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Teaching and Learning about Biomass Energy: The Significance of Biomass Education in Schools

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Received: 10 March 2018; Accepted: 24 March 2018; Published: 28 March 2018

Abstract: Biomass energy can mitigate climate change, revitalize rural economies, and achieve energy independence. Using biomass energy as subject matter content, American agricultural education programs at the secondary school level can prepare future agricultural professionals with science, technology, engineering, and mathematics skills to solve complex issues. Through a state-wide survey (N = 100) in the U.S., this study found agriculture teachers' interest in biomass energy is motivated by economic, environmental, pedagogical, and learning factors. Nine relevant topics were determined as high training needs perceived by teachers. Teacher educators are recommended to incorporate the four factors and nine topics in planning, delivering, and evaluating in-service training programs of biomass energy for agriculture teachers.

Keywords: biomass; bioenergy; agricultural education; STEM education

1. Introduction

Energy is vital to socio-economic development of any country [1]. The strong economy of the United States has been propped by an abundant, stable energy source, such as petroleum and other fossil fuels [2]. However, the United States met a serious energy challenge, because of a short supply of fossil fuels and vanished cheap energy [3]. Policy-makers saw this challenge and the U.S. 2007 Energy Independence and Security Act was enacted to increase the production of clean renewable energy [4]. Many renewable energy sources have been developed [5]. Biomass energy is a unique renewable energy source that can be combusted to generate heat and power as well as converted into biofuels, such as bioethanol or biodiesel [1,6]. The U.S. Department of Energy has advocated using biomass energy to provide a significant portion of America's energy needs, reduce foreign oil imports, reinforce national energy security, boost the rural economy, and improve environmental quality [7].

1.1. Merits of Biomass Energy

Biomass is the organic material originating from plants, animals, and other organisms [1], and sequestrates carbon and captures sunlight in plant materials through photosynthesis [8]. Corn grain, stover, soybean, switchgrass, straw, and wood chips are commonly used biomass for energy purposes in the U.S. [9]. Heat, power, and biofuel energy generated from biomass are collectively called biomass energy or bioenergy [10]. In 2010, biomass energy contributed 4.3 quadrillions Btu of energy, which counts 5.7% of total energy production in the United States [11]. Biomass energy accounts for nearly half of all renewable energy production in the U.S. [12]. Ideally, the use of biomass energy is a process of recycling carbon biomass energy without generating new Greenhouse Gas (GHG); yet, the chemical and mechanical processes of producing biofuel release additional GHG [13]. Although with this amount of GHG taken into consideration, biofuel has 29% less GHG emissions than fossil fuels [14]. Gustavsson et al. [15] found using biomass can result in a high fulfillment of climate change mitigation through GHG emissions reduction as well as oil use reduction. Without biomass energy, Souza et al. [16] concluded, it is not possible to reach the target of global temperature reduction of 2 °C set by the Paris Agreement. Besides the environmental impact, bioenergy industry has boosted the economy and employment. In 2016, the bioenergy sector created 130,677 jobs in the U.S. [17]. Aslan [18] found biomass energy had a positive impact on U.S. economic growth. This positive economic impact becomes more considerable in biomass energy production regions. For instance, the state of Iowa has the largest bio-ethanol production capacity and the second largest biodiesel production capacity in the U.S. [19]. Biomass energy produced 4.7 billion Gross Domestic Product (GDP) and more than 42,000 jobs in Iowa during 2016 [20]. Urbanchuk [20] also indicated the biomass energy industry has continuously boosted Iowa's economy for over a decade.

1.2. Challenges of Biomass Energy

Just as any other new technology, however, challenges exist in relation to biomass energy. Food security is the most crucial challenge faced by the biomass energy industry [21]. Biofuels have been a major factor contributing to rapid price increases during the past several years in the international grain markets [22]. Grains were transferred from the food market to the fuel market and farmland was designated as biofuel production [23]. Rosegrant [23] also indicated higher food prices reduce access to food and result in serious consequences for health, productivity, and well-being. The challenge is mainly, but not exclusively, caused by the broad adoption of first-generation biomass—grain. Therefore, policy-makers and scientists are currently devoted to research and commercialization of the second-generation biomass—cellulosic biomass as well as the third-generation biomass—algal biomass [24]. The cellulosic biomass technique allows producers to have a wide variety of crops for biomass production. Scientists have developed diverse energy cropping systems to produce biomass, including both annual and perennial plants species [25]. Diverse biomass cropping systems have a comprehensive carbon cycle and prevent soil erosion and nitrogen losses [25]. However, the lack of an established market hindered producers from adopting a diverse biomass cropping system [26]. Villamil et al. [27] advocated environmental campaigns need to be made to increase awareness and education on energy crops. In addition, harvesting cellulosic biomass requires removal of plant residues [28]. Producers are concerned about how the simultaneous harvest of grain and stover will affect grain productivity, soil quality, and long-term sustainability [29]. Furthermore, storage and transportation of cellulosic biomass are different from grains. Ash content and gross energy are the extra standards to judge biomass quality [30]. Even though scholars hold optimistic opinions about the commercialization of algal biofuel [31], no existing literature indicates the marketing of algal biomass has been or plans to be developed. More educational efforts are required to develop this new market.

