student interns will also run test runs of each lab activity to identify areas that may confound future students when performing the labs during regular coursework. Lab test run data will also be used to generate rubrics for the labs, and student interns will assist in rubric creation to insure straightforward quantifiable assessment as assessments are performed by different instructors or assistants.

Senior students participating in the capstone course and working on projects that focus on improving plastics circularity will be preparing abstracts and posters for presentation of their projects at the PSU Undergraduate Research Colloquium. The audience includes PSU campus students and faculty across all disciplines. Students will also present their initial research ideas to PETAC attendees at the fall PETAC meeting and ask for support and input as they become more deeply involved in the project. Support may be in the form of technical expertise, facility tours, or donation of materials or equipment. Students will present their posters again to the PETAC attendees at the spring PETAC meeting. The PETAC audience is more technical and consists mainly of members of the plastics industry. Students may present their work upon request if an industrial partner visits to conduct a student tutorial on a machine or material or requests a tour of the PET department.

Our training to improve plastics circularity learning activities will also be communicated to the Pittsburg State University Office of Marketing and Communication. This office routinely prepares articles for the website and social media accounts that highlight the advances made by PSU faculty and students in areas of interest for faculty and students, alumni, and the Pittsburg, Kansas community. The Office of Marketing and Communication also prepares press releases in the four-states area of southeast Kansas, southwest Missouri, northeast Oklahoma, and northwest Arkansas. The press releases often go to local papers and television stations which also run stories on their web pages and social media accounts.

Results and activities related to the TIPC grant will become the focus of research papers that will be submitted for presentation at multiple regional and national conferences such as ANTEC, National Plastics Expo (NPE), the American Society of Engineering Education (ASEE), and SolidWorks World. ANTEC, NPE and SolidWorks World have hundreds of thousands of attendees from businesses all over the world. ASEE also has thousands of attendees who are mostly in Institutions of Higher Education (IHE). While presenting at these conferences we will make our project information and outcomes available to all who are interested. By sharing this information IHEs will be able to replicate our learning modules, review how we work with industry partners, and build upon our successes.

Pittsburg State University also has an annual professional development day for faculty immediately prior to the start of the fall semester. The training to improve plastics circularity learning activities will also be shared in a break-out session to highlight how in-class lecture and hands-on training can improve student understanding of sustainable concepts and prepare them to better serve their industries and communities with sustainable practices in a successful technical career.

Future Work

The faculty and administration within the Engineering Technology programs at PSU firmly believe in our ABET accreditation model and strive to continuously improve our programs. Analyzing data from the TIPC project, assessing outcomes, and making improvements will help us build a robust sustainability mindset for our students who will take that knowledge with them to industry.

We are currently purchasing over $300,000 in equipment and will be setting up and calibrating over the summer/fall of 2023. Faculty with summer contracts will be working with high school and college interns to help create curriculum based upon plastics circularity for several courses. Over the next two years faculty will be gathering data and feedback from students to improve the modules. The faculty will also continue to publish their work and disseminate their findings to the plastics community through papers, posters and conference presentations.

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