PROFESSIONAL PAGES

THE CURRENT AND FUTURE STATE OF WOOD SCIENCE EDUCATION IN THE UNITED STATES

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Abstract. Eleven institutions were asked to participate in a meeting looking at the future of the discipline early in 2018 (Oregon State University, University of Idaho, Mississippi State University, North Carolina State University, Virginia Technology University, Auburn University [AU], University of Minnesota, University of Maine, West Virginia University, Pennsylvania State University, and Michigan Technological University). Efforts were made to invite the department head or a senior representative of each program. All institutions accepted the invitation. Participants were asked to complete a set of questions regarding their individual programs. Each representative then provided a 30-min overview of their programs and the changes/planned changes to occur. Two of the programs involved were new/or being established included AU and Michigan Technological University. Both of these universities previously had wood science programs and are now re-establishing them. It is important to emphasize that of the 11 participating institutions, all are land-grant universities except one. Furthermore, the forest economy is significant to the prosperity of the states represented.

Keywords: Wood science education.

INTRODUCTION

Since the 1960s, about every decade scientists raise the question on the future of wood science as a viable academic program (Ellis 1964; Barnes 1979; Ifju 1996; Bowyer 2003; Winistorfer 2003; Shupe 2009). Wood Science programs expanded greatly after World War II with the expansion of our housing market and a strong increase in the demand for forest products. The discipline grew out of forestry programs in most colleges, with a strong interest in the science after wood is harvested. It has become an applied discipline where scientists from a variety of fields (chemistry, business, civil engineering, pulp/paper, chemical/mechanical engineering, industrial engineering, physics, and packaging) work with the most abundant, renewable material on earth. Traditionally, wood science academic programs focused on training young adults to enter into the manufacturing environment such as lumber manufacturing, the pulp and paper industry, and eventually into wood composites such as plywood, oriented strand board, and other engineered wood. In the 1980s, there was an increased emphasis on the business and marketing aspect of the industry, and programs evolved to train students for the entire distribution chain of the industry.

Historically, there always has been a high demand from the forest products industry for students from our programs. However, the discipline has always lacked appeal from students in high school because of reasons such as perception and awareness of the discipline, curricular requirements, and other documented factors. These factors include the negative image of

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forestry (students are currently more interested in ecosystem conservation and species protection), the perceived lack of forestry jobs and low wages, and the limited attraction for women and minorities (Sharik et al 2015). As our country has become increasingly urban (nearly 80%), there remains a strong misunderstanding or no understanding by students of wood science when choosing their college majors. According to Smith (2011), most students have decided on their major by their junior year of high school. Students' choices were based on a strong interest in the subject area and are influenced by their families and friends of families. Wood Science programs in the United States rely heavily on recruiting students once they arrive on campus. Our programs are discovery degrees once students arrive on campus. Many of these students either have not declared a major or struggle in their current major and are looking for something else. Recruiting strategies include current wood science students recruiting new students, faculty speaking to student advisors or in other discipline's classes to create awareness, and holding open houses to students on campus to show our programs. At many departments, this has been somewhat successful, but overall, most programs are under constant pressure to increase student enrollment. Declining enrollments have resulted in a decline of undergraduate programs from 21 in 1979 to 13 in 2014 (Armstrong 2014).

For the long-term viability of our programs and the wood science discipline, we need to become a destination degree for high school students. From a marketing perspective, there are four ways to increase revenue and market share. They include our daily competition (stealing students from other academic programs), offering the product in a new area (on-line or satellite academic programs), offering a new or perceived new product (new degree programs), and buying the competition (merger or adding other academic programs into wood science, such as engineering and business components). Over the past several years, most of the programs in wood science have tried to adjust their academic offerings to be more attractive using these methods. This has included diversifying subject matter offerings, offering new degree programs, broadening their focus, and, in most cases, name changes. This has resulted in some success, but it has also added new challenges. Some of our new customers (students) do not have a strong interest in our traditional forest products industry. Existing faculty question if we are losing our primary focus on wood. Others question what our discipline has become or where it is going.

