Controlled Drainage: Assessment of Yield Impacts and Education Effectiveness

Amanda Locker

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CONTROLLED DRAINAGE: ASSESSMENT OF YIELD IMPACTS AND EDUCATION EFFECTIVENESS

by

Amanda Locker

A Thesis

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In Partial Fulfillment of the Requirements for the degree of

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Dedicated to God and my husband for loving me, inspiring me, and pushing me forward.

Philippians 4:13.
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ABSTRACT

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Controlled drainage is the practice of using a water control structure to hold water in agricultural fields during periods when drainage is unnecessary. The use of this practice may increase crop yields compared to subsurface drainage because during the growing season controlled drainage can capture water from precipitation, and raise the water table for crop use. Results from published studies of controlled drainage impacts on crop yields have been mixed, and the effects of field characteristics and annual weather variation on these impacts are not well understood. For widespread adoption of controlled drainage, more information on how controlled drainage impacts crop yields is needed, as well as education on controlled drainage for more audiences.

To analyze crop yield impacts, two controlled and two free draining quadrants at the Davis Purdue Agricultural Center were compared. A grid system consisting of 10 by 10-meter cells was created to obtain a balanced data set. Crop yield was analyzed by year, annual wetness classification, soil drainage class, and elevation. Controlled drainage significantly increased the corn yield in six out of nine years, and the nine-year corn yield average increased by 2.3%. Soybean yield was significantly higher under controlled drainage in three out of four years, but there was no significant difference in the four-year soybean average. Years were further classified by wet, normal, or dry based on growing season precipitation, and results indicated controlled drainage had the greatest significant impact on corn yield in the dry years. Analyzing yield by soil drainage class and elevation determined that the very poorly drained soils had the most significant response to controlled drainage, while the highest elevations (more than 60 cm above the outlet) were more impacted than elevations closer to the outlet level.

An online learning module using virtual field trip videos was developed to increase student understanding of controlled drainage. It was implemented in an environmental hydrology class at Purdue University with the goal of determining student knowledge gain and perceptions...
of the module. Scores from the content knowledge pre-/post-test indicated students significantly scored higher on the post-test. Sixteen students were interviewed to glean more descriptive information, finding that students thought the videos helped them understand the concept of controlled drainage and appreciated that the module used real-world data from a research site. Students’ perceptions and knowledge gained after completing the online learning module suggests this can be an effective tool for teaching students about controlled drainage.
CHAPTER 1. INTRODUCTION

Agriculture is an important industry for the U.S. Corn Belt, and increasing crop yield is one of the top priorities for agricultural producers and industry. On poorly drained soil, subsurface tile drainage is extensively used to increase crop yield. Subsurface tile drainage is perforated tubing installed approximately 1 meter below the ground surface. The primary goal is to lower the water table (Kalita and Kanwar, 1992), and resulting benefits include better aeration, improved soil porosity, and warmer soil temperatures in the spring (Fraser et al., 2001; Hill 1976; Gardner et al., 1994). However, traditional drainage does not provide the ability for farmers to manage water draining from their field. With a rise in extreme precipitation patterns and changing temperatures, storing water in the soil for use when needed by crops is increasingly important.

Controlled drainage (CD) is a practice that has the potential to hold water in the landscape. The primary purpose is reducing nitrate loads to lessen the negative environmental impact from drained agricultural land. In addition to the nitrate reduction benefits, controlled drainage has the potential to increase crop yield compared to free draining fields if the outlet in the water control structure is raised during the growing season to potentially store water in the soil profile for crop use.

Existing studies on the yield benefits of this practice have shown mixed results, with some studies finding yield increases and others finding no effect or decreases in yield. Most of these studies analyzed less than four-years of crop yield data (Tan et al., 1998; Drury et al., 2009; Wesstrom and Messing, 2007; Fausey, 2005; Poole et al., 2013; Delbecq et al., 2012; Jaynes, 2012; Helmers et al., 2012; Cooke and Verma, 2012; Ghane et al., 2012). Long term studies on how CD impacts crop yields are needed to provide greater insight into how the effects vary by weather condition. Spatial variability of field characteristics may also influence CD effect on yields. Elevation and soil drainage class are two factors that are expected to play a large role on yield benefits from controlled drainage because of the potential available water for crops. However, only two published studies have analyzed elevation impacts (Delbecq et al., 2012; Ghane et al., 2012). A few studies have analyzed soil moisture availability (Hughes, 2015; Schott et al., 2017), but the impact of soil drainage class on yield has not directly been studied.
In addition to inconclusive yield impacts, another barrier to implementation of controlled drainage (CD) is the lack of understanding of what it means and how it works. The practice is difficult for farmers and others to understand given its complexity as well as the fact that the practice cannot easily be observed since it is mostly underground. Many conservation practices are demonstrated at field days where students, farmers, or others can see the practice, but if people take a trip to see controlled drainage sites, they would not be able to see much of what is taking place. Educational technologies such as videos, can help diminish the barrier of teaching about CD. Using an online learning module that contains videos and animations, can help to visualize how the practice works and what is happening underground. Using videos to teach concepts not easily visible have been tested in published studies (e.g. Lang et al., 2012) and the use for teaching about CD is promising.

A 13-year study of controlled drainage at the Davis Purdue Agricultural Center in east-central Indiana provided an opportunity to address both these issues. The CD research and extension site has been the focus of many previous theses (Adeuya, 2009; Utt, 2010; Brooks, 2013; Bou Lahdou, 2014, Hughes, 2015). Published papers have quantified the effects of controlled drainage on drain flow (Saadat et al., 2018a) and nitrate load (Saadat et al., 2018b), as well as the need for active management to manage the water table (Saadat et al., 2017). Delbecq et al. 2012 analyzed the first five years of crop yield impacts of CD at this site, but the full 13 years, have not been published. This site also provides an opportunity to teach university students as well as Extension audiences about controlled drainage and its impacts, due to the extensive data on hydrologic, water quality impacts. This work focuses on creating and using an online learning module to teach students about the basic concepts of CD. Promoting the understanding of controlled drainage will increase the impact of the 13-year research study.
1.1 Objectives

The overall goal of this study is to increase understanding of controlled drainage so that farmers will be able to make more informed decisions about adoption and students will have up-to-date knowledge of innovative conservation practices they may encounter in the future. Specific objectives for this work are to:

1. Assess the effect of controlled drainage on yield and determine how soil drainage class or elevation may drive that effect.
2. Create an online learning module to teach students about controlled drainage.
3. Evaluate knowledge gained and applying those concepts to real-world scenarios and students’ experience.

1.2 Organization

This thesis is divided into four chapters, two of which are papers to be submitted for publication. Chapter 2 addresses the impact of controlled drainage on yield and how soil drainage class or elevation may drive that effect. Chapter 3 describes the creation of the online learning module and evaluation of its success. Conclusions and future research suggestions are presented in Chapter 4.

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CHAPTER 2. IMPACT OF CONTROLLED DRAINAGE ON CROP YIELD INCLUDING WITHIN-FIELD VARIABILITY

A version of this chapter will be submitted for publication. Refer to the article:
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Key words. Controlled drainage, Drainage water management, Subsurface drainage, Crop yield, Soil type, Soil drainage class, Elevation

2.1 Introduction

Controlled drainage, also known as drainage water management, is the practice of using a water control structure to hold water in drained agricultural fields during periods when drainage is unnecessary. The primary purpose of controlled drainage is reducing nitrate losses from drained agricultural land, and reductions in nitrate loads to surface waters have been found in various studies from 18% to 79% depending on the drainage system, design, location, soil, and site conditions (Skaggs et al., 2012; Ross et al., 2016). The benefits of controlled drainage are expected to increase as climate change leads to both a rise in spring precipitation (Pryor et al., 2014) and increased potential for soil water deficits in summer due to increased evapotranspiration (Hatfield et al., 2011).
In addition to the nitrate load reduction benefits, controlled drainage (CD) has the potential to increase crop yields compared to free drainage (FD), when the outlet in the water control structure is raised during the growing season to potentially store water in the soil profile for crop use. Pease et al. (2017) found in a modeling study on projected climate change effects in the Western Lake Erie Basin that controlled drainage would become more effective as a means to retain crop available water in the soil profile. However, it also has the potential to reduce yields, particularly in wet years because the water table recedes more slowly after a rainfall event when the outlet is raised (Saadat et al., 2017). With both beneficial and detrimental effects possible, studies of controlled drainage effects on crop yield have shown mixed results.

2.2 Literature Review

2.2.1 Published Controlled Drainage Yield Impacts

Skaggs et al. (2012) reviewed ten papers analyzing crop yield impacts of controlled drainage measured at sites around North America and in Europe, and four more have been published since that time for a total of 14 papers. These contain 26 separate analyses, as several include more than one crop, often corn and soybeans, while two papers analyzed the same sites (Helmers et al., 2012; Schott et al., 2017) and two analyzed the same data (Crabbe et al., 2012; Sunohara et al., 2014). Of these analyses, 12 found yield increases with CD, two found a decrease, and 12 found no difference.

Yield increases have been reported from Iowa in the west to North Carolina in the east and also in Europe. Jaynes (2012) found that CD significantly increased soybean yield by 8% on a 22-ha farm in central Iowa. In Indiana, Delbecq et al. (2012) found an increase in corn yield under CD, using a spatial panel regression method and an elevation-based analysis described below. In Ohio, Ghane et al. (2012) analyzed 23 site years of data over four years on seven farms. On average controlled drainage had a statistically higher yield for corn, popcorn, and soybean by 3.3%, 3.1%, 2.1%, respectively, and yield decreased in only four site years with CD. In a five-year study in eastern Ontario, Crabbe et al. (2012) and Sunohara et al. (2014) found an average increase in corn yield of 3% and in soybean yield of 4%. In North Carolina, Poole et al.
(2013) found CD significantly increased corn yield by 11% and soybean yield by 10%, and had no significant effect for winter wheat. In Sweden, Wesstrom and Messing (2007) monitored three 40 m x 50 m plots, over a four year period and found a positive effect on cereal yields between 2% and 18%.

Other studies, also ranging from Iowa in the west to Nova Scotia in the east, found yield decreases under CD or no effect. In southeast Iowa, Helmers et al. (2012) compared CD and FD (as well as shallow drainage and undrained plots) for four years on eight plots ranging in size from 1.2 to 2.4 ha, and they found no effect on soybean yield and a reduction in corn yield. Schott et al. (2017) continued this research for five additional years and found CD did not reduce corn or soybean yields. Jaynes (2012) found no effect for CD in two corn years in Iowa. In Illinois, Cooke and Verma (2012) analyzed four pairs of fields and determined that the effect of CD on corn and soybean yield was inconclusive. Fausey (2005) found no CD effect on corn or soybean yield in Ohio. Drury et al. (2009) in Ontario analyzed two years of corn data and two years of soybean data on a clay loam soil and determined that CD had no significant effect on crop yield. Tan et al. (1998) monitored two field sites over a two-year period in Ontario, one field managed with no-till and the other field managed by conventional tillage and found no effect on soybean yield with CD. In Nova Scotia, Canada, Smith and Kellman (2011) found CD decreased corn yield by 14% compared to FD on small plots in one relatively wet year.

2.2.2 Effect of Seasonal Wetness/Dryness

The effect of CD on yield is influenced by overall seasonal wetness or dryness, and also the distribution of rainfall over the growing season. Skaggs et al. (2012) stated that controlled drainage benefits on yield are maximized in years when a wet period during the growing season is followed by a dry period, followed by another wet period because it provides the best conditions for controlled drainage to conserve soil water that can be used by crops. However, only a few studies explicitly related differences in CD yield performance to moisture conditions and temporal patterns. Kross et al. (2015) evaluated corn and soybean growth in CD and FD under different seasonal and rainfall conditions in eastern Ontario, using leaf area index (LAI) and total above-ground dry
biomass as indicators of crop growth. They found that corn LAI and biomass were greater under CD relative to FD in drier years, while the opposite was observed for soybean, indicating that there could be differences in how corn and soybean yield respond to CD in wet and dry years. Poole et al. (2013) found the effects of CD on yield were more related to the amount of drainage water conserved and timing with respect to growth stages, rather than its impact on average water table depth by production year. For example, in a year with below average rainfall in June and July CD conserved 19 mm of drainage water and had a significant impact on corn yield (Poole et al., 2013). Schott et al. (2017) found that the lack of statistical differences between drainage treatments and water table were likely due to rainfall patterns. The availability of water for crop use has been measured through soil moisture but results remain inconclusive. Schott et al. (2017) found no difference in soil water content during the growing season between CD, FD, and undrained in the top 80 cm of the soil profile. The minimal findings between the different treatments and soil water contents could be due to the monthly time scale being too large of a range to distinguish differences because rainfall through the years was substantially different. Hughes (2015), analyzed soil moisture across four sites throughout the Midwest and found late-season deficit and early season excess soil moisture correlated with yield, however, there were few significant differences in excess stress between FD and CD.

2.2.3 Effect of Elevation

Changes in elevation across the field are expected to affect yield impacts of CD, as the closer in elevation the crop root is to the water control structure the more access crop roots would have to the water table. However, few studies have analyzed yield and elevation for CD, possibly because preferred CD sites are installed on flat fields allowing for crop roots to have the same reach to the water table at any point in the field. Ghane et al. (2012) defined an “area of interest” as an elevation increase equal to the difference of the outlet elevation level depth in the CD control structure from the maximum effective root depth, 1.2 m for corn and .9 m for soybean. Their analysis of the crop yield only within the area of interest found a corn and soybean yield advantage from CD of 3.5%-6% that was greater than the increase found on an entire field analysis. Delbecq et al.
(2012) used a logarithmic transformation of elevation, and found the “effective elevation range”, defined as the field area within 0 to 0.61m above the water control structure, had 5.8% to 9.8% higher yields on the west and east sides, respectively. Cooke and Verma (2012) plotted yield versus elevation and found the relationship to be different each year of their study.

2.2.4 Effect of Soil Properties

Soil properties are also expected to affect the impact of CD on yield, particularly soil drainage class or natural drainage class which refers to the frequency and duration of wet periods under conditions similar to those under which the soil is formed. A poorly drained soil is defined as a soil in which water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods (Soil Survey Manual, 2017). Soil and elevation are related, and when mapping soil boundaries, soil scientists commonly look for relief features on topographic maps to help locate the boundaries as relief helps identify landforms commonly related to different soils (Soil Survey Manual, 1993). While an expectation is that the most poorly drained soils should have higher yield than other soil types in the drier years and lower yield in wet years, the interaction with CD is likely more complex. No studies have yet been published that examine the relationship between soil types (specifically soil drainage class) and CD effects on yield. Raising the water table using CD could lead to lower yields in poorly drained soils, but CD likely also has the greatest potential to increase yield during drier years on these soils.