Biomass energy is proven to help reduce GHG; yet, it may also cause other negative environmental impacts. Meyer [32] indicated increased biomass production could have noticeable consequences on water consumption. Water quality deteriorates by agricultural drainage containing pesticides and fertilizer sediments [33]. Low-water-consuming crops can be cultivated as a solution [34], but how to make biomass energy production more environment-friendly remains a critical conversation among producers, researchers, and educators [35].

1.3. Education for Biomass Energy

As discussed, biomass energy is critical to the environment, the economy, and society. Meanwhile, biomass energy is a complex issue, replete with challenges from both agricultural productivity and environmental preservation. To sustain the world's food, energy, water, soil, and biodiversity, education is the most important avenue for future efforts [36,37]. Jennings and Lund [38] concluded education is essential for the development of renewable energy. It is wise to discover which form of education can support biomass energy's sustainable development.

Agricultural education is " . . . a program of instruction in and about agriculture and related subjects, such as natural resources . . . " [39] (p. 10) that offered at secondary, postsecondary, and adult levels [40]. The secondary school based agricultural education is the most common format in the U.S. [39]. Agricultural education programs prepare students for entering and advancing in agricultural professions [40]. The rapid growth of the renewable energy market has caused a problem of a shortage of skilled professionals to design, install, and maintain bioenergy systems [41]. A larger workforce is needed for producing and harvesting biomass [42]. Such an issue may be addressed through agricultural education programs because training workforce professionals for food, fiber, and energy production is a mission of agricultural education [43,44]. Because of the complexity of biomass energy involved with land use, food production, energy, natural resources, and climate change, this topic ought to be embraced by both agricultural education and environmental education programs [44,45]. Poudel et al. [46] reminded educators to be conscious of the interrelationships between agricultural and environmental issues. Although environmental education is interdisciplinary and holistic instruction and agricultural education is inclined to vocational instruction, overlapping principles and philosophies were found in their mission statements [47]. Kirts [47] believed "agricultural education provides an important subject matter niche for environmental education" (p. 35). In fact, secondary school agricultural teachers have undertaken environmental educators' role in schools. The curricula content standards and the teacher education programs have incorporated environmental education components, including soil, water, wildlife, forests, air conservation, ecosystem services management, etc. [39,48].

Science, technology, engineering, and mathematics (STEM) education has become a priority in the public K-12 educational system [49]. STEM integration has been promoted by both environmental and agricultural educators [50–52]. Hodson [53] identified renewable energy resources as an area of science education that would benefit individuals as well as society in the future. Hodson [53] also emphasized biomass energy should be promoted in the science curricula. Halder et al. [54] indicated the biomass energy system is a new, challenging topic, but demands more consideration in education for young people. Although biomass and bioenergy are not typically included in the K-12 curriculum [55], the STEM movement made biomass a hotspot. The National Science Foundation, U.S. Department of Energy, and U.S. Department of Agriculture have sponsored professional development programs for secondary school agriculture and science teachers teaching STEM content through biomass energy [56,57].

Özbas [58] studied high school students' perceptions and attitudes toward bioenergy and found students like to accept biomass energy education. Past studies have shown secondary school agricultural teachers had positive perceptions toward biomass education and were interested in teaching this topic [59,60]. However, no study has examined the factors underlying agriculture teachers' perceptions toward biomass energy education. Knobloch [61] contended teachers' cognitive and motivational beliefs influence decisions for integrating non-required topics into their instruction. Teachers tend not to implement additional instructional resources into their classroom instruction unless they see a value and understand how to implement the resources [61,62]. Without knowing the factors underlying teachers' perceptions toward a subject, teacher educators lack important information to plan, design, and implement in-service programs [63]. To encourage and facilitate agriculture teachers in teaching biomass energy, two research questions need to be addressed:

1. Why are agricultural teachers interested in teaching biomass energy?
2. What training do agriculture teachers need for instruction in biomass energy?