To answer these questions and more, a national meeting was held of the leading undergraduate programs in the United States in May of 2018 at Virginia Tech (VT). The meeting was a result of numerous conversations among faculties of different universities over the past few years on how we are all trying to remain relevant in an ever-changing academic environment. The following discussion will present the findings and conclusions of the meeting.

RESULTS

Participants initially described the changes in their programs in recent years. To stay relevant on campus, many academic units have undertaken changes related to major modification and/or creation. In the last 5 years, there has been a significant amount of differences in the nomenclature of both departments and majors. Some of these changes have been accompanied by administrative transformations. Table 1 summarizes the changes that the group reported regarding name modifications, the administrative change that accompanied the name change if any occurred, or the creation of new degree programs.

The following universities have created, merged, or replaced degree programs: VT, West Virginia University (WVU), University of Idaho, Mississippi State University (MSU), University of Minnesota (UMN), Auburn University (AU), North Carolina State University (NCSU), and Pennsylvania State University (Penn State). Michigan Technological University is still in the development phase. The recent dynamics in wood degree programs has also been parallel to further changes. VT Department of Sustainable Biomaterials both changed the department's

Table 1. Name changes of wood science departments and degree creation or development.

Institution	Current name	Area (department, major, etc.)	Administrative change
Virginia Tech	Department of Sustainable Biomaterials	Department/ major	Created Packaging Degree in 2012. Renamed department in 2012 from Wood Science and Forest Products.
Mississippi State University	Department of Sustainable Bioproducts/Sustainable Bioproducts	Department/ major	Renamed department from Forest Products to Sustainable Bioproducts/started new Sustainable Bioproducts major.
University of Minnesota	Bioproducts and Biosystems Department/SSM	Department/ major	Created Department from Biosystems and Agricultural Engineering and Bio-based Products/created major from Bioproducts Marketing & management to SSM.
University of Idaho	Department of Forest, Rangeland & Fire Sciences/Renewable Materials	Department/ major	Department of Forest Products & Department of Rangeland Science were merged into a single department with Department of Forest Resources. Degree was renamed from Forest Products.
North Carolina State University	Sustainable Materials and Technology	Major	Replaced the B.S. Wood Products program in 2013 and replaced it with the B.S. Sustainable Materials and Technology.
Pennsylvania State University	BioRenewable Systems	Major	Merging of the Wood Products major and Agricultural Systems Management to form a new program.
West Virginia University	Forestry and Sustainable Biomaterials	Major	Merged Forest Resources Management and Wood Science and Technology as Forestry and Sustainable Biomaterials.
Auburn University	Sustainable Biomaterials and Packaging	Major	Brand new undergraduate degree that works across campus with five different units.
Michigan Technological University	Forest Biomaterials in development phase	Major	Major in Forest Biomaterials in development.

B.S., Bachelor of Science; SSM, Sustainable Systems Management.

name and created two new degree programs in 2012. WVU added two new areas of emphasis to the Wood Science and Technology major: Sustainable Low-Rise Residential Construction, and Renewable Materials Marketing. WVU has discussed the possible creation of the following areas of emphasis/majors: Packaging, and Industrial Forest Operations/ Utilization. WVU has also undertaken significant curriculum modifications, including reduction of degree requirements from 128 to 120 credit hours, and the addition of capstone and senior project courses. MSU started a new Sustainable Bioproducts undergraduate major. Oregon State University (OSU) added a renewable materials major and established an educational advisory board for the new major. The UMN formed a new major from Bioproducts Marketing & Management to form Sustainable Systems Management (SSM). Two tracks were added to UMN's SSM major: Corporate Sustainability Systems track and Energy Systems track. This major is the only sustainability-related major in the entire Twin City campus. AU formed a brand new major called Sustainable Biomaterials and Packaging. This program is a new undergraduate degree that works across the campus with four colleges, and the degree is housed in the School of Forestry and Wildlife Sciences. NCSU eliminated the Bachelor of Science degree and the Wood Products program in 2013 and replaced it with Sustainable Materials and Technology. Penn State merged two majors: Wood Products major and Agricultural Systems Management to form the BioRenewable Systems major. The University of Idaho merged two different departments (see Table 1) to form Forest, Rangeland & Fire Sciences. As a result, students interested in forest operations are now majoring

in Forestry program. The University of Idaho has also restructured courses and curriculum (eg expanded list of restricted electives—21 Credit Hours of the 120 Credit Hours total). Furthermore, each focus group participant reported other actions that have taken place to stay relevant. These reported changes to the department in the last 5 years are discussed in the following section.