2.3 Objective

The lack of yield effect due to controlled drainage in so many previous studies suggests that more detailed analysis of temporal and spatial variability could help clarify the interactions. Analyzing the wetness or dryness of individual years, as well as the moisture patterns within the year, may clarify the variation in crop yield effects over years. A spatial analysis to separate different soil types and elevation above the water control structure may clarify the influence of these sub-field characteristics on the
relationship. The objective of this study was to evaluate the effect of CD on corn and soybean yield in dry and wet years and determine how soil type or elevation may drive that effect. A 13-year study of controlled drainage in eastern Indiana (Saadat et al., 2017; Saadat et al., 2018a; Saadat et al., 2018b) provided detailed yield and field data to explore these factors.

2.4 Materials and Methods

2.4.1 Site Description

The research site is at the Davis Purdue Agricultural Center (DPAC) (40.266°N, 85.160°W; Figure 1). One 15.8 ha field is split into four quadrants; two with controlled drainage (NW, SE) and two free draining (SW, NE). The drainage system was installed in September 2004 with 10 cm (4 in.) laterals at an approximate depth of 1 m and spacing of 14 m (Utt, 2010). Each quadrant outlets into a 15 cm (6 in) submain that connects to the 20 cm main and then outlets into the 25 cm county main located in the NW corner of the controlled drainage quadrant. The county main is not adequate, impeding flow during very wet conditions and potentially exerting drainage control on the “free draining” quadrants during these periods.
Continuous corn (*Zea mays* L.) was grown from 2005-2010, followed by a corn-soybean (*Glycine max* L. Merr.) rotation from 2011-2017. Nine years of corn yield data (2005-2010, 2012, 2014, and 2016) and four years of soybean yield data (2011, 2013, 2015, and 2017) were available. Table 1 indicates the dates for planting, harvest, and when the outlet elevation was raised in the water control structures.
Table 1 Planting and harvest dates for DPAC

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Planting</th>
<th>Harvest</th>
<th>Outlet elevation raised to 40 cm for growing season</th>
<th>Date and depth the outlet elevation was adjusted during the growing season</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Corn</td>
<td>Apr. 19</td>
<td>Oct. 31</td>
<td>June 21</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>Corn</td>
<td>May 8</td>
<td>Oct. 30</td>
<td>June 20</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>Corn</td>
<td>May 3</td>
<td>Oct. 8</td>
<td>May 24</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>May 7 = 100 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>June 9 = 60 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jun 25 = 100 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jul 11 = 40 cm</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Corn</td>
<td>Apr. 28</td>
<td>Oct. 14</td>
<td>Apr. 30</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>Corn</td>
<td>May 22</td>
<td>Nov. 2</td>
<td>June 2</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Corn</td>
<td>Apr. 19</td>
<td>Sept. 23</td>
<td>Apr. 23</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>May 11 = 100 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>July 7 = 60 cm</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Soybean</td>
<td>June 7</td>
<td>Oct. 24</td>
<td>June 22</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Corn</td>
<td>Apr. 23</td>
<td>Oct. 10</td>
<td>Jan. 9</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>Soybean</td>
<td>May 20</td>
<td>Oct. 14</td>
<td>May 23</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Corn</td>
<td>Apr. 27</td>
<td>Oct. 21</td>
<td>May 13</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Soybean</td>
<td>June 6</td>
<td>Oct. 12</td>
<td>Mar. 31</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>Corn</td>
<td>Apr. 26</td>
<td>Oct. 7</td>
<td>June 7</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>Soybean</td>
<td>Apr. 24</td>
<td>Oct. 3</td>
<td>Apr. 28</td>
<td></td>
</tr>
</tbody>
</table>

The farm manager adjusted the outlet elevation four times in 2008, and twice in 2009 and 2010.
2.4.2 Yield Data

Geo-referenced yield points were collected using an Ag Leader Integra yield monitor in a CaseIH 2334 combine and adjusted to a moisture content of 15.5% for corn and 13% for soybean. Yield data were cleaned and processed in SMS Advanced Software (Ag Leader Technology, Ames) with the following setting start delay 6 seconds, stop delay 4 seconds, flow shift 12 seconds, minimum yield 0 metric tons per hectare, and maximum yield 25.1 metric tons per hectare (400 bushels per acre). The settings varied slightly each year depending on the data. The swath width was 4.6 meters wide for corn and 6.1 meters for soybeans. Cleaned and processed yield data were then imported into ESRI ArcGIS Pro 2.0 and the end rows were removed. Spatial analysis was completed in ArcGIS Pro 2.0. All data were projected into Universal Transverse Mercator, North American Datum 1983, Zone 16.

To create a spatially balanced data set, a grid consisting of 10 x 10-meter polygon cells (approximately two combine passes) were created inside of each quadrant (Figure 2). This size was selected to provide spatial detail while ensuring that each cell contained yield points. The grid determined a numbering system of rows and columns for each cell in the grid, which allowed for comparison of yield for different years in the same location. For each year, the yield of each cell was calculated as the average of all yield points within the cell. Calculating the average within each cell does introduce heteroscedasticity because of non-constant variance for each mean, but the prediction error for the average yield within grids is smaller than the prediction error for any yield point because the average yield estimator has a higher precision than the yield point estimator (Delbecq et al., 2012; Haining, 2003). To correct for heteroscedasticity a weight was applied to each cell, because cells with more yield points had less variability in the calculated average. The weight was applied to help balance the standard error associated with each cell average and was based on the count of the yield points that make up the average within each cell. Similar methods were performed by both Delbecq et al. (2012) and Anselin et al. (2004). Using a grid with average yield reduced the effect of measurement error for individual yield monitor observations (Anselin et al., 2004). The entire field grid had 1019 cells and the number of cells within each quadrant are 255 cells (NW, NE), 237 cells (SW), and 272 cells (SE).
2.4.3 Defining Growing Season Wetness Classification from Precipitation

Years were classified as wet, dry, and normal years, based on growing season (May thru August) precipitation at the research site. Precipitation data were collected by a tipping bucket located at an onsite weather station. Observed precipitation totals were compared to the growing season normal from May through August for the Farmland 5NNW station from 1981-2010 (http://climod.unl.edu/), located less than 3.2 kilometers from the onsite weather station. Yearly wetness classification was based on ± 1 standard deviation (112mm) from the 30-year normal (430 mm), meaning that growing seasons with precipitation of 542 mm or more were classified as wet, and growing seasons with precipitation of 318 mm or below were classified as dry (Figure 3). There were four dry years, six normal years, and three wet years.
2.4.4 Influence of Water Table in Each Year

Controlled drainage would not be expected to increase crop yield unless water is stored in the field. Growing season water table depth was used to define the extent to which water was held by controlled drainage, and explore the potential benefit or detriment on crop yield. Water table depth was measured in 5 cm (2 in) diameter wells installed to a depth of approximately 2 m in each quadrant midway between two subsurface drainage laterals (Adeuya, 2009). Hourly water table was measured by a Global Water WL16 Water Level Logger and averaged to daily measurements. The number of days during the growing season that the water table was clearly above the tile drain depth was used as an indicator of potential beneficial effects of controlled drainage. The depth of the water table at the well in relation to the tile drain depth was determined by Saadat et al (2018), and to be conservative days were only counted when the water table was at least 15 centimeters above the estimated tile drain depth. The number of days was averaged for the two CD quadrants and the two FD quadrants. Although the data record included 107,064 hourly water table points, some points were missing, and if data were missing for more than half the month, the other quadrant in the same treatment was used for the entire month. In 2010, no water table was available from July 9 to August 9.
and water table data were not available for 2005 or 2017. The years 2005 and 2017 were dropped from the water table analysis but still included in the yield analysis.

Controlled drainage may have detrimental effects when the water table is too close to the surface, causing crops to experience aeration stress. The depth at which detrimental effects are expected has often been identified as 30 cm (Wesseling, 1974; Kanwar et al., 1988) and therefore the number of days the water table was within 30 cm of the surface, commonly known as SEW$_{30}$ (Sieben, 1964), was used as an indicator of potential detrimental water table effects.

2.4.5 Effect of Soil Drainage Class and Elevation

Yield impact of controlled drainage was analyzed by soil type using an order 1 soil map of the field conducted by G. Steinhardt of the Purdue University Agronomy Department. The soil types consisted mainly of Blount silt loam (somewhat poorly drained), Condit silt loam (poorly drained), and Pewamo clay loam (very poorly drained). The NE quadrant has a very small portion of Glynwood silt loam (moderately well drained) which was combined with the Blount soil for statistical analysis. The majority soil type in each yield cell was assigned to the entire yield cell for analysis. (Figure 4a).

Yield impact of controlled drainage was also analyzed by elevation, using the LiDAR-based elevation from IndianaMap Framework data (Indiana Office of Information Technology, 2012). The average elevation within each yield cell was assigned to the cell. Elevation relative to the elevation at the water control or the lowest point in the field was used, calculated by subtracting the cell elevation from the lowest point in the field for FD or from the elevation of the water control structure at the ground level for controlled drainage. The SE quadrant had two water control structures, and therefore relative elevation in each cell were calculated with respect to the closest water control structure lower than the cell (Figure 4b).
For most of the field the soil drainage class and elevation classification follow the expected pattern of the lower elevations consisting of the very poorly drained soils. However, in the NW quadrant the very poorly drained soil is located on the east side and consists of all three elevation ranges. The number of 10 by 10-meter cells by soil drainage class and elevation for each quadrant is summarized in Table 2.

Table 2 Number of cells in each quadrant for soil drainage class and elevation.

<table>
<thead>
<tr>
<th>Drainage Class</th>
<th>NW</th>
<th>NE</th>
<th>SW</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWP</td>
<td>78</td>
<td>137</td>
<td>68</td>
<td>60</td>
</tr>
<tr>
<td>PD</td>
<td>117</td>
<td>109</td>
<td>131</td>
<td>120</td>
</tr>
<tr>
<td>VPD</td>
<td>60</td>
<td>9</td>
<td>38</td>
<td>92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation</th>
<th>NW</th>
<th>NE</th>
<th>SW</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30 cm</td>
<td>45</td>
<td>38</td>
<td>35</td>
<td>82</td>
</tr>
<tr>
<td>30-60 cm</td>
<td>96</td>
<td>62</td>
<td>38</td>
<td>115</td>
</tr>
<tr>
<td>&gt;60 cm</td>
<td>114</td>
<td>155</td>
<td>164</td>
<td>75</td>
</tr>
</tbody>
</table>
2.4.6 Statistical Analysis

For the spatial and temporal analysis within the quadrants, a linear mixed model was created to analyze yield for each cell. The grid allowed for a row and column system that was used to consider spatial correlation as described below. The yield response equation to be estimated was

\[ 
\text{yield}_{ijt} = \beta_0 + X_{ijt}\beta + r_{ij} + \varepsilon_{ijt} \quad (1) 
\]

where \(\text{yield}_{ijt}\) is the average yield per grid cell in \(i\) column and \(j\) row in the \(t\)th year. The fixed effects \(X_{ijt}\beta\) are drainage treatment (CD or FD), soil drainage classes, elevation, and wetness classification. Interactions and their significance were examined by treatment and wetness classification for soil drainage class and elevation. The random effects are represented in \(r_{ij}\) and \(\varepsilon_{ijt}\). The random effect \(r_{ij}\) accounted for the temporal effect over the years, also known as compound symmetry. The gridded system of rows and columns allowed the model to manage the spatial correlation contained in \(\varepsilon_{ijt}\) by assuming the following spatial covariance structure for two yield cells in the field for the same year as

\[ 
\text{Cov}(y_a, y_b) = \sigma_s^2 \exp\{-d_{ab}/\theta\} \quad (2) 
\]

where \(d_{ab}\) is the Euclidean distance between point \(a\) and point \(b\) and the correlation decays exponentially with \(d_{ab}\). This covariance exponential equation is used for the covariance in the same year with different locations. In different years and the same location, the covariance was calculated by \(r_{ij}\) (compound symmetry). This statistical model helps account for the repeated measurements by modeling correlation of measurements on the same plot across years, which is important for making accurate inference (Piepho et al., 2011). The model was used for corn and soybean yield separately because the model fitting was based on corn yield and the model diagnostics for soybean yield do not fit as well as corn, but to make comparisons across crops the same model was used for soybean yield. For the year-by-year and the average year comparison of controlled and free drainage, the above model was used with treatment as the only fixed effect with a Gaussian spatial covariance structure as
\[ \text{Cov}(y_a, y_b) = \sigma_s^2 \exp\{-d_{ab}^2/p^2\} \]  

where \(d_{ab}\) is the Euclidean distance between point \(a\) and point \(b\) and the correlation decays exponentially with \(d_{ab}\).

To further investigate how yield is impacted by different levels of the fixed effects, a least square means test was used. Model-based estimates for the effect size were computed using the LSMEANS statement in SAS version 9.4. The least squares means were computed based off the model estimates and tested to determine significant (\(p < .05\)) differences in yield using the least square means test with a Tukey-Kramer adjustment. Both the LSMEANS test p-value and adjusted p-value are shown in the results. The adjusted p-value is a more conservative p-value and reduces the family error for multiple comparisons. Tukey-Kramer adjustment was used to account for multiple comparisons of means because it accounts for unbalanced populations and interactions.

Statistical analyses were performed using SAS/STAT® software (SAS Institute Inc. 2013) version 9.4. The liner mixed model SAS code was developed using the PROC GLIMMIX procedure.

2.5 Results

2.5.1 Year-by-Year Comparison of Crop Yields

Controlled drainage significantly increased corn yield in six out of nine years, and by 2.3% on average over all nine years (10.2 Mg ha\(^{-1}\) vs 9.9 Mg ha\(^{-1}\), Figure 5) The greatest corn yield increase in the controlled drainage quadrants occurred in 2007 (5.7%), 2009 (5.4%), and 2012 (4.8%), which were all dry years. In one very wet year (2010), yields were low overall and there was a significant decrease in yield in the CD quadrants (8.2 Mg ha\(^{-1}\) CD vs 8.6 Mg ha\(^{-1}\) FD). There was no significant difference due to CD in 2014 (a wet year) or 2016 (a normal year).
Figure 5 Annual and nine-year mean corn yield averages for controlled and free drainage. Means within years or for the nine-year average with a different letter are significantly different (ρ=0.05).

Controlled drainage significantly increased soybean yield in three out of four years, but the four-year average difference between treatments was not significant (Figure 6). The mean soybean yield increases for CD were 1.4%, 2.9%, and 2.2% for 2011, 2013, and 2015, respectively. In 2017, CD significantly decreased yield by 5.8%.

Figure 6 Annual and four-year average soybean yield averages for controlled and free drainage. Means within years or for the four-year average with a different letter are significantly different (ρ=0.05).
2.5.2 Influence of Water Table in Each Year

In every year the CD quadrants, averaged together, had more days when the water table was above the subsurface tile drain than the FD quadrants averaged together (Table 3). However, CD only raised the water table to a potentially detrimental level (30 cm) more times than FD in 2 out of 13 years.