2. Theories and Methods

2.1. Theoretical Framework and Operationalization

This study was guided by Ajzen's Theory of Planned Behavior (TPB) [64–66] and Bandura's Social Cognitive Theory [67–69]. Both theories provided robust explanations on informational and motivational behavior changes [70]. TPB has guided studies related to agriculture teachers' instructional decisions [52,71,72]. Ajzen's TPB depicted people's behavior is driven by intentions and determined by perceived control; intentions are led by an attitude towards behavior, subjective (social) norms, and perceived behavior control [64–66]. TPB provides a solid theoretical foundation for this study's instrument development. To measure how an agriculture teacher perceives biomass and its education, we operationalized attitude into items expressing potential benefits and drawbacks of biomass energy. Subjective (social) norms were operationalized into items related to how biomass energy could influence individuals, and society. Perceived behavior control was operationalized by teachers' self-efficacy regarding teaching biomass. Ajzen [66] acknowledged perceived behavior control owes a great debt to Bandura's [68] work on self-efficacy. Self-efficacy is comparable to perceived behavior control [66].

Self-efficacy is an important concept in Social Cognitive Theory [67–69]. Bandura [69] defined self-efficacy as "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations" (p. 2). Teachers' self-efficacy is expressed as their perceived confidence and comfort level of performing instruction regarding a topic in the classroom [73,74]. Strong self-efficacy, an aggregation of personal factors, provide stronger motivations and predictions to perform a behavior [75]. Teacher self-efficacy has influenced teachers' job satisfaction, student motivation, and student achievement [76]. We focused on teachers' instructional self-efficacy that operationalized through items related to classroom integration of biomass energy education.

Teacher self-efficacy was suggested to become a central consideration in teacher in-service training programs [77]. Besides the instructional self-efficacy, it is necessary to measure teacher self-efficacy in specific pedagogical topics at the development stage of in-service training [78]. Borich [79] proposed a needs assessment model for teacher in-service training. Borich [79] described a training need as " ... a discrepancy between an educational goal and trainee performance in relation to this goal" (p. 39). The model incorporated self-efficacy and perceived importance for each pedagogical topic. Borich's model operationalized self-efficacy into perceived competence in specific topics. By implementing Borich's Needs Assessment Model, we can identify topics pertaining to biomass energy perceived importantly by teachers but with low self-efficacy.

2.2. Methods and Procedures

To answer the two research questions, three research objectives were developed:

(1) To identify factors underlying agriculture teachers' perceptions toward biomass education.
(2) To determine the proportion of variance in teachers' perceptions explained by these factors.
(3) To identify primary training topics of biomass energy needed by agriculture teachers.

2.2.1. Instrumentation

This quantitative study adopted a descriptive-correlational research design using survey questionnaires [80]. The survey contained two instruments. The first instrument targeted the first two research objectives and measured teachers' perceptions towards biomass energy and its education. Twenty items (see Appendix A) with a five-point Likert-type scale (1 = Strongly Disagree to 5 = Strongly Agree) were developed. Items were based on theories and the literature review and edited by a panel of experts composed of nine scholars in the fields of bioenergy and agricultural education. Participants were asked to indicate the level of agreement for each item.

The second instrument targeted the third research objective and measured teachers' training needs on thirteen instructional topics of biomass energy. We implemented the Borich Needs Assessment Model and his instrument's development techniques [79]. This instrument employed two five-point Likert-type scales. Teachers were asked to indicate the level of importance on the first scale and indicate their perceived level of competence on the second scale regarding each topic. Topic items were based on the literature review and the expert panel's advice. Specific topic items will be shown in the result section. To ensure testing adequacy and feasibility, a pilot study with a small group of secondary school agriculture teachers (N = 10) from Iowa was conducted before officially administering the survey. An approval from Institutional Review Board was acquired in June 2013 prior to data collection.

2.2.2. Data Collection

The state of Iowa is a leading state of biomass and bioenergy production in the United States [19]. Agricultural education programs are very popular among Iowa's secondary schools [81]. Thus, the research population was secondary school agriculture teachers in the state of Iowa. At the time of this study, 247 (N = 247) agriculture teachers served in Iowa secondary schools, based on the Iowa agriculture teacher directory. Because of the limited size of the target population, instead of using a sampling technique, this survey was administrated to the total population. A mixed-mode survey distribution was utilized to increase the response rate [82]. A hard-copy and an electronic copy of the questionnaire were distributed to all secondary school agriculture teachers in Iowa during summer 2013. One-hundred fourteen responded to the survey. After removing blank and incomplete surveys, there were 100 valid surveys (N = 100) resulting in a 40.5% response rate.