Further Changes in the Department

Recruitment has also been an important focus for the participating academic units. As a recruiting strategy, VA Tech has started an aggressive campaign through a campus recruiting program focusing on undeclared majors. Recruiting efforts have also been taken through two department student clubs by students to recruiting students. A full-time recruiter was appointed in 2015 by the College of Natural Resources, focusing on a statewide approach recruiting students. The efforts have resulted in a doubling of the student population since 2013. NCSU started teaching general education classes called Sustainable Materials for Green Housing, Recycling to Create a Sustainable Environment, and Industrial Ecology. Furthermore, NCSU hired a sustainable materials and technology student service assistant to help with recruitment.

Participants were asked to identify what was driving changes in their departments. Seven out of the eleven universities that participated named enrollment as a driving force within their department. It is clear that low enrollment is a pressing matter. In parallel, a significant number of participants have noticed a trend of a "changing student" in current enrollment population. This population is described as a very "urban" oriented population. The student's interests have changed over the years; nowadays, students want to make a positive impact by working with business, industry, and government. Similarly, the society has moved toward a sustainability-driven society with broader sustainability interest such as environmental, economic, and social. Currently, the shifting interests and opportunities that are born from the importance allocated to bio-based products and agriculture give wood science–related programs an opportunity. Such programs provide a platform to provide technology, science, and business integration.

The recent dynamics in these programs has been reflected in the recent changes in wood science faculties. At VT, the recent breadth of the faculty expertise led the department out of traditional wood science research. The University of Idaho has identified a diluted emphasis as breadth of department has expanded. OSU identified faculty demographics and turnover as a change driver in the department. AU, Penn State, and the University of Maine are all acquiring new faculty members. Auburn is hiring 100 new faculty members across the university over the next 5 years. At Penn State, retiring faculty means an opportunity for new. The University of Maine currently has 11 of 20-tenure track in probationary period.

Administrative and funding changes have also served as a driver to change. VT, AU, and OSU cited that changing university budget models have influenced their programs. Further changes also mentioned were the university's policies, declining state funding, and declining traditional wood science research funding.

Positive Changes in Each Department in Recent Years?

In recent years, wood science–oriented departments have seen the creation of a new majors or significant transformation in the curriculum. These changes have been accompanied directly or indirectly by an increase in enrollment and in faculty appointments. Eight participants associated such modifications with positive milestones in recent years. Other positive changes include modifications in the learning process, moving toward experimental learning. The University of Idaho has developed and expanded the capstone project and has expanded opportunities of undergraduate research experience.

OSU obtained one of the nation's top research collaborations in the area of advancement of structural wood products and mass timber design; the outcome is the Tallwood Design Institute. OSU added expertise in engineering/architecture and processing/design. The focus was determined on the advancement of structural wood products. Penn State University is currently working on the agricultural engineering building project. Penn State has had the highest growth in faculty in 20 yr and the new BioRenewable Systems major has had a strong growth in undergraduate and graduate students. VT is hiring new faculty in the areas of data analytics and the circular economy.

Positive changes in recent years were seen through various individual examples. The University of Maine increased development activity/resources, providing more than $400,000 in undergraduate scholarships and flexible funds. The University of Maine has witnessed increasing research activity, capacity, and facilities. These positive attributes have provided some cover for low enrollment (eg a relatively strong graduate student enrollment is viewed in combination with undergraduate enrollment). However, the University of Maine's "wood science program" (Forest Operations, Bioproducts, & Bioenergy) is not a standalone unit; it is in the same academic unit as Forestry, and Parks, Recreation, & Tourism. This combination into a larger academic unit has benefits for small wood science–related programs.