Table 3 Number of days during the growing season when the water table was above the subsurface tile drain and within 30 cm of the surface.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yearly Classification</th>
<th>Crop</th>
<th>Days water table above the drain</th>
<th>Days water table within 30 cm (SEW\textsubscript{30}) of surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Normal</td>
<td>Corn</td>
<td>12</td>
<td>47</td>
</tr>
<tr>
<td>2007</td>
<td>Dry</td>
<td>Corn</td>
<td>6</td>
<td>35</td>
</tr>
<tr>
<td>2008</td>
<td>Normal</td>
<td>Corn</td>
<td>24</td>
<td>41</td>
</tr>
<tr>
<td>2009</td>
<td>Dry</td>
<td>Corn</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>2010</td>
<td>Wet</td>
<td>Corn</td>
<td>27</td>
<td>32</td>
</tr>
<tr>
<td>2011</td>
<td>Normal</td>
<td>Soybean</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>2012</td>
<td>Dry</td>
<td>Corn</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>2013</td>
<td>Dry</td>
<td>Soybean</td>
<td>12</td>
<td>57</td>
</tr>
<tr>
<td>2014</td>
<td>Wet</td>
<td>Corn</td>
<td>31</td>
<td>67</td>
</tr>
<tr>
<td>2015</td>
<td>Wet</td>
<td>Soybean</td>
<td>43</td>
<td>70</td>
</tr>
<tr>
<td>2016</td>
<td>Normal</td>
<td>Corn</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>

The percentage crop yield difference ((CD-FD)/FD)*100%) increased with the percentage difference in days above the drain for CD compared to FD quadrant (Figure 7). Crop yield for CD appeared to increase as the days the water table was above the drain increased between treatments.
2.5.3 Influence of Wet and Dry Years

The difference in effect of controlled drainage on corn yield among the nine years was likely due in part to differences in wetness conditions. Grouping years by wetness classification based on growing season rainfall clarified that the significant positive effect occurred in dry years, rather than normal or wet years (Figure 8). The linear mixed model indicated a significant interaction between treatment and yearly wetness classification. In the dry years, yield was 5.9% higher under controlled drainage (8.7 Mg ha\(^{-1}\)) than under free drainage (8.2 Mg ha\(^{-1}\)), compared to a 2.3% increase for all years combined. Yield was high in the normal years under both free and controlled drainage and controlled drainage was likely not needed to conserve moisture and did not increase yields. In the wet years, yield was lower under controlled drainage, but the effect was not significant. Corn yield was significantly different between dry and normal years for both CD and FD.

Figure 7 Percent increase in number of days the water table was above the drain for controlled drainage compared to the mean crop yield differences.
Figure 8 Least square means corn yield difference for average yearly wetness classification by treatment. Means with a different letter are significantly different (p=0.05).

The impact of yearly wetness classification for soybean yield was not as clear as corn yield, with no significant difference between CD and FD in any of the wetness classifications. Soybean yields were highest in the dry years and lowest in the wet years in both CD and FD treatments. The difference between the controlled drainage yield in dry and normal years was not significant using the LS-means adjusted p-value, although it was with the LS means p value, which is shown in Figure 9.

Figure 9 Yearly wetness classification for least square means estimated soybean yield for CD and FD for the entire field, no significant differences.
2.5.4  Yield Impacts by Soil Drainage Class

The analysis by wet and dry years for corn showed that the effect of controlled drainage was greater in dry years than normal years, which was expected (Table 4). The 9.2% increase for the very poorly drained soils in the dry years shows how CD can provide more moisture to the corn plant. Corn yield in the wet years was lowest in the very poorly drained soil, but the difference between free and controlled drainage was also the most significant. This was not expected, as the potential of controlled drainage to decrease yields by causing aeration stress in wet years would seem to be greatest in the very poorly drained soils. One factor that may have influenced the results is that the very poorly drained soil type is more prominent in the CD quadrant, particularly the SE quadrant. Furthermore, wetness did not continue through the entire growing season, and the early wet conditions may have caused the crop roots to be stunted, exacerbating water stress near the surface later in the season that could be alleviated by the added water storage of controlled drainage.

Table 4 Least squares means estimated corn yield for CD vs FD by soil drainage class and yearly classification.

<table>
<thead>
<tr>
<th>Yearly Wetness Classification</th>
<th>LS-means estimated corn yield Mg ha⁻¹</th>
<th>Yield Difference ((\text{CD-FD})/\text{FD}*100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VPD (CD)</td>
<td>PD (FD)</td>
</tr>
<tr>
<td>Dry</td>
<td>8.9</td>
<td>8.2</td>
</tr>
<tr>
<td>Normal</td>
<td>10.9</td>
<td>10.5</td>
</tr>
<tr>
<td>Wet</td>
<td>8.7</td>
<td>7.9</td>
</tr>
<tr>
<td>Overall Estimate</td>
<td>9.5</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Asterisk (*) Indicates significance with an LSMEANS p-value= .05. ** indicates significance with the LSMEANS adjusted p-value=.05.

Controlled drainage had the greatest impact for soybeans in the very poorly drained soil during the wet year, and significantly increased yield in the dry year, similar to the effect in corn (Table 5). In all soil types, yield was lower during the wet year than the normal and dry years.
Table 5 Least squares means estimated soybean yield for CD vs FD by soil drainage class and yearly classification.

<table>
<thead>
<tr>
<th>Yearly Wetness Classification</th>
<th>Ls-means estimated soybean yield Mg ha(^{-1})</th>
<th>Yield Difference (((\text{CD-FD}/\text{FD})\times100%))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VPD CD</td>
<td>FD</td>
</tr>
<tr>
<td>Dry</td>
<td>4.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Normal</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Wet</td>
<td>3.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Overall Estimate</td>
<td>3.7</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Asterisk (*) Indicates significance with an LSMEANS p-value = .05. ** indicates significance with the LSMEANS adjusted p-value = .05.

2.5.5 Yield Impact by Elevation

For corn, controlled drainage had a significant yield benefit during dry years at the 30-60 cm elevation and >60 cm elevation and did not lead to significant differences in normal or wet years at any elevation (Table 6). The increase in yield in the dry years and overall at the highest elevations (more than 60 cm above the control structure) was not expected, as even if moisture is held by controlled drainage the effect would be less more than 60 cm above the water table. It has generally been assumed that the yield benefit of CD does not extend above 60 cm of elevation above the structure (i.e., Delbecq et al., 2012; Ghane et al., 2012). However, these results suggest that the effective zone for controlled drainage could extend to higher areas of the field. Corn roots can penetrate deeper in the soil profile during certain dry conditions (Sharp and Davies, 1985). Furthermore, in the dry years stress due to lack of water has more potential to harm yield, meaning that CD can lead to larger yield improvements at higher elevations.
Table 6 Controlled drainage and free drainage LS-means estimated corn yield by yearly wetness classification and elevation.

<table>
<thead>
<tr>
<th>Year Classification</th>
<th>Ls-means estimated corn yield Mg ha⁻¹</th>
<th>Yield Difference (CD-FD)/FD)*100%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;30 cm CD FD</td>
<td>30-60 cm CD FD</td>
</tr>
<tr>
<td>Dry</td>
<td>8.8 8.4</td>
<td>8.7 8.3</td>
</tr>
<tr>
<td>Normal</td>
<td>11 10.9</td>
<td>11 10.9</td>
</tr>
<tr>
<td>Wet</td>
<td>8.6 8.8</td>
<td>9.1 9.3</td>
</tr>
<tr>
<td>Overall Estimate</td>
<td>9.4 9.4</td>
<td>9.6 9.5</td>
</tr>
</tbody>
</table>

Asterisk (*) Indicates significance with an LS-means p-value= .05. ** indicates significance with the LS-means adjusted p-value=.05.

The only statistically significant increase in soybean yield was at the higher elevation (>60 cm) with all years combined (Table 7). Free drainage had a decrease in yield as elevation increased during the dry and normal year. The lack of significant yield differences in individual wetness classification could be due to only having four years of data.

Table 7 Controlled drainage and free drainage least squares means estimated soybean yield by yearly wetness classification and elevation.

<table>
<thead>
<tr>
<th>Year Classification</th>
<th>LS-means estimated soybean yield Mg ha⁻¹</th>
<th>Yield Difference (CD-FD)/FD)*100%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;30 cm CD FD</td>
<td>30-60 cm CD FD</td>
</tr>
<tr>
<td>Dry</td>
<td>4 4</td>
<td>4.0 3.9</td>
</tr>
<tr>
<td>Normal</td>
<td>3.8 3.9</td>
<td>3.8 3.9</td>
</tr>
<tr>
<td>Wet</td>
<td>3.3 3.1</td>
<td>3.3 3.3</td>
</tr>
<tr>
<td>Overall Estimate</td>
<td>3.7 3.7</td>
<td>3.7 3.7</td>
</tr>
</tbody>
</table>

Asterisk (*) Indicates significance with an LSMEANS p-value= .05.

2.6 Discussion

This study found a small, but significant increase in corn yield with controlled drainage. Statistical significance might have been achieved here but not in numerous previous studies due to both the long data record, and the grid-based analysis method.
Nine years of corn yield data were available at this site, which is more than previous studies. Many other studies had far fewer years, and although controlled drainage may have been beneficial, the yield increases were not statistically significant for most studies. Within individual years, the grid-based analysis with a linear mixed model effectively used the large amount of data available across the 4.2 ha plots, increasing the sample size while accounting for spatial correlation in the linear mixed model. Several previous studies evaluated how controlled drainage impacted yield on a year to year basis by comparing limited replications for each treatment, but found no effect within years. For example, Helmers et al. (2012) and Schott et al. (2017) used a general linear model to analyze two mean replications per treatment, and found CD had no effect on corn or soybean yields for individual years. Jaynes (2012) in Iowa used a PROC MIXED procedure and found no effect for CD for two corn years, but one year for soybeans was significantly higher. Drury et al. (2009) in Ontario used a general linear mixed model to analyze two years of corn data and two years of soybean data and determined that CD had no significant effect on crop yield. The yield benefits of controlled drainage are known to be strongly influenced by the temporal pattern of precipitation and water storage in the soil (Skaggs et al., 2012), but this is difficult to quantify in a single metric. Poole et al. (2013) examined water table and drain flow between CD and FD with respect to crop growth stages over the growing season for two years of data. Breaking down precipitation patterns and water table in individual representative years can help give insight into the yield benefits of controlled drainage.

Controlled drainage significantly increased yield in 2009, which was a dry year with precipitation events after the outlet was to 10 cm on June 10 (Figure 10). In the CD quadrant, there were 50 days when the water table was above the subsurface tile drain (expected to benefit yields) while only 11 days in the FD quadrants. Yield may be adversely affected when the water table rises above 30 cm below the surface, quantified as the SEW30. There were two more days when the water table was within 30 cm of the surface for CD than FD, but this did not cause lower yields.

Similar patterns and results occurred in 2007 and in 2012 when some precipitation occurred during the month of May and the outlet in the water control structure was raised. This period of precipitation was followed by very dry conditions in June, July, and
August. The twelve days when the water table was above the subsurface tile drain likely had a slight benefit for CD during June.

![Graph showing water table depths and precipitation data for NW and SW quadrants in 2009.](image)

Figure 10 Comparison of water table depths for the NW quadrant and the SW quadrant in 2009 (top). Precipitation and drain flow for the same quadrants (bottom).

In years when moisture conditions are optimal for corn yield, controlled drainage may not provide a benefit. For example, corn yields around the state of Indiana were high during 2016. The outlet elevation was raised on June 7 and precipitation was plentiful over the growing season. There were no significant yield differences between treatments, likely due to beneficial timing of precipitation and the crop not needing the additional water from CD.

Crop yield may be reduced in wet years, and controlled drainage can make it worse. During the 2010 wet year, yield in the CD quadrants was significantly lower than in the FD quadrants. However, this was likely not due to CD as the outlet was not raised during most of the growing season because of the wet conditions, and even in July and August,
the outlet elevation was at 31 to 61 cm. This confirms that the wet conditions resulted in lower yields, but not due to poor management.

2.7 Conclusion

Controlled drainage significantly increased the nine-year mean corn yield by 2.3%, while mean soybean yield was not significantly different. Corn yield under CD was significantly higher than FD in six out of nine years and soybean yield in three out of four years. There was only one year when CD significantly decreased corn and soybean yield.

The linear mixed model provided additional insight on the influence of other variables and their interactions. Classifying the years by wetness helped to clarify how CD impacted yields differently in wet and dry years. Overall, CD significantly increased yields in the dry years by 5.9%. Soybean yields were higher under CD in dry years, but the difference was not significant, possibly due to only four years of data vs. nine years of corn. Yields were highest in the normal years in both FD and CD, and although the yields under CD were slightly higher, the effect was not significant.

The spatial analysis using gridded data provided greater information on influential characteristics. In this study, the very poorly drained soils had the greatest positive response to controlled drainage, while the elevations at which the response was greatest were those more than 60 cm above the water control structure, challenging a common assumption that controlled drainage will not impact yield in areas more than 60 cm above the water control structure. The grid-based linear mixed model analysis could be expanded to include different variables such as soil moisture or variable fertilizer application rate. It could also be used on other fields to determine spatially and temporally varying yield impacts of controlled drainage.

2.8 References

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CHAPTER 3. ONLINE LEARNING MODULE FOR CONTROLLED DRAINAGE

Subsurface tile drainage is commonly installed to increase productivity on agricultural land in the Midwest. For many years the focus has been to remove the water from agricultural fields as fast as possible, but with an increase in water quality and climate change issues, this focus has shifted to designing systems that can store water in the landscape. Controlled drainage is one practice which holds water in the landscape. Designing drainage systems that balance the economic benefit for the producer and water quality benefits for private and public use is a challenging task for the next generation of drainage engineers.

Therefore, there is a need for promoting and teaching research-based drainage innovations such as controlled drainage. Two issues educators face are the lack of availability to field sites installing subsurface tile drainage, and the nature of subsurface tile drainage being completely underground. This creates a barrier for lecturing professors as well as extension educators who offer field days. Field trips to research and demonstration site, which are standard education methods for other innovative agricultural technologies, do not allow participants to see the practice at work.

Educational technologies can help diminish the barrier of teaching about controlled drainage. To better explain certain practices that can be complex to teach through traditional teaching methods, educators can create animations and videos. Student access to technology and the internet has grown exponentially creating opportunities to integrate online drainage education into the classroom. In 2015, 28% of all college students had taken at least one course online (Allen and Seaman, 2016). One way to implement additional drainage education is to create online learning modules that contain real-world data and virtual field trips (VFT). A virtual field trip gives students full autonomy by allowing them to make their own observations without a lecturer on the site explaining what they should be observing (Stainfield et al., 2000). This is beneficial because it is not possible to take students on a field trip to see the installation of subsurface tile drainage each year, and virtual field trips can introduce students to research sites away from campus.
A controlled drainage field site located in eastern Indiana at the Davis Purdue Agricultural Center provides an opportunity to educate students. The thirteen-years of research on crop yield and water quality at this site is only impactful if the research reaches those who make decisions about drainage, now and in the future.

3.1 Objectives

The objectives of this study were to (1) create an online learning module to teach students about controlled drainage and (2) evaluate knowledge gained and application of concepts to real-world scenarios and students’ experience.

