GROWING ACADEMIC RESILIENCE IN STUDENTS OF SCIENCE
THROUGH MIMICRY OF FOREST RESILIENCE

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

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DEDICATION

This research is dedicated to the students who inspired me to become a teacher in the first place. You remind me that the learning process is messy and is supposed to be challenging. Thank you for being my teacher.
ACKNOWLEDGEMENT

I am so lucky to have the support of a team of professionals, who gave their time to review the content and provide valuable feedback. Robyn Klein, biomimicry expert, supplied energy and insight in the development of the research methods and understanding of nature’s genius. She continually encouraged efforts to refocus and directly connect forest mechanisms with classroom strategies. Walt Woolbaugh put up with the many stops, starts, and fits of uncertainty with a steady and gentle patience. His supportive feedback guided this work in positive and enlightening directions. Jessica Hartnett provided statistical data analysis support and ensured the techniques used were valid and the data appropriately interpreted. Ellen Losano-Ramsey and Lindsay Hall provided hours of detailed grammatical and stylistic editing to ensure the story was coherent and concise. Teaching colleague John Voss provided technical and moral support throughout the process. Finally, I would like to send an endless amount of thanks and love to my family for their patience and consistent support.

All of these team members provided ideas and insights that helped to feed the mother tree in her effort to strengthen the forest.
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ABSTRACT

For this education-based classroom research project, inspiration was drawn from the mechanisms used to transmit nutrients and information between individual organisms in a forest through the mycorrhizal network. Whereas forest resilience is based on speed of recovery and ability to regenerate biomass, academic resilience is based on the student’s ability to recover from a setback and remain engaged in the learning process. The goal of the project was to mimic the communication network observed in forest mycelium and thus transmit information and receive feedback from students continuously in an effort to support the growth of academic resilience.

The hypothesis of this project was that in fostering communication between students and creating opportunities for communication between individual students in the classroom, overall student academic resilience, grit, and content understanding would increase. During the 9-week study, students communicated their level of confidence in understanding content, provided insight into misconceptions they may have been developing, and gave advice to other students to enhance understanding of the material being taught. A culminating whole-class inquiry project was used to require students to work together on finding the solution to a problem.

While not statistically significant, positive growth in resilience was observed in 57% of project participants, (N=83), but honors-level students reported higher levels of resilience at the start of the project than those of their general-level counterparts. A statistically significant growth in grit and content understanding was observed in honors-level students. Growth by at least 20% in content understanding over the course of the project was observed in 91% of all student participants.

No singular data point was determined to be a predictor of student capacity for resilience, but development and use of a regular survey process provided insight into student mindset and opinion. Due to student inability or unwillingness to give themselves credit, development of a resilience recognition program is recommended as part of the next phase of research to foster awareness in the classroom of actions that exemplify resilience.
INTRODUCTION AND BACKGROUND

Forests are naturally resilient and have developed and perfected this important ability over the past 3.8 billion years. A variety of mechanisms are used by nature to enhance resilience and increase the odds of both ecosystem and individual organism survival. For this education-based classroom research project, inspiration was drawn from forest mechanisms used to transmit resources from resource-rich areas to resource-deficient areas through the mycorrhizal network, a symbiotic relationship between trees and fungi. For this classroom research project, the students were the “trees” and the various combinations of students in the classroom made up the “forest.” A network of communication tactics designed to connect students with each other and the teacher, the “mycorrhizal network,” was employed to move information from knowledge-rich sources to knowledge-deficient sinks.

The fundamental hypothesis for this classroom research project was that if mechanisms for enhancing forest resilience are replicated in the classroom, student academic resilience, grit, and content understanding would increase. Whereas forest resilience is based on speed of recovery and ability to regenerate biomass, academic resilience is based on the student’s ability to recover from a setback, and move forward while remaining engaged in the learning process.

Students come to the classroom with their own foundational connections, supports, and experiences, which are the basis for their personal resilience ecosystem. Connections with their family, friends, community, and school provide the landscape for an individual’s resilience. Strengthening these connections and opening lines of communication to foster a community of information exchange will not only improve
content understanding but also enhance a student’s willingness to rebound from a setback.

Connections work, in part, because they can foster confidence. Confidence throughout the learning process is important in keeping students motivated and engaged in learning. The students involved in this classroom research project were primarily in the tenth grade at a small, rural high school in Pennsylvania. Students generally elect to take chemistry after completing a course in biology in their ninth grade year and successfully completing the Pennsylvania Keystone content exam in biology. Students are nominated to honors-level chemistry based on personal interests, future goals, success on the state exam, and ninth grade science teacher recommendation. Students in general-level chemistry have a range of reasons for taking the course, including personal interest and future goals, as well as seeking to complete the minimum number of science credits required to meet high school graduation requirements. Student motivation and confidence varied widely between study participants.

The purpose of this classroom research project was to mimic natural resilience mechanisms found in a forest to advance:

1. A framework for understanding barriers to improving academic resilience.
2. Instructional practices that foster development of academic resilience.