MSU has seen an increase in federal awards and greater interest and attention to wood construction from the Engineering and Architecture colleges. AU has consistently ranked 2nd or 3rd in research dollars per faculty. University of Idaho has had an increase in positions and increased requests from stakeholders and employers. North Carolina State has seen an increased minority representation, especially in female students.

Challenges

The vast amount of changes that have occurred within formal traditional wood science programs have brought a set of new challenges to overcome. Resources and enrollment are two of the most significant challenges and obstacles impeding change. Resources in diverse ways are a challenge to the participating academic units. Faculty members were a concern for seven of the participants. Among the concerns are retiring faculty, number of vacant positions, and strain due to low number of faculty. Faculty resources also challenge new programs and growth. New faculty hires in areas such as Sustainable Biomaterials/Packaging faculty are needed to fulfill the growth in the current academic units.

There has been a substantial improvement in enrollment with the recent changes that have occurred during the last years within formally traditional wood science programs. Nevertheless, enrollment is still considered one of the biggest challenges faced by the academic units (six of the 11 participants addressed the issue). Two participants recognized that they are not considered a destination degree program for high school students. Instead, they are discovery degree for students once on campus. Therefore, there is still a challenge to communicating the value of the degree offered to younger generations.

Research funding is also a concerning matter that is considered both as a challenge and an obstacle impeding change for some of the participating institutions. There has been a decline in research funding by federal/state agencies and there is an overall notice of the decline in research funding in wood science. Funding landscapes have changed toward being more interdisciplinary and collaborative. Parallel, budget constraints are also a concern (five of the 11 focus group participants considered budget an obstacle). The lack of resources limits the capacity to support growth (in terms of faculty and staff), teaching, advising, mentoring, job placement, etc. One of the group participants also reported aging facilities as an obstacle to change.

Furthermore, the recent changes that the wood science programs have undergone have brought new concerns. Broadening the scope of the programs has left a concern for the inability to cover key, traditional expertise areas. By contrast,

there is still the perception that the new programs are traditional wood science programs. The change goes beyond exterior perception; faculty also has had to adapt to change. One participant reported going into to less traditional areas of wood science has faced resistance from faculty members who want to continue with the traditional wood products path. Resistance to change goes beyond the scope of wood science; the recent ongoing dynamics in these academic units/departments requires a significant amount of effort and willingness to change. This willingness to change and adapt is hard to find in faculty members who are full professors (already have made a career path on certain areas) and especially a challenge when it is now time for the faculty to retool.

Beyond faculty and perceptions, names such as "Environment Engineering" from disciplines such as civil engineering are challenging the recent name changes in the academic units/departments by confusing and providing competition. The change has also affected interactions within the industry. Traditional industry partners' have misperceptions; meanwhile, there are sustainability tracks that do not have jobs that are well defined.

What is the "Wood Science Discipline" Today?

When participants were asked "What they thought their discipline was today?" the recognition of change was implicit in every participant's answer. Either the discipline is undergoing change or needs to change. Furthermore, it was acknowledged that it is a material-focused discipline, where other disciplines collide to meet at a specific material or materials. *"We apply the STEM disciplines (Science, Technology, Engineering and Math) to the most renewable, natural material on earth, wood and other sustainable biomaterials"* (Smith). *"The discipline is sector-specific material science"* (Hansen). Other focuses are even broader: "utilization of plants for materials and energy." *"This incorporates business, technology, and the sciences relating to applications development, engineering, and marketing/sales of the associated materials/energy outputs"* (Heinemann). However, others reduce the materials to natural forests: *"transformation of natural forest systems to materials, chemicals, and energy for society in a sustainable (environmental/social/economic) manner"* (Shaler). *"Currently there is a perception that the discipline is leaning more towards forestry and engineering than in the past decade"* (Burns and Wang). *"It is also considered much broader than it was years ago, nowadays it has expanded to include sustainability, renewable resources, and energy systems"* (Espinoza).