The following research questions guided this study:

1. Does student participation in an online learning module increase knowledge gained about controlled drainage?

2. What are students’ perceptions of using an online learning module with real research site data and virtual field trips for learning about controlled drainage?

3.2 Literature Review

3.2.1 Cognitive Theory Used in the Creation of the Online Learning Module

Cognitive Load Theory (Paas et al., 2003; Sweller et al., 1998; Van Merriënboer and Sweller, 2005) suggests that any learning experience has three components that include intrinsic load, extraneous load, and germane load. Intrinsic load is the cognitive load due to complexity of the knowledge that is being acquired, without reference to how that knowledge is acquired (Van Merrienboer and Sweller, 2005) and determined by element inactivity (Sweller, 2010). This can relate to the difficulty of the subject matter as well as the prior knowledge a learner has. Extraneous cognitive load is any material that does not help the learner achieve the desired outcomes and is under the control of instructors (Van Merrienboer and Sweller, 2005). Germane cognitive load is an “effective” cognitive load that refers to the working memory resources devoted to intrinsic load minus the resources devoted to extraneous load (Mayer et al., 2014). All
categories of cognitive load relate to the concern of acquiring, storing, and using the information.

The Cognitive Theory of Multimedia Learning (Mayer et al., 2014) pulls from many cognitive theories especially the Cognitive Load Theory mentioned above. Multimedia learning, also known as multimedia principle, is learning through words and pictures, with the principle idea that individuals learn more deeply through both rather than just words alone. Words can be printed or spoken, and pictures can be either static or dynamic graphics. The theory is based on three assumptions the dual-channel assumption, the limited capacity assumption, and the active processing assumption (Mayer et al., 2014). The dual-channel assumption states that humans process visual material and audio material in two separate channels. Using both channels allows for working memory to be maximized resulting in meaningful long-term memory. The limited capacity assumption resembles cognitive load, because humans are limited to the amount of information they can process at one time in each channel. This assumption forces the learner to make decisions about the pieces of information to pay attention to. The active processing assumption assumes humans actively engage in cognitive processing to organize selected information into a mental representation (mental map) of their experiences.

Figure 11 shows the model of Cognitive Theory of Multimedia Learning, which represents the human information processing system. The top row represents the verbal channel and the bottom represents the visual channel. The arrows represent the step by step cognitive processes of selecting, organizing, and integrating the information. The arrow from “Words” to “Ears” represents spoken text being registered in the auditory sensory memory, and the arrow “Words” to “Eyes” corresponds to spoken text being registered as visual sensory memory (Mayer et al., 2014). The main concepts of multimedia learning take place in working memory which temporally holds and manipulates knowledge in active consciousness. The back and forth arrows from “Sounds” to “Images” represents the learner mentally converting a word such as “dog” into a mental picture of dog and vice versa for images to sounds.
Multimedia environments can lead to meaningful learning if the learner engages in five cognitive processes (Mayer et al., 2014). The first two are selecting words and images, the next two are organizing the words and images into a mental model, and the last is integrating the words and images with each other and relevant prior knowledge (long-term memory). These do not need to occur in this order for a learner to learn. It is important for students to build the connections between the relevant words and pictures to successfully learn through the multimedia environment. There are three proposed demands on cognitive capacity for the multimedia learning theory. Extraneous processing is analogous to extraneous cognitive load and refers to cognitive processing that has nothing to do with the lesson and is caused by poor instructional design. Essential processing is mentally representing the presented material in working memory and is caused by the complexity of the material. Generative processing refers to cognitive processing to make sense of material and is caused by a learner’s motivation. Thus, online learning should be designed to reduce extraneous processing, manage the complex material, and encourage generative processing.

3.2.2 Best Practices for Online Learning Module Development

A published study on best practices for adult online learning found the three common themes for a successful course are course design, instructional effectiveness, and connectivity (Grant and Thornton, 2007). Many published papers have referenced detailed organization and planning as the first critical step of online teaching (Dykman and Davis, 2008; Coppola et al., 2002; Karuppan and Karuppan, 1999). Dykman and Davis (2008) further explained that preplanning includes developing specific objectives.
overall and for each unit, clearly listing assignments, and describing the deliverables. Detailed planning and setting guidelines of what is expected from the students at the beginning of the online course will decrease student misunderstandings (Almala, 2007; Li and Irby, 2008).

Designing lower-level and higher-level cognitive activities is another important aspect in online learning (Dunlap et al., 2007). Bloom’s revised taxonomy (Anderson et al., 2001) can be one tool to help educators design measurable lower and higher cognitive activities by using the cognitive process and knowledge dimension. The knowledge dimension ranges from factual knowledge to metacognitive knowledge.

Bloom’s Taxonomy of cognitive process dimension is a continuum of lower-level cognitive skills represented by the bottom layers such as remember and understand and higher-level cognitive skills such as analyze, evaluate, and create (Figure 12).

![Bloom's Taxonomy](https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/)

Learning should be an active process and online learning modules can promote active learning (Anderson, 2008). There is not one universally accepted definition of active learning, but there are generally accepted definitions. Prince (2004) defines active learning is any instructional method that engages students in the learning process. Online
learning modules can promote active learning by including tests, quizzes, case studies, video clips, readings from hyperlinks, and problem-solving assignments with real-world problems (Phillips, 2005). Some of the characteristics of active learning are that students are engaged in activities such as reading and writing, students are involved in higher-order thinking such as analysis and synthesis, and students are developing skills (Bonwell and Eison 1991; Cook and Babon, 2017).

A literature review on the success factors of online learning videos by Diwanji et al. (2014) found the top categories for success to be content/style, support material, production phase, distribution medium, social media, gamification concepts, mobile technology, and internalization. These categories are inter-connected and can have a positive impact on video development. Successful videos also have in-depth preproduction phases for video development because this impacts student video engagement (Guo et al., 2014). Brame (2015) believed cognitive load is the primary consideration when creating a video due to the limited working memory of the learner, and the fact that learners are selective about the information they pay attention to. The other two items to consider are non-cognitive elements that impact engagement (e.g. short videos and an enthusiastic narrator) and features that promote active learning (e.g. integrate questions in the video).

Guo et al. (2014) used data from 6.9 million video-watching sessions from four courses on the edX MOOC platform to analyze how video production affects student engagement. They found video length to be the most important factor for student engagement and recommend videos last less than six minutes. Other key recommendations were having movement in videos, an enthusiastic narrator, and videos that incorporate the instructor (e.g. a talking head within the video).

Virtual field trips (VFTs) are a powerful tool to break barriers that are common with traditional field trips (Garner and Gallo, 2005). There are many hurdles with traditional field trips that VFTs can overcome such as large student numbers, costs, liabilities, weather, and variability in experiments (Garner and Gallo, 2005). Some of the best practices for VFTs are planning, learner-centered experience and active student learning, differentiated instruction, multiple opportunities for learner success, and cooperative learning (Klemm and Tuthill, 2003). Just like traditional field trips, virtual
field trips require planning and preparation to be successful. Virtual field trips should be structured, and instructors should provide students with background knowledge before taking the VFT (Lacina, 2004).

3.2.3 Assessment and Effectiveness of Online Learning Tools and Video

Using online tools and technology to increase student knowledge has expanded over the past years. Cook and Babon (2017) evaluated the use of weekly online quizzes based on preparatory materials to enhance learning outcomes, and they found 94% of students completed the quizzes with an average score of 83%. Four animal science courses implemented online interactive study resources through Softchalk, and 84% of students indicated on a survey that the activities positively impacted their grade (Pulec et al., 2016). A biology course implemented self-assessment modules to help students make connections between topics in biology for a deeper understanding, and students ranked the modules a 4.36 on a survey for helping assess understanding (Peat & Franklin, 2002). Maige and Bauer (2013) used flash games to help students prepare for their exams, and survey results supported that the flash games positively impacted the students’ grades. A plant breeding unit was developed for an online interactive tool called “iFARM” for two undergraduate agronomy courses (Torres-Avila et al., 2013). The unit was evaluated by using a pre-/post-test with different questions to account for general knowledge, and results showed slightly lower post-test scores, but the module was a beneficial tool for student learning.

The assessment of virtual field trips and videos for teaching students are commonly evaluated by a pre-/post-test and surveys. The effectiveness of an e-learning environment with interactive videos, non-interactive videos, no instructional videos, and a traditional classroom were evaluated by using a pre-/post-test design and questionnaire (Zhang et al., 2005). Results showed the post-test gain from the group with interactive video had significantly higher scores and higher learner satisfaction. Sixty-seven undergraduate students in a physical science course were randomly assigned to a physical field trip or a virtual field trip treatment, and they found little differences in achievement and attitude scores between treatments (Garner & Gallo, 2005). These findings suggest that both treatments equally prepared students for their exam. Sweet (2014) used a pre-
/post-test and Likert survey to describe the effectiveness of a traditional and virtual dairy field trip, and she found both field trips were an effective method for teaching students about specific educational standards.

Virtual field trips can also be used before visiting an actual field site to familiarize teachers and students with the site to better prepare them for the limited field time. Arrowsmith et al. (2005) developed a virtual field trip for undergraduate students to prepare them for fieldwork and found students could learn about the area and maximize their experience when at the field. A biology course for teachers (K-6) used a VFT before an actual field trip and the students thought it was a useful tool for understanding different phenomena (Shonfeld et al., 2003). Granshaw and Duggan-Haas (2012) used three different models for virtual field environments (more complex and interactive than a VFT) to familiarize geoscience teachers with the field site and have them practice investigative fieldwork. These studies found that it was very beneficial to supplement VFTs before going to a field site to better prepare students and educators.

3.3 Methods

3.3.1 Student Participants

This study took place in Environmental Hydrology (AGRY 337) at Purdue University, West Lafayette in the spring of 2018. Sixty-three students were enrolled in the course and the module was mandatory for all students. The Purdue catalog entry states the course “is designed to provide undergraduate students with both the basics of how water moves through the environment and current theories as to how hydrologic response is modified by environmental change at a variety of temporal and spatial scales”.

3.3.2 IRB Approval

The University’s Human Research Protection Program Institutional Review Board approved this study on March 1, 2018 under protocol number 1802020290 (Appendix B.3). The Institutional Review Board determined an exemption under category 1 and 2.
3.3.3 Module Development

The instructional design of this online learning module used the principles of the Cognitive Theory of Multimedia Learning explained in the literature review. The module was designed to be concise with verbal and visual elements in the module, so students could easily grasp the most important contents. It consisted of three sections and had two specific goals: (1) to introduce students to basic concepts about controlled drainage, (2) to allow students an opportunity to apply controlled drainage concepts to real-world scenarios. All sections of the online learning module included an introduction with learning objectives, a video, a learning assignment (except for section two), a non-graded self-check quiz, and a summary. Ten different learning objectives were developed for the module using measurable verbs following Bloom’s Taxonomy, and each relate to a lower or higher cognitive skill (Table 8).

Table 8 The online learning module learning objectives and cognitive skill level.

<table>
<thead>
<tr>
<th>Learning Objectives</th>
<th>Bloom’s Taxonomy (cognitive skill level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Explain what controlled drainage is</td>
<td>Understand (lower)</td>
</tr>
<tr>
<td>2. Identify where controlled drainage is appropriate</td>
<td>Analyze (higher)</td>
</tr>
<tr>
<td>3. Describe why controlled drainage is useful</td>
<td>Understand (lower)</td>
</tr>
<tr>
<td>4. Demonstrate how to manage the outlet elevation within a water control structure</td>
<td>Apply (lower)</td>
</tr>
<tr>
<td>5. Explain how controlled drainage works at an actual site location</td>
<td>Understand (lower)</td>
</tr>
<tr>
<td>6. Recognize how controlled drainage and weather impacts yield</td>
<td>Understand (lower)</td>
</tr>
<tr>
<td>7. Recognize the importance of long term monitoring</td>
<td>Understand (lower)</td>
</tr>
<tr>
<td>8. Recall one way to complete continuous monitoring</td>
<td>Remember (lower)</td>
</tr>
<tr>
<td>9. Demonstrate how controlled drainage impacts loads and concentrations</td>
<td>Create (higher)</td>
</tr>
<tr>
<td>10. Analyze real-world site data</td>
<td>Analyze (higher)</td>
</tr>
</tbody>
</table>
The entire online module was created using Blackboard Learn, a virtual learning environment available to all students. The three videos presented the learning material to the students and were designed with the intention of creating a virtual field trip experience about the controlled drainage field at the Davis Purdue Agricultural Center. Scripts were created for each video and edited, which resulted in a clear and concise narration. Narration was recorded by a professional narrator. Video footage was filmed throughout 2016 and 2017 during research trips to the DPAC. Animations throughout the videos were created using PowerPoint 2016 and Camtasia 9, and the final videos were created in Camtasia 9. Three shorter videos rather than one long video were created to promote student engagement.

3.3.3.1 Section 1: Controlled Drainage: Why, What, Where, & How

Section 1 of the online learning module taught students the basic concepts of controlled drainage.

The learning objectives for section 1:
After successful completion of section 1 students would be able to…

1. Explain what controlled drainage is
2. Identify where controlled drainage is appropriate
3. Describe why controlled drainage is useful
4. Demonstrate how to manage the outlet elevation within a water control structure
10. Analyze real-world site data

The learning objectives were taught through the material presented in the video and by completing the learning assignment. The video provided an overview of controlled drainage, including why controlled drainage is important, what controlled drainage is, where controlled drainage should be installed (suitability), and how to manage the outlet elevation in a water control structure. The video demonstrated what takes place underground in a controlled drainage field when the outlet elevation in the water control structure is raised or lowered (Figure 13). The site suitability described in the video (Figure 14) was based on the Conservation Practice Standard Drainage Water Management Code 554 (NRCS, 2016).
The Learning Assignment 1 gave students the task of being a Conservation Advisor. Their job was to analyze the suitability of two farm fields to decide which field is the best for controlled drainage. Students used Web Soil Survey to obtain a soil map and analyzed field elevation profiles of two real-world farm fields located near Tipton, Indiana. After deciding between the two fields, the students were asked to fill out a management table to inform the producer when he should raise/lower the outlet elevation in the water control structure.
3.3.3.2 Section 2: Controlled Drainage at the Davis Purdue Agricultural Center

Section 2 of the online learning module taught students about the research site at the DPAC and yield benefits from controlled drainage. The learning objectives for section 2:

After successful completion of section 2 the students will be able to...

5. Explain how controlled drainage works at an actual site location
6. Recognize how controlled drainage and weather impacts yield
7. Recognize the importance of long term monitoring

The learning objectives were taught by the video, which introduced students to the research site, tile drainage installation, and the yield benefits at the Davis Purdue Agricultural Center. Google Earth Pro was used to enhance the feeling of traveling to the field by showing the field location. Footage of the field and tile drain installation was filmed using an unmanned aircraft system to enhance an authentic experience for the viewer. The videos from the unmanned aircraft system showed tile drain installation and an overhead view of the field. The videos also introduced how yield was impacted by controlled drainage for nine years of corn data (Figure 15) and four years of soybean data. The impact of yield was further examined by looking at precipitation during the growing season.