2.2.3. Data Analysis

A multivariate statistical method, exploratory factor analysis (EFA) was conducted for factor identification. Henson and Roberts [83] indicated EFA is an exploratory method to generate a theory and is appropriate to use to determine the theoretical constructs underlying the data set for teachers' perceptions toward biomass. A dataset from 100 completed questionnaires provided an adequate sample size for factor analysis [84]. Maximum Likelihood (ML) was selected as the extraction method following suggestions by [85]. Oblique rotation was used to acquire more accurate results for human behavioral research, due to the correlations between factors [85]. Both Direct Oblimin and Promax methods of rotation were conducted to determine a more appropriate rotated factor pattern [86]. To test the suitability for conducting a factor analysis, the Kaiser–Meyer–Olkin Measure of Sampling Adequacy (KMO) test and Bartlett's test of Sphericity were conducted. The correlation matrix (see Appendix B) was examined for coefficients less than 0.03. Item #20 was lower than 0.3 and removed because of a lack of patterned relationships [87]. Costello and Osborne [85] suggested only retaining items with low to moderate communalities (see Appendix C). Therefore, items #2, #3, and #19 were dropped because of their communalities <0.35. The EFA was based on the remaining sixteen items. Sampling adequacy was well established with the KMO measure = 0.63 > 0.5. The results from Bartlett's test (χ^2 (df = 120) = 613.57, $p < 0.001$) indicated the data set is applicable to conduct factor analysis [86]. Although a five-factor solution provided eigenvalues equal to or greater than 1.0, four-factor solutions showed the most obvious drop in scree plots. The factor loading matrix showed items #1, #7, and #18 have cross-loadings and weak coefficients ($r < 0.4$); hence, these additional three items were removed before the final run for EFA [87].

To identify primary topics related to biomass education needed by agriculture teachers, we calculated the Mean Weighted Discrepancy Score (MWDS) from the second instrument's data. Garton and Chung [88] provided MWDS calculation procedure. MWDS is a numerical score that presents results of the implementation of the Borich Needs Assessment Model [79,89]. Higher MWDS indicates teachers perceived this topic as more important, but less competent. In other words, MWDS reflects teachers' training needs relevant to the topics [88].

3. Results

3.1. Underlying Factors

The final EFA identified four factors from thirteen items with a good model fit (χ^2 (df = 32) = 38.245, p = 0.207). KMO measure = 0.69. Bartlett's test (χ^2 (df = 78) = 519.30, $p < 0.001$) also reflected the data set is applicable to EFA. Factors pattern matrix and loadings are shown in Table 1.

Table 1. Rotated four-factor pattern matrix loadings for teachers' perceptions.

Abbreviated Item Statement	Factor Loadings			
	Factor 1 [a]	Factor 2 [b]	Factor 3 [c]	Factor 4 [d]
Local economy	0.864			
Local job market	0.854			
Farmers' income	0.733			
* Hurt soil		0.776		
* Hurt water		0.970		
* Threaten food security		0.498		
Ease of understanding			0.572	
Ease of practice			0.520	
Ease of course integration			0.850	
Students' desires for learning			0.638	
Science education benefits				0.410
Career benefits				0.955
Higher education benefits				0.622

Note. n = 100. [a] Economic Impact; [b] Environmental and Natural Resources Concern; [c] Teaching Implementation Difficulty; [d] Student Learning Benefits. * Items were reverse coded.

Three items were loaded on the first factor labeled Economic Impact. Economic Impact explained 28.82% of the total variance. Three items were loaded on the second factor: Environmental and Natural Resources Concern, which explained 17.06% of the variance. Four items were loaded on the third factor: Teaching Implementation Difficulty, which explained 13.73% of the variance. Three items were loaded on the fourth factor: Student Learning Benefits, which explained 9.78% of the variance. These four factors together accounted for approximately 69.39% of the variance in the agriculture teachers' perceptions toward biomass energy and biomass energy education.