Change needs to happen in several dimensions of the programs. Direction is one of these dimensions: is there a need to shift the focus on the "intrinsic value" of the forest products or toward other science aspects of the profession such as life cycle assessment (Smith). The discipline further needs rebranding and has to evolve to meet the requirements of the current job market and attract students of future generations (Burns and Wang).

There is also recognition that the current discipline needs to encompass the current change that is happening. The discipline needs *"to embrace the change in demographics and interests while at the same time considering relevant science, technology and business management"* (Espinoza). This changing environment is recognized as conflicting because expectations from the different stakeholders are different, and these expectations intercept within the academic units/departments understudy. "*Our discipline is an effort to meet various customer needs which often seems conflicting. Student expectations often differ from that of the industry and today our discipline reflects the overlap that occurs in the center"* (Via).

The current wood science disciplines are broader in scope than traditional wood science departments and with a strong potential for the future. This potential lays in relevancy, in a healthy job market, as a major pathway for climate change mitigation. Nevertheless, it must overcome the transition in image and competition

from other alternatives and continue to deal with the difficulties of attracting students.

Table 2 summarizes the challenges and opportunities that exist for the discipline identified by the group. Our identity and branding were attributed to low student enrollments and were the top challenges recognized. Creating a national message and having an organized, marketing campaign for the profession were key opportunities that exist for us to work on.

MODELING THE CURRENT STATE OF WOOD SCIENCE EDUCATION

One way to look at this would be through a **System Dynamics Perspective**. This method illustrates the complexity of the issues facing our discipline. Systems thinking is a way to see the world from a holistic perspective; it involves understanding and seeing the world as a complex system. In a system, you need to understand that "you can't just do one thing" and "everything is connected to everything else" (Sterman, Business Dynamics-Systems Thinking and Modeling for a Complex World 2000). System Dynamics is a technique that is fit for analyzing and modeling behavior in complex environments and interrelationship of the system components (Delgado-Maciela et al 2018). Causal loop diagrams (CLDs) are a tool to capture the structure of systems. "*A causal diagram consists of variables connected by arrows denoting the causal influences among the variables*" (Sterman 2000). CLDs have been used to model things such as inventive problem (Delgado-Maciela et al 2018), e-business models (Kiani et al 2009), and population health problems (McGlashan et al 2016) among other things.

The arrows, within a CLD have a signal associated that is denominated link polarities. Link polarities do not describe the behavior of the variables, but rather they describe the nature of the system. In other words, they describe what happens if the variables were to change (Kiani et al 2009) (Sterman 2000). Link polarities have a positive sign to indicate that there is a positive effect related to the cause; therefore, if a variable increases, the other one also increases or if a variable decreases, the other one also decreases. A negative sign indicates a negative effect; therefore, if a variable decreases, the other one increases or if a variable increases, the other one decreases (Sterman 2000). The dynamics within the system is modeled through feedback loops. Feedback loops may be a balancing loop (B) or a reinforcing loop (R). Figure 1 exemplifies how these types of loops work. A reinforcing loop, as the name states, "reinforces"; in the example when birth rate increases, the population decreases. A balancing loop, as the name states, "balances"; therefore, when the population increases, the death rate decreases; hence, the population decreases.

Figure 2 has been developed to capture the structure of dynamics in "wood science undergraduate programs" in the United States. The CLD diagram developed focuses on describing the drivers for ongoing change in wood science–related academic programs or departments. The system boundaries for this approach were identified as changes generated in

Table 2. Challenges and opportunities.

Challenges	Opportunities
Branding of programs	Create a national message
Low enrollment	Marketing our programs/discipline
Low (no) identity among high school students	Increased collaboration among stakeholders
Institutional support	White paper to USDA to promote discipline
Changing industry	National survey of stakeholders to determine new needs
Resources	Continued collaboration among departments
Who are new stakeholders	Mass timber
Marketing	Capturing value of forest (carbon, climate, water) in wood science
Changing student	Broaden scope of this group to go international

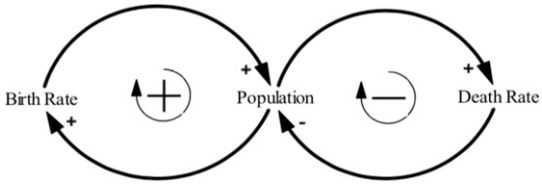

Figure 1. Feedback loops.

academic units or departments by the needs of the students and potential applicants.