Figure 15 Nine-years of yield data at the controlled drainage field locate at the Davis Purdue Agricultural Center.
3.3.3.3 Section 3: Water Quality Monitoring and Impacts of Controlled Drainage

Section 3 taught the students how researchers monitor water quality at the Davis Purdue Agricultural Center and the water quality results.

The learning objectives for section 3:

After successful completion of section 3 the students will be able to…

5. Explain how controlled drainage works at an actual site location
7. Recognize the importance of long term monitoring
8. Recall one way to complete continuous monitoring
9. Demonstrate how controlled drainage impacts loads and concentrations
10. Analyze real-world site data

The learning objectives in this section were taught through the video and the learning assignment. The video taught students about monitoring equipment, water table, tile flow, soil moisture, water quality sampling, concentration data, and load data. This was the longest video, lasting 7 minutes and 46 seconds. Actual measured data from the research site was used to demonstrate how the data varies by treatment (controlled drainage vs free drainage). For example, the video showed how the water table behaves in the free and controlled drainage quadrants (Figure 16), how water samples were taken at the field with an ISCO automated water sampler, and how those samples were processed at a Purdue University laboratory.

![Water Table Data Comparison](image)

Figure 16 Water table data comparing controlled and free drainage.
The Learning Assignment 2 used in section 3, focused on water quality and had two parts: (1) graphing monthly tile flow and calculate nitrate concentrations and loads, (2) comparing controlled drainage and free drainage tile flow, downloaded from the online data archive for the controlled drainage research site (Abendroth et al., 2017). The students were asked to calculate monthly and annual nitrate concentrations, and to analyze tile flow between the controlled and free draining quadrants. After comparing concentration values and tile flow they were then asked to calculate monthly nitrate-N loads.

3.3.4 Evaluation Instruments and Data Analysis for Research Question 1

Research Question 1: Does student participation in an online learning module increase knowledge gained about controlled drainage?

The instruments used to evaluate this question were a content knowledge pre-/post-test and learning assignment scores based on data with no identifiers. The number of students who participated in each evaluation instrument is listed in Table 9. Fifty-three students completed the post-test, however, two of those students did not complete the pre-test. However, one student scored a zero on the pre-test, and because students were able to submit the pre-test without answering any questions it was deemed this student did not try on the pre-test, and the score was removed from the analysis. Only the remaining fifty student scores were used for the match paired analysis in SPSS. There were 63 students enrolled in the course.

<table>
<thead>
<tr>
<th>Evaluation Instrument</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>61</td>
</tr>
<tr>
<td>Post-test</td>
<td>53</td>
</tr>
<tr>
<td>Completed both pre-/post-test</td>
<td>51 (50 used in the analysis)</td>
</tr>
<tr>
<td>Learning Assignment 1</td>
<td>60</td>
</tr>
<tr>
<td>Learning Assignment 2</td>
<td>59</td>
</tr>
</tbody>
</table>
3.3.4.1 Content Knowledge Pre-Test and Post-Test Instrument

The pre-test consisted of twelve multiple-choice content knowledge questions (Appendix B.1). All questions on the pre-/post-test had a correct answer and each question related to a learning objective. These questions assessed the student participants’ knowledge regarding the basic concepts of controlled drainage before completing the online learning module and after completing the module. The tests were automatically graded in Blackboard Learn.

The pre-/post-tests scores were paired for each student and analyzed in IBM SPSS Statistics 22 to assess the knowledge gained. Descriptive statistics were analyzed to determine the normality of the data. The differences between the pre-/post-test scores were normally distributed based on a Shapiro-Wilk test which indicated no significance. A matched paired t-test was used to determine if there was a statistical difference between pre-test scores and post-test scores.

An item analysis for each individual question on the pre-/post-test was extracted from Blackboard Learn and contained information on the percent of students who answered each question correctly. It was not possible to obtain an individual question analysis on only the students who completed the pre-/post-test. Although the number of students differed, all itemized question data was analyzed.

The pre-/post-test multiple choice questions focused on learning objectives 1-4 and 6-9. To accurately evaluate the knowledge gained from the online learning module the post-question success was linked back to the learning objectives.

3.3.4.2 Learning Assignment Evaluations

The learning assignments were graded by the professor using a detailed rubric for consistency. Learning Assignment 1 was out of five points and did not require any calculations, while Learning Assignment 2 was out of seven points and required students to calculate monthly tile flow and nitrate loads.

Rubric statistics reports were generated from Blackboard Learn and included data from all the students who submitted the learning assignments. These reports indicated the average score on each individual question in the learning assignments, as there was no option to only select the student scores who submitted both the pre-test and post-test.
Sixty student scores were available for Learning Assignment 1 and 59 for Learning Assignment 2. In addition, the assignments were viewed for patterns on what students succeeded and struggled with because this is useful for assignment improvement. These results were linked back to the learning objectives.

3.3.4.3 Bloom’s Taxonomy Lower and Higher Level Cognitive Skill Evaluation

To further analyze the content knowledge gained from students’ participation in the module lower-level and higher-level cognitive skills were evaluated. There were 3 learning objectives that were higher-level skills and 7 that were lower-level skills.

The module was designed to teach students the basics of controlled drainage which started with lower-level skills and then worked towards higher-level cognitive skills in section 3. Students worked through higher-level cognitive skills in both learning assignments but mostly in Learning Assignment 2. In Learning Assignment 1 students were asked to identify the best field for controlled drainage. To select the correct answer students had to analyze real-world soils data they downloaded as well as an elevation profile. This example shows how identifying the best field for controlled drainage is a higher-level skill because students needed to master the knowledge and understanding of controlled drainage to be able to apply their knowledge to analyze the two fields.

Learning Assignment 2 had students demonstrate how controlled drainage impacts loads and concentrations by analyzing real-world site data and explain how controlled drainage works at an actual site location. Students were asked to download tile flow data and nitrate-N concentration data for the Davis Purdue Agricultural Center. With the tile flow data, they had to create a graph and analyze which treatment had higher tile flow during certain months. To determine the differences for nitrate-N loads between treatments, students had to synthesize the nitrate concentration data to obtain monthly average concentrations, which they then multiplied by the monthly tile flow to calculate monthly nitrate-N loads and the percent reduction. This was one of the most challenging tasks in the entire learning module.
3.3.5 Evaluation Instrument and Data Analysis for Research Question 2

Research Question 2: What are students’ perceptions of using an online learning module with real research site data and virtual field trips for learning about controlled drainage?

The instrument used to evaluate research question 2 was face-to-face interviews, conducted to glean more descriptive details about the online learning module than a traditional evaluation survey. Interviewing students to obtain more in-depth information about their perceptions related to online education is a common practice (Song et al., 2004; Petrides 2002). The information from the interviews was used to evaluate the online learning module and help determine improvements for future modules.

Students were invited to participate in a voluntary interview to obtain their perceptions and feedback regarding the online learning module. Students were informed that the interview is voluntary, confidential, and would not impact their grade in the class. Those who were interested in participating in the interview were given a consent form to sign. Sixteen students were interviewed, and the interviews ranged from 8-20 minutes, conducted in Purdue buildings after the students had completed the online learning module. Most interview questions were closed questions and had a narrow focus. Some of the questions asked about their experience learning with the online learning module, their likes/dislikes about all aspects of the module, and their view on which animation helped them learn the most about controlled drainage. Interview questions are in Appendix B.2. The number of interviews conducted was not predetermined, instead the focus was to achieve saturation, defined as no longer gaining any new or relevant data during the data collection process. Saturation is usually considered the most important factor when selecting a sample size for qualitative interviews (Mason, 2010; Dworkin, 2012). Interviews were recorded with permission from the students, transcribed, and coded using NVivo 12 Pro. A quantitative approach was used for analyzing the interview questions because most questions related to a yes/no answer and then focused on the why/how.
3.4 Results and Discussion

3.4.1 Results for Research Question 1

3.4.1.1 Students’ knowledge gained from the pre-test and post-test

The 50 students who completed both the pre-test and post-test scores were analyzed. The class average on the pre-test before taking the online learning module was 53%, ranging from a low of 8% to a high of 92%. The class average score on the post-test was 81%, ranging from 50% to a high of 100% (Figure 17). One student obtained a lower score on the post-test compared to the pre-test. Students spent an average of six minutes on the pre-test and seven minutes completing the post-test. Student participants had a mean score increase of 3.32 (SD=2.22) on the post-test (Figure 18), and a paired t-test showed that this was significant.

![Figure 17 Distributions of pre-test and post-test scores.](image)
3.4.1.2 Individual question analysis for the pre-/post-test

Table 10 identifies the test question, the learning objective, the score on the pre-test, the score on the post-test, and the percent difference between the tests. The post-test questions that 90% or more of students answered correctly related to learning objectives 3, 4, 6, and 7. These learning objectives (3,4,6,7) were related to describing why controlled drainage is useful, understanding how to manage the outlet elevation within a water control structure, recognizing how CD impacts yield, and recognizing the importance of long-term monitoring, respectively. The post-test questions that 80% or more students answered correctly related to learning objectives 1, 2, 4, 6, and 9. The two lowest scoring questions (11 & 12) on the post-test are both content knowledge for learning objective 9 (demonstrate how controlled drainage impacts loads and concentrations). Three questions corresponded to learning objective 9, and >60% of students correctly answered two of those questions. The test score results and the learning assignment 2 results (discussed more below) showed that the module should be revised to clearly address the differences between nitrate loads and nitrate concentrations. The post-test scores indicated that students gained knowledge for all the learning objectives with the highest scores for learning objectives 3, 4, 6, and 7.
Table 10 Individual question analysis for pre-/post-test.

<table>
<thead>
<tr>
<th>Multiple Choice Question</th>
<th>Learning Objective</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent of students correctly answering the question</td>
<td>N=61</td>
<td>N=53</td>
<td>Percent Difference (Post-test - Pre-test)</td>
</tr>
<tr>
<td>1. Controlled drainage is….</td>
<td>1</td>
<td>41</td>
<td>85</td>
<td>44</td>
</tr>
<tr>
<td>2. Which of these is not a site requirement for controlled drainage?</td>
<td>2</td>
<td>57</td>
<td>87</td>
<td>29</td>
</tr>
<tr>
<td>3. Controlled drainage is one tool for reducing the loss of which nutrient from entering streams?</td>
<td>3</td>
<td>87</td>
<td>100</td>
<td>13</td>
</tr>
<tr>
<td>4. Before planting the outlet elevation in the water control structure is (choose one): Raised or Lowered</td>
<td>4</td>
<td>64</td>
<td>89</td>
<td>25</td>
</tr>
<tr>
<td>5. During the growing season (May-September) the outlet elevation in the water control structure is (choose one): Raised or Lowered</td>
<td>4</td>
<td>54</td>
<td>91</td>
<td>37</td>
</tr>
<tr>
<td>6. After harvest the outlet elevation in the water control structure is (choose one): Raised or Lowered</td>
<td>4</td>
<td>43</td>
<td>76</td>
<td>33</td>
</tr>
<tr>
<td>7. How would you expect controlled drainage average soybean yield to compare to free drainage average soybean yield?</td>
<td>6</td>
<td>16</td>
<td>83</td>
<td>67</td>
</tr>
<tr>
<td>8. How would you expect controlled drainage to influence corn yield compared to free drainage during dry years?</td>
<td>6</td>
<td>77</td>
<td>98</td>
<td>21</td>
</tr>
</tbody>
</table>
9. A 5-year study of free and controlled drainage field found the following differences in corn yield:
   - Year 1: 4% (free drainage higher)
   - Year 2: 7% (controlled drainage higher)
   - Year 3: 3% (controlled drainage higher)
   - Year 4: 10% (controlled drainage higher)
   - Year 5: 0% (yields are equal)

   What do these results tell you about monitoring corn yield?

10. Controlled drainage can typically reduce drainage volumes and nitrate loads by how much?

11. What is the most common way controlled drainage decreases nitrate loads?

12. How are nitrate and phosphorus concentrations impacted by controlled drainage?

<table>
<thead>
<tr>
<th></th>
<th>7</th>
<th>85</th>
<th>96</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>9</td>
<td>77</td>
<td>89</td>
<td>12</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>20</td>
<td>62</td>
<td>43</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
<td>3</td>
<td>19</td>
<td>16</td>
</tr>
</tbody>
</table>

The largest differences from pre-test to post-test were for questions 1, 7, and 11. These questions were related to information about what controlled is, how it impacts yield, and how it decreases nitrate loads. Students excelled on question 8 and 7, with question 8 being the only question that 100% of students answered correctly. Student performed well on the post-test on questions related to outlet elevation management with increases ranging from 25%-37%. This is not surprising as many students mentioned the animation of raising and lowering the outlet elevation to be their favorite during the interviews.

3.4.1.3 Learning Assignment 1

The average score on Learning Assignment 1 was 4.5 points (out of 5) or a 90%. The average score per question is listed in Table 11. The highest scoring questions were 2, 4, and 5, which go with learning objectives 2, 4, and 10. Indicating most students were able to correctly identify where controlled drainage is applicable, demonstrate how to
manage the outlet elevation within a water control structure, and analyze real-world site data. Students’ performed well at completing a table of soil drainage classes for each field and creating a management table of when to raise and lower the outlet elevation. This was not surprising, many students during interviews mentioned they liked using the Web Soil Survey and have used the website before in previous classes. Additionally, almost every student during the interview mentioned their favorite animation was the raising and lowering of the outlet elevation in the water control structure throughout the season (discussed more below). This could be why the scores were higher for these two questions.
Table 11 Learning Assignment 1 average scores for individual questions.

<table>
<thead>
<tr>
<th>Question</th>
<th>Learning Objectives</th>
<th>Average Score in Percent N=60</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assuming the control structure is at the lowest elevation of the field, how many feet away from the water control structure will be controlled in each field if the structure can manage up to a 2 ft change in elevation?</td>
<td>2,10</td>
<td>82%</td>
</tr>
<tr>
<td>2. Which field is more suitable for controlled drainage?</td>
<td>2,10</td>
<td>92%</td>
</tr>
<tr>
<td>3. Why is installing controlled drainage useful for the farmer?</td>
<td>3</td>
<td>77%</td>
</tr>
<tr>
<td>4. Complete a table with the soil drainage classes in each field.</td>
<td>2,10</td>
<td>98%</td>
</tr>
<tr>
<td>5. Complete a management table informing the producer on when he/she should raise and lower the outlet elevation in the water control structure.</td>
<td>4</td>
<td>94%</td>
</tr>
</tbody>
</table>

The questions students missed the most were question 1 and 3. Question 1 was missed the most because students assumed a 2 ft change in elevation across the entire field and not from the lowest elevation at the water control structure. The lowest average score was on question 3. Common wrong answers for this question were related to farmers saving money by reducing the loss of nitrate and mistaking drainage with controlled drainage. An example answer, “controlled drainage can make farmers grow
crops where it is not suitable for growing crops”, but this is a benefit of tile drainage not CD. Further improvements to the educational material should make sure students understand the different terminology (controlled vs free).