3.2. Training Needs Assessment

Table 2 shows teachers' average level of perceived importance and the average level of perceived competence for each relevant topic. Topics were ranked by their MWDS. All topics were rated as somewhat important to very important. However, the levels of competence in teaching the topics were low (<3.0). Nine topics were identified in great need for future in-service training with MWDS greater than 5.00. The top nine topics included: "Harvesting biomass for sustainability" (7.44), "Selection of plant species for biomass production" (6.75), "Soil modification for biomass production" (6.55), "Farming systems including biomass, food crops, and livestock production" (6.36), "Basic procedures used to convert biomass to biofuel" (6.32), "Carbon cycle in biomass production" (6.29), "Harvesting biomass for profit" (6.19), "Biological material for biomass" (5.94), and "Marketing information about biomass" (5.60). The topic "History of bioenergy and related biomass" received MWDS less than 3.00, indicating less of a need for in-service education.

Table 2. Importance, competence, and mean weighted discrepancy score (MWDS) of topics related to biomass.

Ranking	Topics	Imp. Level [a]	Comp. Level [b]	MWDS [c]
1	Harvesting biomass for sustainability	4.02	2.17	7.44
2	Selection of plant species for biomass production	3.90	2.23	6.75
3	Soil modification for biomass production	3.82	2.10	6.55
4	Farming systems, including biomass, food crop, and livestock production	3.85	2.20	6.36

Table 2. *Cont.*

Ranking	Topics	Imp. Level [a]	Comp. Level [b]	MWDS [c]
5	Basic procedures used to convert biomass to biofuel	3.80	2.13	6.32
6	Carbon cycle in biomass production	3.82	2.19	6.29
7	Harvesting biomass for profit	3.85	2.24	6.19
8	Biological material for biomass	3.79	2.23	5.94
9	Marketing information about biomass	3.76	2.27	5.60
10	Biomass feedstock	3.70	2.42	4.73
11	Use of biomass feedstock	3.68	2.42	4.61
12	Policy issues related to biomass	3.50	2.30	4.20
13	History of bioenergy and related biomass	3.34	2.51	2.76

Note. n = 88. [a] Importance Level: 5 = Very Important, 4 = Important, 3 = Somewhat Important, 2 = Of Little Importance, 1 = Not Important. [b] Competence Level: 1 = Not Competent, 2 = Little Competent, 3 = Somewhat Competent, 4 = Competent, 5 = Very Competent. [c] MWDS: Mean Weighted Discrepancy Score.

4. Discussion

This study identified four underlying factors that explained why agriculture teachers positively perceived biomass energy and were interested in teaching about biomass energy. The first factor, Economic Impact, reflected agriculture teachers tend to teach biomass energy because they realize the economic benefits that biomass energy brings to the local communities [20]. Agriculture education in secondary schools represents career and technical education (CTE) programs that aim to prepare students for employment in current or emerging occupations [90]. Agriculture teachers may also see tremendous job opportunities for their students in producing, harvesting, and processing biomass [42]. It is no surprise that teachers like to teach a subject close to students' Socioeconomic Status (SES) and their academic achievement. The biomass energy industry has created a demand for grains and other agricultural products [91], and increased farm income for American farmers [92]. Given one-third of the students in agricultural education programs come from farm backgrounds and most students come from rural areas [93], farm income was close to the SES. Sirin [94] indicated SES had a medium to strong correlation to academic achievements. Economic impact is not a unique concern only for biomass by agriculture teachers. Other established pedagogical content of agricultural education includes Supervised Agricultural Experience [95] and Agricultural Mechanics [96] have placed economic impact as a core component of the pedagogical content areas.

The second factor underlying agriculture teachers' perceptions toward biomass energy is Environmental and Natural Resources Concern. Teachers generally care about environmental issues, because education contributes to society's awareness towards renewable energy and environmental behaviors [54]. Environmental and Natural Resources is a Career Development Event (CDE) in agricultural education programs. Students are expected to master skills, including soil tests and profiles, water analysis, and waste management [97]. Soil and water conservation and food security are covered by the national research agenda of agriculture education [44]. Roberts et al. also called for agriculture teachers to develop effective educational programs and curriculum in areas of food security, soil and water conservation, and renewable energy.

Another reason the Environmental and Natural Resources Concern was identified as a factor was that agriculture teachers may recognize the potential positive or negative impacts of biomass production towards soil, water, and food security. Although a diverse biomass cropping system helps prevent soil erosion and nitrogen losses [25], the environmental impact varies by management strategy. Biomass-based on perennial energy crops (e.g., switchgrass) clearly reduced soil losses, increased soil carbon, decreased nutrient discharges, and improved water quality [98]. However, when the biomass is based on crop stover, stover removal practices may lead to soil loss and carbon loss to a certain extent [98]. The Food and Agriculture Organization of the United Nations (FAO) was concerned about biomass energy driving agricultural commodity and food prices to surge in past years [22]. Nevertheless, increased food prices brought more income for farmers, and powered agricultural and rural development [21]. Koizumi [21] did not believe grain-based biomass production always has a negative impact on food security. Through analysis of price elasticity, Koizumi [21] concluded U.S. soybean and corn grain are an effective biomass feedstock that responds to price changes in supply. In summary, this factor reflected the complexity of biomass energy. As Poudel et al.'s viewpoint [46] that environmental and agricultural issues are complex and interrelated, a context must be provided to motivate students' learning. The context of biomass energy provides a good common ground to engage students in learning both agriculture and environment. Agriculture teachers are encouraged to be prepared to teach and lead students to recognize, reflect, and solve complex issues in agriculture, environment, and natural resources [44].