Participants found that in recent years, there has been a presence of a "changing student" that is more environmentally interested, more urban oriented, and more concerned about sustainability. The increase in the presence of changing "student" has increased the change in academic units/departments; these changes are easily identifiable through examples such as departmental name changes, creation of majors, or merges. The change in academic units/departments attracts more "changing students." Therefore, there is a reinforcing loop (R) called **"Change (Student & Academic Unit)."** The change in academic unit/department also is part of a second reinforcing loop (R) called **"Changing Research."** As change within the department increases, new faculty hiring increases and, therefore, the breadth of research increases. Funding direction has expanded; these are more integrative and look at new market opportunities (eg biorefinery, nanocellulose, application, etc.).

As the breadth of research increases, the change in academic unit/departments also increases; therefore, the reinforcing loop (R) called **"Changing Research"** is completed. Faculty is a key driver in driving change within academic unit/departments, as faculty hiring increases the change in department increases; therefore, a reinforcing loop (R) called **"Faculty and Change"** is formed.

A balancing loop (B) called **"Resistance to Change"** was identified, as the change in breadth of faculty research has augmented, the less traditional wood science research is performed, and, therefore, the inability to cover key traditional areas increases. Traditional wood science

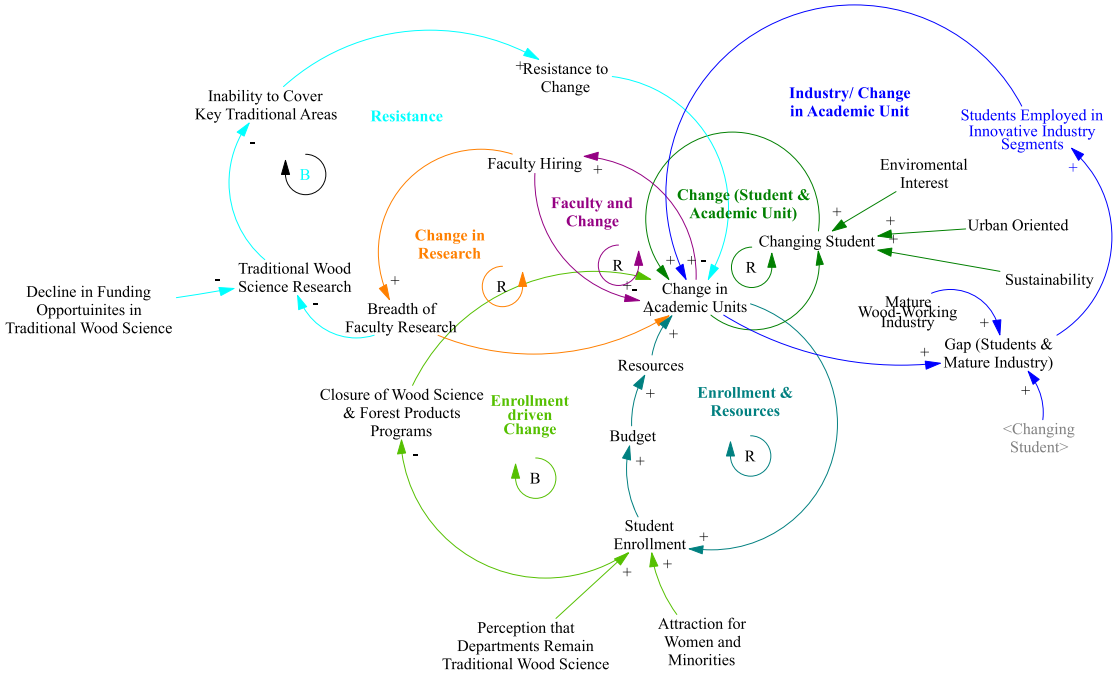

Figure 2. Systems dynamics model of causal loop diagram change in academic units.

research is also impacted by a decline in funding opportunities in this area. Funding from state and government agencies heavily influences the decline in funding research. The decline in traditional wood science research also increases the inability to cover key traditional areas.