3.4.1.4 Learning Assignment 2

The average score on Learning Assignment 2 was 5.5 points (out of 7) or a 79%. Students struggled the most on this assignment out of any other activity in the module, but this was a higher cognitive learning assignment. The average score per question is listed in Table 12. This assignment focused on learning objectives 5, 9, and 10. The highest scoring questions (7 & 8) with greater than >90% were for learning objectives 5 and 10. The lowest scoring questions (5 & 10) focused on calculating nitrate loads and indicating when drain flow stops flowing. For question 5, some students reported the sum of the concentration values instead of the average concentrations and thus calculated the percent load reduction wrong. Commonly missed answers for question 10 include indicating that the drains did not flow at all, the drains did not stop flowing for months at a time, or that the drains did not stop flowing until spring.
Table 12 Learning assignment 2 average scores for individual questions.

<table>
<thead>
<tr>
<th>Question</th>
<th>Learning Objectives</th>
<th>Percent Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What months have the highest tile flow? Why do you think this is? Think about the major differences in a field during the summer and winter.</td>
<td>5,10</td>
<td>80%</td>
</tr>
<tr>
<td>2. Calculate average concentration for the entire 2013 year for the free (southwest) and the controlled (northwest) and state the difference between free and controlled.</td>
<td>9,10</td>
<td>70%</td>
</tr>
<tr>
<td>3. What months had the highest nitrate loads?</td>
<td>9,10</td>
<td>88%</td>
</tr>
<tr>
<td>4. What quadrant has the highest nitrate loads in most months? Why do you think this is?</td>
<td>5,9,10</td>
<td>84%</td>
</tr>
<tr>
<td>5. What is the annual load for the free (southwest) and controlled (northwest) quadrant? What is the percent load reduction?</td>
<td>5,9,10</td>
<td>64%</td>
</tr>
<tr>
<td>6. Create a nitrate load graph</td>
<td>8,10</td>
<td>86%</td>
</tr>
<tr>
<td>7. Create a monthly tile flow graph</td>
<td>8,10</td>
<td>94%</td>
</tr>
<tr>
<td>8. Is tile flow higher in the NW or SW?</td>
<td>5,10</td>
<td>96%</td>
</tr>
<tr>
<td>9. Look at the peak around November 12th, how much higher is the peak in the SW compared to the peak in the NW? You can move your computer mouse on the graph to see the values.</td>
<td>10</td>
<td>74%</td>
</tr>
<tr>
<td>10. Place your computer mouse on the tile flow around October 5th. How long does it take the NW &amp; SW tile to stop flowing, why?</td>
<td>10</td>
<td>66%</td>
</tr>
</tbody>
</table>

Question 2 asked students to calculate the average concentration for the entire year for the free and controlled drainage and state the difference between the two. For this question the answer for “state the difference” was meant to be the actual number difference (subtracted) between the two drainage treatments. However, many students
interpreted this as stating the definition differences between controlled and free drainage. Students also commonly reported the nitrate concentration annual total and not the average.

Question 4 was misinterpreted by a few students as “quadrant” being the time of the year (e.g. April-June) instead of one of the field quadrants. Careful consideration with word choice should be taken moving forward.

3.4.1.5 Evaluation of Bloom’s Taxonomy of Lower and Higher Level Cognitive Skills

Students were able to successfully reach the lower-level cognitive skills remember and understand from Bloom’s Taxonomy. The post-test scores were a high of 100% for learning objective 3 to a low of 76% of students correctly answering learning objective 4. Most students were able to explain what controlled drainage is, recognize how controlled drainage and weather impacts yield, and recognize the importance of long term monitoring. The lower cognitive process understand had the largest improvement from pre-test to post-test. Students were able to recognize and explain the concepts of controlled drainage and this showed from their test scores.

The module materials were able to push students from lower-level cognitive skills to the higher-level cognitive skills analyze, evaluate, and create. For the higher-level cognitive skill analyze, students scored a 98% on average on Learning Assignment 1. In Learning Assignment 2 the average score for create was a 94% and students scored an 80% on average for correctly analyzing the graph to determine which treatment had higher tile flow. The average percent score for calculating average concentrations was 70% and the average score for calculating loads and the reduction was 64%. This was one of the most challenging tasks in the entire learning module. The lower scores suggest not all students were successfully answering the higher-level cognitive skill questions, but they were attempting an answer. One published study noted the importance of “practice makes perfect” for higher-level cognitive skills (Momsen et al., 2010).
3.4.2 Results for Research Question 2

3.4.2.1 Student Interview Participants Demographics

Table 13 identifies categories and percentages that represent the students who participated in the interview about the online learning module. These questions were used to gauge how their perceptions of the module could differ depending on their personal background. The grade level of the students interviewed varied, and 15 students were in the College of Agriculture and one student was in the College of Science.

Table 13 Student participants demographics.

<table>
<thead>
<tr>
<th>College</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>15 (94%)</td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>1 (6%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>8 (50%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>8 (50%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Agricultural Experiences</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you live on a farm?</td>
<td>3 (19%)</td>
<td>13 (81%)</td>
</tr>
<tr>
<td>Do you have agricultural work experience?</td>
<td>11 (69%)</td>
<td>5 (31%)</td>
</tr>
<tr>
<td>Have you seen a tile drain in person?</td>
<td>10 (63%)</td>
<td>6 (38%)</td>
</tr>
<tr>
<td>Had a previous class that taught about tile drainage?</td>
<td>11 (69%)</td>
<td>5 (31%)</td>
</tr>
</tbody>
</table>

3.4.2.2 Responses to the Interview Questions

Responses to the interview questions are summarized in Table 14. The table characterized the common patterns among students based on their responses. These categories give insight into what students thought about all aspects of the module.

Students were asked to talk about their experience learning about controlled drainage with the online learning module and ten students (63%) mentioned they appreciated the videos, and thought they helped them learn about controlled drainage. Students felt the videos were clear, engaging, and the content was easy to follow no matter their background. Some mentioned the videos were their favorite part of the module.

*I thought the videos were good. I usually do not like videos, but they were informative (Interviewee #11).*
I liked the learning videos. I thought those were really useful. I liked just being able to spend time in those (Interviewee #5).

Six students (38%) talked about how they appreciated the module and thought it was very beneficial. Students felt the assignments were useful to their learning (31%). They thought the assignment instructions were clear and they appreciated the step-by-step instructions. Numerous students mentioned they enjoyed making the graphs in Learning Assignment 2 because it helped them see the differences between controlled and free drainage. One student stated,

“I learn by having to do something after learning it. Those documents were good to go through and do our own calculations with the questions. And go through those maps physically on the computer, those were probably the most helpful for me (Interviewee #9).”

Detailed pre-planning went into creating the module and the videos, and this was recognized by the students. Students felt the module was well organized and had a good flow. They appreciated learning the basics first because this helped them work through the rest of the module. The self-check quizzes and summaries at the end of each section were helpful for students to make sure they understood the material that was presented.

One of the things I just want to say about the module itself is that it was very self-explanatory, and set up very well, to make it easy to follow. I just felt like there was a lot of care in making sure it was easy to read and understand. All the directions were very explicit and that made it a lot more doable. For specifics the flow was good too: you got your introduction, your video, your assignment, content you had to answer, and the self-check quiz. It was a good flow, a good set up, and carried out well (Interviewee #4).

The self-check quizzes were helpful to make sure I had learned what I was expected to learn. Having the (learning) objectives and the summaries were very thorough. And I think useful to have in my mind, what we were going to talk about, and then the summary highlighted what I should have gotten out of it to make sure I had picked up on all of the points (Interviewee #8).
Technology issues and instructional issues were the main drivers for what did not work for the students in the learning module. The self-check quizzes were supposed to show all questions at one time and allow unlimited submissions, but feedback from students indicated some quizzes showed one question at a time and they could not retake quiz three. This technology-related issue can easily be fixed for future use.

The instructional issues students mentioned were problems working with Microsoft Excel in Learning Assignment 2 and a coordinate issue in Learning Assignment 1. Students were asked to download data from a website and create a PivotTable in a Microsoft Excel spreadsheet. Explicit instructions were provided, but students who were using different versions of Microsoft Excel mentioned having issues following the directions listed.

One student mentioned she did not understand the process behind using the data, and that the purpose of the assignment is to learn about controlled drainage not data analysis. This demonstrating potential extraneous load and for future use educators should try to find a balance to reduce this.

The learning assignment was set up to have the learning content embedded inside the module and the homework questions separate in a word document. Students felt the back and forth between the assignment content and questions was choppy. One student mentioned having issues related to Learning Assignment 2 part two when they went to the website to view field data. The students were asked to “hover” their mouse over a tile flow graph at DPAC for 2013 to find the correct answer, but she did not know what exactly she was looking for. This can be improved by providing more in-depth instructions. Even though there were small issues related to the assignments and technology the response from the student interviews showed they still enjoyed the module.

Eleven students (73%) thought the use of real-world data helped them learn about controlled drainage. Students appreciated that they were given real data, and it helped them visualize the site. The following quotes illustrate the positive response to the real-world data:

*I know sometimes in classes we could be given a perfect dataset and that’s not always representative of how it is in the real-world. It is kind of nice to know that it*
can be applied, and there is application of what we learn in class to the real world (Interviewee #12).

If you are just talking about theoretical numbers all the time it doesn’t really matter. If you actually use what really happened here and this happened here, I think it helps to settle in and make ideas more concrete (Interviewee #13).

*I think having the real-world data helped me picture the topography of the actual place (Interviewee #1).*

One student felt she would have learned the concepts of controlled drainage the same no matter if the data was real or made-up, and three students (20%) were undecided. However, one student did feel the use of the real-world data made the assignment seem like a higher quality of learning. These comments suggest that when given the opportunity educators should try to implement real-world data in the classroom.

All students felt the learning assignments helped them learn about controlled drainage. The assignments required the students to download soil information from the Web Soil Survey and create graphs of tile flow and nitrate loads. These activities were two of the top reasons that students felt the assignments helped them learn about controlled drainage. Multiple students felt the activities in the assignments helped them visualize what controlled drainage is and how it works.

Nine students (56%) stated the videos throughout the module felt like a virtual field trip, and five students (31%) did not. The features that made the videos feel like a virtual field trip were seeing subsurface tile drainage being installed and seeing how controlled drainage works underground.

*When you had the video of them putting in the drainage, it made me feel really connected to what was happening. I have seen it before, but most people have never seen them putting in tile drainage. I think it is something interesting and new to a lot of people and it actually puts them investing into what is happening (Interviewee #13).*

*When it had been previously mentioned in class (controlled drainage) it had been hard to visualize. I did not come from an agricultural background, so I didn’t really have any understanding of what a tile drain was. I think seeing it online and in lecture, there*
were a lot of good graphics that explained how it is installed, how it works, and where it is in the agriculture system. (Interviewee #7).

The top reasons students did not think the videos felt like a virtual field trip were due to not enough site history and the narrator felt like a lecture. These reasons can be easily addressed for future virtual field trip development. More content on the history of the Davis Purdue Agricultural Center will provide students with more site background and a more enthusiastic narrator could help lively up the experience. It is not necessary that students feel the videos felt like a virtual field trip, but if they do this has the potential to be more of an active learning experience than passive.

Every student felt the videos helped them learn about controlled drainage. It was surprising that thirteen students (81%) mentioned the raising and lowering of the outlet elevation in the water control structure was the animation that helped them learn the most. Some improvements to the videos that were mentioned include having a “check-in” during the videos or having shorter videos. The ideas for the “check-in” included embedding the self-check quiz into the video, having activities that break up the video, and dividing the videos into more videos would be easier for them to go back and re-watch sections. Other technical issues that were brought up was the audio in some of the older videos not having the greatest quality and some of the audio being off sync with the animation. The ideal video length mentioned was around 5 minutes.

The entire online learning module helped all the students learn about controlled drainage. Students really enjoyed having diversity throughout the module with the videos, self-check quizzes, and assignments. Students felt the module was well planned and had an excellent structure that allowed them to really learn about controlled drainage. They appreciated the material that was taught and had suggestions for how to improve the module. One student would have liked to see the module use a different platform that was not Blackboard Learn because it can be hard to navigate. There was also a mention of setting the scene for the virtual field trips. In the online learning module there was not a section explaining that the students would now “go” on a virtual field trip. One student mentioned she would have liked if we announced in the module that they would be taking a field trip. There could have been more of a field trip ambiance throughout the videos by having a host.
Honestly, I thought it was pretty well organized and helpful. I thought the videos were good and I took a lot of notes on them (Interviewee #14).

Twelve students (75%) were able to describe the differences between the assignments. Most students realized the first assignment was analyzing the site and the second assignment was more data and Excel heavy. This question was asked to obtain more details on if students could tell a difference. Assignment two used higher level cognitive skills and students did recognize this.

The second one felt more calculation based (Interviewee #15).

Learning assignment 1 was the most preferred assignment (56%). Students preferred this assignment because they really enjoyed using the Web Soil Survey and they were more familiar with the material because of other classes. The students who preferred assignment 2 (19%) liked this assignment more because they felt the information learned was more valuable. Some students did not like assignment two because they felt all of the data processing was unnecessary and they could not grasp the concept of what they were achieving until the end of the assignment.

I do think that even though I do not like the calculations as much, doing that in the second assignment is valuable because you get to see the impact between the two different types of drainage (Interviewee #4).