Teaching Implementation Difficulty is the third factor underlying teachers' perceptions toward biomass education. This factor revealed the classic "Perceived Behavior Control" component in the Theory of Planned Behavior [64–66]. Based on Ajzen's theory [66], the presence of this factor will further or hinder teachers' teaching behaviors. Specifically, if teachers perceived themselves having difficulties to understand the principles of biomass production or they thought to teach the practice of biomass production beyond her/his teaching competence, teachers may not execute their teaching behaviors even though they had conceived a teaching intention. On the other hand, students' desires for learning about biomass energy will stimulate teachers' behaviors for teaching this subject. Students will actively engage in learning when they desire to learn [99,100]. Skinner and Belmont [101] found a reciprocal relationship between teachers' behaviors and students' engagement in the classroom. Knowing students have a learning desire for biomass energy, teachers perceive furthering force in teaching and promoting the subject. Also, from the teachers' perspective, if biomass energy, as a subject/topic, is easy to integrate with teachers' existing curriculums, teachers will perceive more volitional control [66]. As a result, teachers' teaching behaviors will be reinforced.

Student Learning Benefits is the last but not least factor underlying teachers' perceptions. Student-centered learning has been pushed in the agricultural education area [61,102]. Research found 60% of sampled agriculture teachers were inclined to use student-centered learning [103]. Hess and Gong [104] believed student-centered learning is a path to college and career readiness. Teachers will teach biomass when they perceive biomass education can increase students' college and career opportunities. Meanwhile, the strong call for STEM integration in agricultural education programs [50,52] made agriculture teachers evaluate instructional decisions by foreseen STEM outcomes. Both Agriculture food and natural resources career cluster content (AFNR) standards [105] and scholars [53,54,56] have placed biomass as an important subject matter content for STEM integration. For instance, Cenusa Bioenergy [106] published a biomass energy curriculum "C6 Biofarm" for secondary schools' agriculture and science teachers' use. "C6 Biofarm" curriculum complied with both AFNR standards and Next Generation Science Standards [106].

Results of the Borich Needs Assessment Model revealed agriculture teachers generally had a low self-efficacy in teaching various related topics of biomass energy. Even though teachers perceived certain topics as important, low self-efficacy still hinders teachers' teaching behaviors. With the aim of MWDS [89], relevant topics were sorted by a combination of levels of perceived importance and self-efficacy. Among the top-ranking topics, evidence was found to further support the four-factor model of EFA. Topics, such as "Harvesting biomass for sustainability," "Soil modification for biomass production," and "Farming systems, including biomass, food crop, and livestock production" reflected teachers' concerns for Environmental and Natural Resources (factor #2). Topics on "Selection of plant species for biomass production," "Basic procedures used to convert biomass to biofuel," "Carbon cycle in biomass production," and "Biological material for biomass" mirrored science education perspectives loaded on Student Learning Benefits (factor #4). Topics on "Harvesting biomass for profit" and "Marketing information about biomass" presented Economic Impact (factor #1). The low self-efficacy and high perceived importance of these topics expressed teachers' in-service training needs for teaching biomass topics and presented Teaching Implementation Difficulty (factor #3).

5. Conclusions and Recommendations

In conclusion, Figure 1 presents how the four factors evolved from the Theory of Planned Behavior [64–66] and extended to the Borich's Needs Assessment Model [79]. On the empirical factor and the theoretical levels, this study answered the research question, why agriculture teachers are interested in teaching biomass energy. This part of the findings is consistent with Knobloch's proposal [61] on teachers' cognitive and motivational beliefs. Economic Impact of biomass energy and Student Learning Benefits of biomass energy education motivate teachers to teach about biomass. Teaching Implementation Difficulty is a cognitive belief and represents teachers' epistemological beliefs about biomass energy in the context of teaching and learning agriculture [61,107]. Environmental and Natural Resources Concern can be interpreted as a social norm based on the Theory of Planned Behavior [64–66] because environmental ethics tend to become an important social norm in modern agriculture industry [108]. On the needs assessment level, this study answered the other research question, what training agriculture teachers need for instruction in biomass energy. Results of needs assessment reflected teachers' low self-efficacy in teaching various topics of biomass. The top-ranking topics of MWDS provided specific guidance for in-service development and further supported the four-factor model.