A reinforcing loop (R) called **"Industry/Change in Academic Unit"** was identified. The changes in the academic units/departments has also provoked that the group identified the gap between students and mature wood-working industry increases. This gap is used to describe the disconnection between the evolving student's interest and the mature wood-working industry. Therefore, as the changing student and the mature wood-working industry increases, the gap between students and the mature wood-working industry is also augmented. As this gap between students and mature industry increases, more students are employed in innovative industry sectors, which in return increase the change in academic units. This change in academic units is provoked by curriculum changes that are undertaken to keep up with innovative industry sectors.

Finally, enrollment is a critical driver to change and to obtain an increase in budget. The "**Enrollment Driven Change"** balancing loop (B) describes how currently the change in academic units/departments is occurring. As the change in academic units/departments increase, the student enrollment also increases and, therefore, there is a decrease in the closure of wood science and forest product programs. Ultimately, if the enrollment is increasing, there is no need to close and also no immediate or drastic change in academic units/departments necessary. Furthermore, the **"Enrollment & Resources"** reinforcing loop (R) displays the effect of the increase in student enrollment on the budget (ie an increase in budget). As the budget increases, the department resources increase, and there is an increase in student enrollment.

Figure 2 illustrates that this is a very complex system with each department being highly influenced by their college and university structure. Each department must identify what are the primary drivers of change within their college and how to address these to meet the goals of the department, college, and university.

THE FUTURE OF WOOD SCIENCE EDUCATION

The findings of this discussion help us identify how our wood science programs can position themselves to be successful in the future. It is clear that we must maintain our fundamental roots in traditional areas of the physical sciences and business applications as they apply to wood and other biomaterials. Yet, the wood science programs need to adapt to the new sciences of sustainability that will be more attractive to young adults. These sciences would include life cycle assessment, carbon, water, and the circular economy (Fig 3). Our accrediting society should consider these sciences into their requirements. The programs must demonstrate to students that

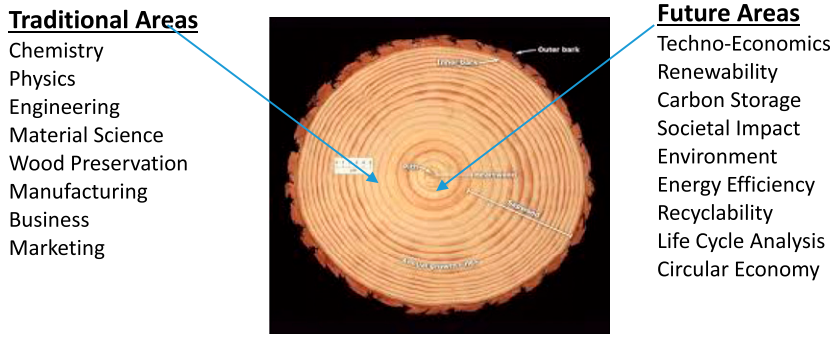

Figure 3. The future of wood science education.

wood science is an environmental effort to efficiently use our natural resources to meet the society's needs for products it uses every day. We must work with forest products industry to share the careers in wood science that will provide a good future for students, while contributing to the sustainability of our natural resources. We need to work with the industry in understanding their future needs for a workforce. Working together, we must develop a national message and brand that conveys the positive attributes of using renewable natural resources to replace our hydrocarbon-based economy. This message has to be marketed to high schools so that students are aware of how careers in wood science can help our environment and society. This message should include the following themes: efficient use of our natural resources, strong job demand, sustainable, assist with rural prosperity, healthy forests, support the bioeconomy, environmental, and innovative.

In summary, we need to strive to become a destination degree for high school students and not continually rely on being a discovery degree once they reach the university. *We live in the best possible time in history to capture wood science and forest products education to make a dynamic impact on society's environmental and economic future. Are we up for the challenge?*

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