I don’t really understand how the process works still with using that much data. I just followed the directions. The directions were easy to use, but I don’t really understand what I did with downloading the data, besides that I followed the directions (Interviewee #8).
Table 14 Responses and patterns for interview question groups. *a* indicates N=15

<table>
<thead>
<tr>
<th>Interview Questions (N=16)</th>
<th>Responses and Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talk about your experience learning about controlled drainage through an online learning module. What worked for you? What did not work for you?</td>
<td>Worked: • Videos were enjoyable and helped them learn (10) • Overall enjoyed the module and thought it was helpful (6) • Assignments were useful (5) • Module was well organized (3) • Quizzes and summarizes were helpful (3)</td>
</tr>
<tr>
<td>Did the use of real-world data help you learn the basic concepts of controlled drainage? <em>a</em></td>
<td>Yes: 11 (73%) • Appreciation for real world application (2) • Appreciation for real non-theoretical data (8) • Helped visualize the site (3)</td>
</tr>
<tr>
<td>Did the two learning activities/assignments help you learn about controlled drainage?</td>
<td>Yes: 16 (100%) • Visualizing the data helped with data interpretation (4) • Enjoyed diversity of activities within the assignments (2) • Assignments helped re-enforce information learned (3) • Enjoyed making soil maps (2)</td>
</tr>
<tr>
<td>Did the videos feel like a virtual field trip to you? If yes, what feature(s) made them feel like a virtual field trip? If no, why did the videos not feel like a virtual field trip?</td>
<td>Yes: 9 (56%) • Viewing tile installation (4) • Seeing how CD works underground (4) • Having videos of professors/professionals out in the field (2)</td>
</tr>
<tr>
<td>Did the virtual field trip videos helped you understand the practice of controlled drainage? Can you give me an example of an animation/video that helped you learn?</td>
<td>Yes: 16 (100%) • Visualizing how CD works underground and how to manage CD throughout the seasons (13) • Viewing tile drainage installation (2)</td>
</tr>
<tr>
<td>Did the entire online learning module help you learn about controlled drainage? <em>a</em> Suggestions for improving the module?</td>
<td>Yes: 15 (100%) • Diversity of activities throughout the module (4) • Enjoyed the structure and organization of the module (2) • Thought the module taught good information (2)</td>
</tr>
</tbody>
</table>
Table 14 continued

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes: 12 (75%)</th>
<th>No: 4 (25%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Besides the content knowledge can you describe the differences between</td>
<td>12 (75%)</td>
<td>4 (25%)</td>
</tr>
<tr>
<td>the two assignments?</td>
<td>· Second Assignment was analyzing data and Excel heavy (5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>· First Assignment was evaluating site information (5)</td>
<td></td>
</tr>
<tr>
<td>Did you prefer one assignment over the other assignment? (Learning</td>
<td>Prefer LA1: 9 (56%)</td>
<td>Prefer LA2: 3 (19%)</td>
</tr>
<tr>
<td>Assignment 1 (LA1) vs Learning Assignment 2 (LA2))</td>
<td>· Enjoyed using the Web Soil Survey in assignment 1 (6)</td>
<td>· Felt the information learned in assignment 2 was more valuable (2)</td>
</tr>
<tr>
<td></td>
<td>· Lack of understanding on why assignment 2 had so much data processing (3)</td>
<td></td>
</tr>
<tr>
<td>Likes/dislikes?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 3.4.2.3 Different Perceptions by Student Demographics

Student demographics were examined for the interview questions listed above that varied in yes/no/undecided responses (except for describing the content knowledge) to see if there were different responses based on background (Table 15).

<table>
<thead>
<tr>
<th>Interview Question</th>
<th>Gender</th>
<th>College Class Level</th>
<th>From a Farm</th>
<th>AG work experience</th>
<th>Seen a tile drain in person</th>
<th>Previous class taught about tile drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M  F</td>
<td>Freshman Sophomore</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did the use of real-world data help you learn the basic</td>
<td>Yes</td>
<td>5 6</td>
<td>3 3 3 2</td>
<td>3 8 8 3</td>
<td>6 5 7 4</td>
<td></td>
</tr>
<tr>
<td>concepts of controlled drainage?</td>
<td>No</td>
<td>3 1</td>
<td>2 1</td>
<td>1 1 1 2</td>
<td>3 3 3 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
<td>4 5</td>
<td>1 2 5 1</td>
<td>3 6 6 3</td>
<td>6 3 6 3</td>
<td></td>
</tr>
<tr>
<td>Did the videos feel like a virtual field trip to you?</td>
<td>Yes</td>
<td>3 2</td>
<td>2 2 1</td>
<td>5 4 1</td>
<td>3 2 3 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>1 1</td>
<td>2</td>
<td>2 1 1</td>
<td>1 1 1 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
<td>6 3</td>
<td>1 4 4</td>
<td>3 6 5 4</td>
<td>8 1 7 2</td>
<td></td>
</tr>
<tr>
<td>Did you prefer one assignment over the other assignment?</td>
<td>First</td>
<td>6 3</td>
<td>1 4 4</td>
<td>3 6 5 4</td>
<td>8 1 7 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Second</td>
<td>1 2</td>
<td>1 1 1</td>
<td>3 3 1 2</td>
<td>2 1 2 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mutual</td>
<td>3 1</td>
<td>1 1 1 1</td>
<td>4 3 1 1</td>
<td>1 3 2 2</td>
<td></td>
</tr>
</tbody>
</table>
Most of the students who felt the real-world data helped them learn about controlled drainage had previous agricultural work experience or were from a farm. All three of the students from a farming background thought the real-world data was helpful. Two out of the three students who were undecided had no previous agricultural experience. Indicating that students who were more familiar with agricultural practices found the real-world data helpful.

Six students not from a farm and all the students from a farm thought the videos felt like a virtual field trip. From those students, 75% had agricultural work experience, saw a tile drain, and had a previous class that taught about tile drainage. When asked what feature/animation in the video helped them learn about controlled drainage, ten students not from a farm and all the students from a farm mentioned visualizing how the outlet elevation raises and lowers throughout the growing season. The two students who mentioned tile drainage installation had never seen a tile drain in-person.

The students who preferred assignment #1 were six students not from a farm and all three of the students from a farm. The students from a farming background may have related more to the assignment, because it dealt specifically with suitability of two farm fields. Three out of four students who did not have an assignment preference had never seen a tile drain in person, and half took a class where they learned about tile drainage.

Some of the common themes when asking the students to talk about their experience learning about CD were how they enjoyed the videos and how they thought the module was beneficial. Only one student out of ten who mentioned they liked the videos was from a farm. Six out of the ten students did have previous agricultural work experience. All six of the students who thought the module was beneficial were not from a farm and half of them had agricultural work experience.

3.5 Discussion

Creating learning objectives for different cognitive levels to support student learning is important (Momsen et al., 2010), because focusing only on lower level skills may not teach students how to think critically (Bransford and Stein, 1993; National Research Council, 2000). The online learning module helped to clarify that students were successful at lower-level skills for remember, understand, and apply. Students did
attempt the higher-level cognitive skills \textit{analyze}, \textit{evaluate}, and \textit{create}. The scores were lower for the higher-level cognitive skills, but it is still important for students to begin reaching passed introductory material.

With a push for more agriculture technology and innovation in the classroom using real research site data and online learning modules could help support this initiative. The real-world data was built into this module to increase student understanding of controlled drainage and to create activities that assess a wider range of cognitive processes. For example, the use of the real-world data made students analyze the data and think critically to correctly answer the assessment questions. However, using real data can be a challenge because of missing data or students not understanding data analysis. Some students struggled when analyzing the concentration data and one student did not understand the process of why the data analysis was needed. Additionally, locating a complete processed dataset was a slight barrier but breaking the data into smaller time frames could help solve this issue. This module used a publicly available website which consists of research data from sites around the Midwest. Increased exposure of research data websites could be one way to help educators implement real-data in their classrooms.

This study suggests similar online learning modules and videos could be beneficial for demonstrating complex or underground processes for educators across different disciplines. One study used a virtual field trip to teach students about Tenerife, Spain and results from a pre-post/test design indicated student learning occurred (Lang et al., 2012). Individuals who create their own videos should consider using the Cognitive Theory of Multimedia Learning, as well as writing scripts and extensively planning out the narration that will go along with the animations. Additionally, these videos can be integrated into classrooms as agricultural case studies. Classes containing students from non-farming backgrounds may find these case studies extra helpful at helping their students to visualize a part of agricultural production.
3.6 Conclusion

Research Question 1: Does student participation in an online learning module increase knowledge gained about controlled drainage?

Students showed a significant knowledge gain between pre-test and post-test. Students’ performance on the learning assignments was positive and they performed well in creating tables and graphs. The scores from the post-test and learning assignments suggests that all the learning objectives for the online learning module were met. Further breaking down the learning objectives by Bloom’s Taxonomy cognitive skill level indicated that students were able to grasp the lower-level knowledge and understanding of controlled drainage, while slightly struggling with higher-level skills of analyzing, evaluating, and creating. Therefore, the online learning module served as an effective method for teaching students about the concepts of controlled drainage.

The videos or entire module could be used in conjunction with traditional lectures to enhance the learning experience for the students, or the videos could be used alone to emphasize concepts taught in the classroom. However, the development of quality videos and online learning modules does take detailed planning and time. Careful consideration should be taken during planning to make sure students understand terminology and content when using an online learning module. The time and cost of developing quality videos and online learning modules can be offset by using them year after year.

Research Question 2: What are students’ perceptions of using an online learning module with real research site data and virtual field trips for learning about controlled drainage?

Overall, students enjoyed learning about controlled drainage through the online learning module. Students felt the module helped them learn because it was appropriately organized by first learning the basics and then learning more detailed information. Most students indicated without prompting during the interview that the videos helped them learn about CD. The videos were especially useful for helping students understand concepts who were not from a farming background.
Most students appreciated that the module used real-world data from a research site instead of theoretical data, and one reason being that it helped them visualize the field site. Students’ mentioned the real-world data helped them understand how controlled drainage could be implemented. The students who had agricultural work experience or were from a farm especially enjoyed the real-world data. The use of the real-world data allowed students exposed students to where and how research is conducted and taught higher-level cognitive skills.

Students’ perceptions and knowledge gained after completing the online learning module suggests this can be an effective tool for teaching students complex processes. Additionally, universities or extension educators who work with real research sites can use these videos to teach a broad audience about their research. This will inform the public of new research being done at the university as well as increase student awareness of research sites around their area.

The videos in the module were created based off the Multimedia Learning Theory by using both spoken narration and animations to simulate the eyes and ears separate processing channels. This theory was used to mitigate extraneous and cognitive load while providing a meaningful learning experience for the student.

3.7 References


Sweet, A. M., 2014. The effectiveness of virtual and on-site dairy farm field trips to increase student knowledge in science, social studies, and health and wellness standards. MS thesis. West Lafayette, IN: Purdue University, Department of Youth Development and Agricultural Education.


CHAPTER 4. CONCLUSIONS AND FUTURE RESEARCH

4.1 Crop Yield Impacts

This thesis found controlled drainage significantly increased the nine-year mean corn yield by 2.3%, while mean soybean yield was not significantly different. For individual years, CD significantly increased corn yield in six out of nine years from free drainage and three out of four years for soybean. Yield decreased in the CD quadrants in only one year for corn and soybean, indicating that controlled drainage could benefit farmers economically in Indiana on fields with similar site conditions as the DPAC.

An in-depth grid-based analysis using a linear mixed model helped to clarify how CD impacted yield differently in wet and dry years. The greatest benefits occurred in the dry years, with CD significantly increasing corn yield. Soybean yields were higher under CD in dry years, but the difference was not significant, possibly due to only having one dry soybean year vs. three dry corn years. This study showed that CD had no overall impact on crop yield during wet years. In normal years CD soybean and corn yields were slightly higher, but the effect was not significant.

Further classification by soil type indicated the very poorly drained soils had the greatest positive response to CD. In the dry years for corn there was a significant increase in yield in the poorly and very poorly drained soils. Overall response for corn and soybean yield was greatest in elevations over 60 cm above the water control structure. In dry years CD had a significant benefit for corn yield at both the 30-60 cm and > 60 cm elevation. Yield at the < 30 cm elevation was higher for CD, but not by a significant amount. There were no significant differences in normal or wet years at any elevation.

Published papers have found mixed results when analyzing crop yield impacts for CD. More than 26 analyses investigated the impact of CD on crop yield. While twelve of the studies showed no statistically significantly impact on crop production, two showed a decrease in yield with CD, and twelve showed an increase. This thesis demonstrated that CD increased crop yield during individual years and increased the average nine-year corn yield. Controlled drainage yield benefits can help offset the cost to the producer for installing and maintaining the practice.
4.2 **Online Learning Module**

Students’ scores from the pre-test to post-test indicated a significant knowledge gain, and the learning assignments scores were evidence that the learning objectives in the module had been met. The learning objectives classified by Bloom’s Taxonomy cognitive skill level indicated that students were able to grasp the lower-level knowledge about controlled drainage, while slightly struggling with higher-level skills. Students enjoyed the module and videos and thought they effectively taught them the concepts about controlled drainage. Thus, the online learning module served as an effective method for teaching students about controlled drainage.

This study suggests online learning modules and videos can be beneficial for demonstrating complex processes and that there is potential to expand use across different disciplines. Modules could be used with traditional lectures to enhance the learning experience for the students, or the videos could be used alone to emphasize concepts taught in the classroom. Individuals who work on research sites can use these videos to teach and promote their research. The use of real-world data helped students learn about controlled drainage and gave them a better understanding of how the process works in practice. Educators should try to implement actual data in the classroom while minimizing extraneous cognitive load.

Universities can create these videos to teach their research to the public or students. Research-based videos will increase student awareness of research sites and research practices. Additionally, these videos can be integrated into extension as an online learning tool or shown during extension presentations. However, developing quality videos and online learning modules takes time and planning. It is important to plan out the narration and the animation/footage that will go along with the narration. During the planning stage developers must consider terminology and content for a variety of audiences. Using videos and modules for multiple years would offset the initial time and cost of developing the materials.
4.3 Future Research

Future research on crop yield impacts of controlled drainage could look at precipitation patterns throughout the growing season compared to crop growth stages to try to create a metric for when CD is the most beneficial. The yearly wetness classification was a good overall view of the yield differences. However, investigating precipitation patterns and the amount of water conserved in the landscape during key crop growth stages (e.g. silking) could lead to a better understanding of when controlled drainage is the most beneficial.

This gridded analysis method could be expanded to examine other variables such as soil moisture, hybrid, fertilizer applications, and other soil properties, although the degrees of freedom would need to remain appropriate for the yield data available. Adding different variables into a yield analysis might give insight into the relationship these variables have with CD compared to FD.

There is a need to better understand what happens to the water in the CD fields. Modeling studies would be beneficial to investigate where the water in the controlled drainage fields go. Yield increases at higher elevations found in this study could be related to lateral seepage, vertical seepage, or preferential flow, which might be studied through modeling or additional field studies.

Future research related to the online modules could expand the use of the videos by implementing them into extension education. Many extension workshops depend on real-world data and teach concepts about drainage. Evaluating extension presentations that include the use of videos as an educational tool would be beneficial. A larger population can be reached by using videos in extension if the videos are posted on an online platform. Furthermore, the videos could be shown before participants go out to the field during an extension field day. Using videos before a field trip can help participants focus on the content when at the field site.
APPENDIX A. SUPPLEMENTAL INFORMATION FOR CROP YIELD EFFECTS OF CONTROLLED DRAINAGE

Appendix A.1 SAS CODE to Calculate Yield Impacts for Wetness classification, Elevation, and Soil type

Below is the linear mixed model SAS code that was used in Chapter 2. The class line includes all the classifications variables used in the analysis. The model line indicates all the variables and interactions used in the model. The random lines indicate the grid “id” as the repeated measure by “year” and type= the covariance structure used (exponential). The lsmeans statements are used for each interaction in the model statement and was adjusted by the Tukey- Kramer method. This same code was used for soybean yield.

```sas
proc glimmix data=corndata plots= residualpanel;
class soil year id Treatment ele_factor pre_factor;
model yield = ele_factor soil Treatment pre_factor treatment*pre_factor Treatment*ele_factor*pre_factor Treatment*soil*pre_factor Treatment*ele_factor Treatment*soil/solution;
weight Point_Count;
random intercept/ subject=id;
random _residual_ / subject = year type = sp(exp) (id_row id_col);
lsmeans Treatment*soil*pre_factor/ pdiff adjust=tukey ilink;
lsmeans Treatment*ele_factor*pre_factor/ pdiff adjust=tukey ilink;
lsmeans Treatment*ele_factor/ pdiff adjust=tukey ilink;
lsmeans Treatment*soil/ pdiff adjust=tukey ilink;
lsmeans Treatment*pre_factor/ pdiff adjust=tukey ilink;
store MyResults"number";
run;
```

Below is an example sheet of the data for corn yield (Figure 19).