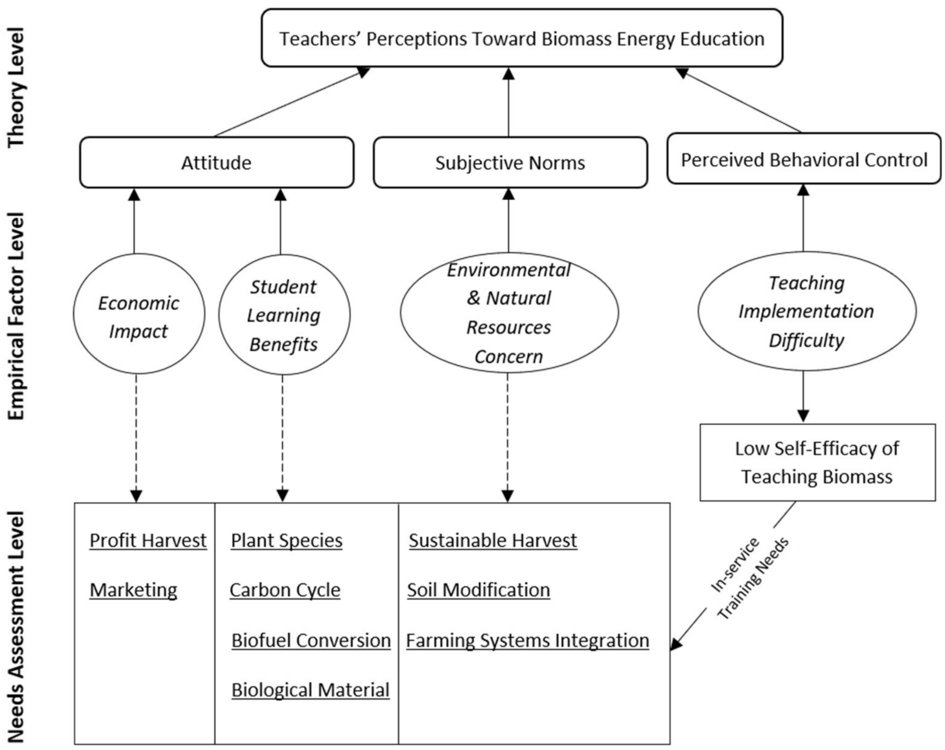

Figure 1. Overview of Conclusions. Four identified underlying factors evolved from Ajzen's Theory of Planned Behavior [64–66] and extended to Borich's Needs Assessment Model [79].

Education contributes to the whole society's awareness and attitudes towards bioenergy [54,58,109]. Teachers should make efforts to increase students' social awareness, enhance learning motivation, develop innovative solutions, and apply them to sustainability [58,110]. To achieve these goals, teachers must be well trained in this subject matter content. This study provided valuable information towards development of in-service programs. Teachers are more likely to teach biomass energy in their classroom instruction when they see reasons and values for teaching biomass energy subject matter.

It is recommended teacher educators make efforts to collect and present information about economic impact, job creation, and educational opportunities for biomass energy. In addition, teacher educators should be prepared to address teachers' concerns on environmental impact of biomass production, such as soil disturbance, nutrient loss, water consumption, etc. Agricultural and environmental educators should work together with science educators to develop engaging teaching strategies and content areas to integrate STEM education. In terms of specific topics, the nine topics with top MWDS rankings should be given priority during program planning. In a program delivery phase, teacher educators are encouraged to show the linkage between the topics and their motivation and concerns. We also encourage teacher educators to conduct program evaluations to re-assess teachers' motivating factors and instructional topics. We foresee dynamic topics, as the change of newer technology and updated policies. However, we believe these four factors will provide a good overall guidance for agriculture teachers' in-service program development related to biomass energy education. We narrowed our research scope within the state of Iowa. Consequently, generalization is a limitation of our study. Although we expect similar findings could be found in other Midwest states in the U.S. because of similar social and biophysical environments, further empirical studies are recommended on a broader research population of agriculture teachers.

Acknowledgments: This article is a product of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, USA. Project No. 3813 and sponsored by the Hatch Act and State of Iowa funds.