The data has a column for:

- the year, id of the yield cell, soil drainage class, LiDAR based elevation, quadrant number,
- the point count of how many yield points are inside the grid, the average yield in each cell,
- the row number for the cell, the column number for the cell, the treatment, precipitation, elevation based off the lowest elevation or water control structure, the yearly wetness classification, and the elevation category.
Figure 19: Example data sheet for corn

This code analyzed yield for individual years:

```sas
proc glimmix data=corn plots=residualpanel;
class year id Treatment;
where year=2016;
model yield = Treatment/solution;
weight Point_Count;
random _residual_ / subject =id type = sp(gau) (id_row id_col);
run;
```

This code analyzed each individual year and not yearly wetness classification. These results were not used in this thesis due to model fit issues.

```sas
proc glimmix data=corn plots=residualpanel;
class soil year id Treatment ele_factor;
where year=2016;
model yield = ele_factor3 soil Treatment Treatment*ele_factor Treatment*soil/solution;
weight Point_Count;
random _residual_ / subject =id type = sp(exp) (id_row id_col);
lsmeans Treatment*ele_factor/ pdiff adjust=tukey ilink;
lsmeans Treatment*soil/ pdiff adjust=tukey ilink;
run;
```
Appendix A.2 Yield Arithmetic Averages

Chapter 2 presented results based on LSMEANS estimated from the model, arithmetic averages were also calculated and presented below. All tables are presented in bushels per acre because this is most helpful for producers.

Table 16 Average corn yield by year.

<table>
<thead>
<tr>
<th>Year</th>
<th>Corn Yield (bushels per acre)</th>
<th>Yield Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CD</td>
<td>FD</td>
</tr>
<tr>
<td>2005</td>
<td>160.1</td>
<td>154.1</td>
</tr>
<tr>
<td>2006</td>
<td>157.3</td>
<td>151.1</td>
</tr>
<tr>
<td>2007</td>
<td>106.8</td>
<td>101.0</td>
</tr>
<tr>
<td>2008</td>
<td>188.1</td>
<td>183.9</td>
</tr>
<tr>
<td>2009</td>
<td>176.6</td>
<td>167.6</td>
</tr>
<tr>
<td>2010</td>
<td>130.9</td>
<td>136.9</td>
</tr>
<tr>
<td>2012</td>
<td>129.3</td>
<td>123.4</td>
</tr>
<tr>
<td>2014</td>
<td>190.8</td>
<td>189.6</td>
</tr>
<tr>
<td>2016</td>
<td>218.1</td>
<td>218.3</td>
</tr>
<tr>
<td>Average</td>
<td>162.0</td>
<td>158.4</td>
</tr>
</tbody>
</table>

Table 17 Average corn yield for all elevation ranges by treatment.

<table>
<thead>
<tr>
<th>Year Classification</th>
<th>Corn Yield (bushels per acre)</th>
<th>Yield Difference (CD-FD)/FD*100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Controlled</td>
<td>Free</td>
</tr>
<tr>
<td></td>
<td>&lt;30 cm</td>
<td>30-60 cm</td>
</tr>
<tr>
<td>Dry</td>
<td>147.5</td>
<td>139.5</td>
</tr>
<tr>
<td>Normal</td>
<td>181.7</td>
<td>182.5</td>
</tr>
<tr>
<td>Wet</td>
<td>142.6</td>
<td>160.1</td>
</tr>
<tr>
<td>overall</td>
<td>161.6</td>
<td>163.2</td>
</tr>
</tbody>
</table>
Table 18 Average corn yield for soil type by treatment.

<table>
<thead>
<tr>
<th>Year Classification</th>
<th>Corn Yield (bushels per acre)</th>
<th>Yield Difference (CD-FD)/FD)*100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VP</td>
<td>150.7</td>
<td>142.6</td>
</tr>
<tr>
<td>P</td>
<td>139.0</td>
<td>137.7</td>
</tr>
<tr>
<td>SWP</td>
<td>120.6</td>
<td>119.7</td>
</tr>
<tr>
<td>Free</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VP</td>
<td>179.1</td>
<td>168.9</td>
</tr>
<tr>
<td>P</td>
<td>184.2</td>
<td>181.3</td>
</tr>
<tr>
<td>SWP</td>
<td>177.2</td>
<td>173.5</td>
</tr>
</tbody>
</table>

Table 19 Average soybean yield by year.

<table>
<thead>
<tr>
<th>Year</th>
<th>Soybean Yield (bushels per acre)</th>
<th>Yield Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>61.4 cm</td>
<td>60.5 cm</td>
</tr>
<tr>
<td>2013</td>
<td>60.2 cm</td>
<td>58.5 cm</td>
</tr>
<tr>
<td>2015</td>
<td>52.0 cm</td>
<td>50.8 cm</td>
</tr>
<tr>
<td>2017</td>
<td>52.8 cm</td>
<td>56.0 cm</td>
</tr>
</tbody>
</table>

Table 20 Average soybean yield for all elevation ranges by treatment.

<table>
<thead>
<tr>
<th>Year Classification</th>
<th>Soybean Yield (bushels per acre)</th>
<th>Yield Difference (CD-FD)/FD)*100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled</td>
<td>Free</td>
<td></td>
</tr>
<tr>
<td>&lt;30 cm</td>
<td>62.1 cm</td>
<td>59.7 cm</td>
</tr>
<tr>
<td>30-60 cm</td>
<td>61.3 cm</td>
<td>61.8 cm</td>
</tr>
<tr>
<td>&gt;60 cm</td>
<td>57.7 cm</td>
<td>57.2 cm</td>
</tr>
<tr>
<td>Normal</td>
<td>Free</td>
<td></td>
</tr>
<tr>
<td>&lt;30 cm</td>
<td>57.1 cm</td>
<td>57.5 cm</td>
</tr>
<tr>
<td>30-60 cm</td>
<td>58.0 cm</td>
<td>60.2 cm</td>
</tr>
<tr>
<td>&gt;60 cm</td>
<td>56.0 cm</td>
<td>57.8 cm</td>
</tr>
<tr>
<td>Wet</td>
<td>Free</td>
<td></td>
</tr>
<tr>
<td>&lt;30 cm</td>
<td>49.9 cm</td>
<td>43.6 cm</td>
</tr>
<tr>
<td>30-60 cm</td>
<td>52.9 cm</td>
<td>53.6 cm</td>
</tr>
<tr>
<td>&gt;60 cm</td>
<td>52.3 cm</td>
<td>51.6 cm</td>
</tr>
</tbody>
</table>

Table 21 Average soybean yield for soil type by treatment.

<table>
<thead>
<tr>
<th>Year Classification</th>
<th>Soybean Yield (bushels per acre)</th>
<th>Yield Difference (CD-FD)/FD)*100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled</td>
<td>Free</td>
<td></td>
</tr>
<tr>
<td>VP</td>
<td>4.2 cm</td>
<td>3.9 cm</td>
</tr>
<tr>
<td>P</td>
<td>4.1 cm</td>
<td>4.1 cm</td>
</tr>
<tr>
<td>SWP</td>
<td>3.7 cm</td>
<td>3.8 cm</td>
</tr>
<tr>
<td>Free</td>
<td>Controlled</td>
<td></td>
</tr>
<tr>
<td>VP</td>
<td>3.4 cm</td>
<td>3.7 cm</td>
</tr>
<tr>
<td>P</td>
<td>3.6 cm</td>
<td>3.5 cm</td>
</tr>
<tr>
<td>SWP</td>
<td>3.4 cm</td>
<td>3.5 cm</td>
</tr>
</tbody>
</table>
APPENDIX B. SUPPLEMENTAL INFORMATION FOR THE ONLINE LEARNING MODULE

Appendix B.1 Pre-/Post-Test Questions

1. Controlled drainage is….
   a. The concept of installing tile drainage in an agricultural field
   b. The concept of installing tile drainage very shallow in agricultural fields to control irrigating the field
   c. The concept of using a water control structure to hold water in drained agricultural fields during periods when drainage is unnecessary *
   d. The concept of diverting subsurface drainage water into on-farm ponds or reservoirs, where it is stored until it can be used by the crop later in the season

2. Which of these is NOT a site requirement for controlled drainage?
   a. Cover crops *
   b. Land surface slope <1%
   c. Poorly drained soils
   d. Managing drainage without impacting neighbors

3. Controlled drainage is one tool for reducing the loss of which nutrient from entering streams?
   a. Magnesium
   b. Nitrate*
   c. Potassium
   d. Calcium

4. Choose the best answer for the following statements:
   When using controlled drainage…..
   Before planting the outlet elevation in the water control structure is (choose one):
   a. Raised
   b. Lowered*

5. Choose the best answer for the following statements:
   When using controlled drainage…..
   During the growing season (May-Sept.) the outlet elevation in the water control structure is (choose one):
6. Choose the best answer for the following statements:

When using controlled drainage.....

After harvest the outlet elevation in the water control structure is (choose one):
   a. Raised*
   b. Lowered

7. How would you expect controlled drainage to influence corn yield compared to free drainage during dry years?
   a. The two treatments have negligible differences
   b. Free drainage increase yield
   c. Controlled drainage increases yield *

8. How would you expect controlled drainage soybean yield to compare to free drainage soybean yield?
   a. The two treatments have negligible differences *
   b. Free drainage increases yield
   c. Controlled drainage increases yield

9. A 5-year study of free and controlled drainage field found the following differences in corn yield:
   - Year 1: 4% (free drainage higher)
   - Year 2: 7% (controlled drainage higher)
   - Year 3: 3% (controlled drainage higher)
   - Year 4: 10% (controlled drainage higher)
   - Year 5: 0% (yields are equal)

What do these results tell you about monitoring corn yield?
   a. Controlled drainage always increases yield.
   b. One year of data would be adequate to determine the effect.
   c. Several years of data are needed for evaluating patterns and variability *
   d. Nothing can be learned from this study.
10. Controlled drainage can typically reduce drainage volumes and nitrate loads by how much?
   a. 2-10%
   b. 30-50% *
   c. 60-90%
   d. 90-100%

11. How are nitrate and phosphorus concentrations impacted by controlled drainage?
   a. No significant difference*
   b. Higher total phosphorus loads and lower concentrations
   c. Lower total phosphorus loads and higher concentrations
   d. Higher total phosphorus loads and concentrations in the free drainage quadrants

12. What is the most common way controlled drainage decreases nitrate loads?
   a. Increases denitrification
   b. Increases deep seepage
   c. Reduces drain flow*
   d. Increases nitrogen uptake by crops
Appendix B.2 Interview Questions

To help improve the online learning module for controlled drainage I would appreciate your feedback. This interview is voluntary and confidential. This interview should take 10-20 minutes of your time. Any question can be skipped without fear of penalty.

1. Talk about your experience learning about controlled drainage through an online learning module.
   a) What worked for you and why did this work for you?
   b) What did not work for you and why?

2. The online learning module used real-world data based on the research site at the Davis Purdue Agricultural Center. Did the use of real-world data help you learn the basic concepts of controlled drainage? If yes, how?
   a) What did you like about using real-world data?
   b) What did you not like about using real-world data?

3. In the module you completed two learning activities. Learning activity one focused on site suitability and management of controlled drainage, while learning activity two focused on evaluating water quality at the research site. Besides the content knowledge can you describe the differences between the two assignments?

   a) Did these two learning activities/assignments help you learn about controlled drainage? If yes, ask how
   b) Did you prefer one assignment over the other assignment? If yes, ask Why?
   c) What did you like about the learning activities/assignments? Any specific parts of the assignment.
   d) What did you not like?
4. A virtual field trip uses technology to bring the experience of going to an on-site field trip directly to the student. In the online learning module, we were trying to simulate a virtual field trip by using the set of videos throughout the module. Did the videos feel like a virtual field trip to you?
   a) If yes, what feature(s) made them feel like a virtual field trip?
   b) If no, why did the videos not feel like a virtual field trip?

5. If you took a real field-trip to the Davis Purdue Agricultural Center you would not be able to see the subsurface tile drainage or how controlled drainage holds water in the field. Do you think the virtual field trip videos helped you understand the practice of controlled drainage? Did the virtual field trip videos help you understand what was taking place underground in a controlled drainage field?
   a) If yes ask, Can you give me an example of a section or animation in the video that helped you learn about controlled drainage?
   b) If no, why did the virtual field trip not help you understand the practice of controlled drainage?

6. What did you like about the videos?
7. What did you not like about the videos?
8. Do you have any suggestions for improving the videos?
9. Did the entire module help you learn the concepts of controlled drainage?
10. Do you have any suggestions for improving the module?
11. Any other thoughts or comments?

Demographics:
What is your year in school?
   a) Freshman
   b) Sophomore
   c) Junior
   d) Senior
   e) Graduate
What is your major? _______________
Do you live on a farm? ________________________
Have you had an agricultural internship or agricultural work experience? 
__________________
What is your gender? ___________
Have you seen a subsurface tile drain in person? ________________________
Have you had a previous class where you learned about tile drainage? _____
    If yes, what class? ________________________
What grade do you expect to receive in this class?  A   B   C   D   F
Appendix B.3 IRB Protocol [Ref. #1802020290]

To: FRANKENBERGER, JANE R., BOWLING, LAURA C., LOCKER, AMANDA, A., WILLIAMS, MARYSHANNON
From: DICLEMENTI, JEANNIE D, Chair
Social Science IRB
Date: 03/01/2018
Committee
Action: (1) (2) Determined Exempt, Category (1) (2)
IRB Action Date: 03 / 01 / 2018
IRB Protocol #: 1802020290
Study Title: The Effects of an Online Learning Module on Students' Controlled Drainage Knowledge and Learning Experience.

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b).

Before making changes to the study procedures, please submit an Amendment to ensure that the regulatory status of the study has not changed. Changes in key research personnel should also be submitted to the IRB through an amendment.

General
• To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student’s attendance and enrollment decision will not be shared with those administering the course.
• If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
• When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution’s IRB to determine requirements for conducting research at that institution.
• When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). Submit this documentation as an FYI through Coeus. This is an institutional requirement.

Categories 2 and 3
• Surveys and questionnaires should indicate
  ◦ only participants 18 years of age and over are eligible to participate in the research; and
  ◦ that participation is voluntary; and
  ◦ that any questions may be skipped; and
  ◦ include the investigator’s name and contact information.
• Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
• When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.

Category 6
• Surveys and data collection instruments should note that participation is voluntary.
• Surveys and data collection instruments should note that participants may skip any questions.
• When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.

You are required to retain a copy of this letter for your records. We appreciate your commitment towards ensuring the ethical conduct of human subjects research and wish you luck with your study.