Author Contributions: Guang Han and Robert Martin conceived and designed the experiments; Guang Han and Robert Martin performed the experiments; Guang Han analyzed the data; Guang Han and Robert Martin contributed reagents/materials/analysis tools; and Guang Han wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Appendix A

See Table A1.

Table A1. Item statements of teachers' perceptions survey instrument.

Item #	Statements
1	Using biomass for fuel can improve energy security
2	Biomass has helped lower the price of oil
3	The federal government supports the development of biomass production
4	Biomass production contributes to the local economy
5	Biomass production contributes to the local job market
6	Biomass production increases farmers' incomes
7	The use of biomass as energy helps to reduce greenhouse gas emissions
8	Biomass production does not hurt the soil *
9	Biomass production does not hurt water resources *
10	Biomass production does not threaten food security *
11	The principles of biomass production are easy to understand
12	The technology of biomass production is easy to practice
13	Teaching about biomass production is relevant to science education
14	Teaching about biomass production will help students with their careers
15	Teaching about biomass production will help students with future higher education
16	Teaching about biomass production is easy to integrate into the existing curriculum
17	Students want to learn about biomass production
18	Teaching about biomass production will be a challenge for the teacher
19	More training will be needed for agriculture teachers before teaching about biomass production
20	There is no significant difference between teaching about regular crop (food) production and biomass production

Note. * Items are reversed coded.

Appendix B

See Table A2.

Table A2. Item correlation matrix of teachers' perceptions survey instrument.

Item #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.000	0.345	0.090	0.400	0.295	0.352	0.345	0.119	0.089	0.068	0.254	0.277	0.290	0.286	0.233	0.241	0.399	−0.060	0.105	−0.083
2		1.000	0.221	0.334	0.237	0.323	0.279	0.013	0.090	0.106	0.113	0.155	0.044	0.055	0.094	0.083	0.172	−0.098	0.077	0.089
3			1.000	0.222	0.224	0.181	0.205	−0.027	−0.043	−0.090	0.229	0.188	0.033	0.121	0.106	0.064	0.057	−0.174	0.104	0.110
4				1.000	0.774	0.664	0.276	0.143	0.133	0.154	0.055	0.149	0.104	0.310	0.255	0.134	0.183	−0.031	−0.002	−0.049
5					1.000	0.657	0.262	0.100	0.119	0.199	0.040	0.193	0.180	0.330	0.296	0.195	0.148	−0.034	−0.025	−0.050
6						1.000	0.321	0.138	0.157	0.254	0.100	0.122	0.008	0.297	0.260	0.143	0.143	−0.090	−0.072	0.013
7							1.000	0.168	0.263	0.108	0.151	0.152	0.315	0.135	0.207	0.227	0.218	−0.061	0.046	0.191
8								1.000	0.755	0.371	0.005	−0.030	0.232	0.107	0.169	0.131	0.031	−0.109	−0.063	0.057
9									1.000	0.491	−0.039	−0.161	0.114	0.071	0.088	0.051	0.006	0.002	−0.105	−0.041
10										1.000	0.039	−0.038	0.193	0.051	0.070	0.038	0.093	−0.137	0.027	0.172
11											1.000	0.482	0.159	0.107	0.192	0.483	0.298	−0.176	−0.159	−0.107
12												1.000	0.263	0.209	0.227	0.394	0.309	−0.078	−0.020	−0.091
13													1.000	0.477	0.377	0.400	0.320	−0.031	0.051	0.119
14														1.000	0.695	0.208	0.270	−0.074	0.107	0.032
15															1.000	0.269	0.315	−0.034	0.081	−0.048
16																1.000	0.586	−0.242	−0.215	−0.133
17																	1.000	0.025	0.020	−0.088
18																		1.000	0.373	0.087
19																			1.000	0.257
20																				1.000

Appendix C

See Table A3.

Table A3. Item Communalities of teachers' perceptions survey instrument.

Item #	Initial Communalities	Extraction Communalities
1	0.432	0.358
2	0.276	0.287
3	0.266	0.156
4	0.683	0.800
5	0.684	0.743
6	0.608	0.590
7	0.426	0.383
8	0.674	0.590
9	0.753	0.999
10	0.500	0.295
11	0.427	0.332
12	0.368	0.320
13	0.537	0.409
14	0.641	0.999
15	0.549	0.518
16	0.597	0.763
17	0.501	0.496
18	0.395	0.999
19	0.345	0.359
20	0.300	0.217

Note. Extraction Method: Maximum Likelihood.

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