Centered on the idea that resilience can be developed and nurtured, the primary focus question is, “To what degree can growth in academic resilience be facilitated in the classroom?” A secondary focus for this research is related to understanding how connectivity impacts growth and development of student resilience. Research questions
are summarized in Table 1. Five areas of resilience, including self, family, friends, community, and school were identified as components to understanding student capacity for resilience growth. If resilience is able to be increased in students, then increasing student confidence and opening lines of communication could be an integral part of facilitating that growth.

Table 1

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Goal for asking this question:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Question:</strong> “To what degree can growth in academic resilience be facilitated in the classroom?”</td>
<td>Develop an understanding of each student’s individual resilience ecosystem.</td>
</tr>
<tr>
<td><strong>Secondary Questions</strong></td>
<td>Determine if a predictor of student capacity for resilience growth can be identified.</td>
</tr>
<tr>
<td>What indicators can be used to predict the area of individual resilience a student needs most support in developing?</td>
<td></td>
</tr>
<tr>
<td>To what extent did academic resilience improve in students who were more connected in information-sharing activities?</td>
<td>Determine if students who participate more in information networking build greater academic resilience and grit.</td>
</tr>
<tr>
<td>To what extent did content understanding improve in students who were more connected in information-sharing activities?</td>
<td>Track whether resilience built during classroom learning is correlated with success on assessments.</td>
</tr>
</tbody>
</table>

**CONCEPTUAL FRAMEWORK**

For this project, inspiration was drawn from biological research conducted in the study of the mechanisms of mycorrhizal network communication. The communication mechanism that forests use to inoculate and prepare for disaster was applied in the classroom to enhance communication strategies to facilitate deeper content understanding and increase student academic resilience. The following sections outline research
findings associated with the enhancement of resilience, both in forests and in adolescents in an academic setting.

**Mycorrhizal Networking and Forest Resilience**

The mycelium is a network of thread-like hyphae (Figure 1) that can extend long distances and provide nutrients to plants and other organisms throughout the soil.

![Figure 1. Development and growth of fungus mycelium. Note. Growing on a beech wood block. Initial colony growth (12d-40d) forms a densely cross-linked network. Further expansion (60d) is fueled in part by recycling of redundant material, eventually thinning out to a minimal skeleton as the resource is consumed (100d). (Heaton et al., 2012)](image)

In the laboratory, mycelium has been found to span several decimeters underground (Agerer, 2001). Ecological research has shown that trees are able to use the mycorrhizal network, which is a symbiotic relationship between fungus mycelium and tree roots, to communicate through the soil over long distances to other trees (Simard, 2016). Communication using this network between individuals, even individuals of
different species, involves material transfer in the form of carbon, nutrients, water, defense signals, and allelochemicals (Simard, Beiler, Bingham, Deslippe, Philip, & Teste, 2012).

The long structures within the mycelia’s architecture can strengthen in some basidiomycetes species of fungus, such as *Boletus, Cortinarius, Paxillus, Piloderma, Pisolithus, Rhizopogon, Suillus*, and *Tricholoma*, to become highly specialized conductive organs, called cords (Heaton et al., 2012). When the mycelium forages for resources in an ecosystem and finds nutrition, the cords thicken and form thick conduits, or highways, that can move resources directly (Cairney, 2005). Fungus mycelium is capable of colonizing and exploring over long distances (Falconer, Bown, White, & Crawford, 2007). As some regions of the mycelium expand, other regions may regress during foraging activities, depending on the quantity and quality of resources available, the presence of other organisms, and the ecosystem’s microclimates (Boddy, 1999). The cord network is isolated from the ecosystem using hydrophobic sheaths, so resources are not siphoned into the environment as they pass through the network (Heaton et al., 2012). This isolation of the resources allows individuals that are at a great distance from each other to be connected. If a particular cord is not encountering the resources the organism requires, some species of fungus can recycle the biomass that makes up that particular cord back into the organism. The biomass is then redistributed to another location where exploration and foraging may result in larger gains (Falconer et al., 2007).

At this point, it is important to define the term “resources.” Plants need nutrients, such as water, carbon, nitrogen, and phosphorus, for growth, but they have other resource
needs too. Having information about the forest and any impending danger allows individuals within the ecosystem to prepare and protect themselves against the danger. Forest organisms do not communicate with words, but rather through the production of specific chemicals. Organisms communicate exposure to a disease by producing an enzyme in a high concentration. The enzyme makes its way into the mycorrhizal network and flows from a high concentration area to low concentration areas. Photosynthetic rates in trees, growth rates of tree and fungal communities, locations of nutrient sources within the ecosystem, and release of enzymes that signal an organism is experiencing distress from disease, insect infestation, drought, or forest fire are some of the factors that affect concentration gradients of water, nitrogen, carbon, and defense-signaling enzymes (Simard et al., 2012; Song, Zeng, Xu, Li, Shen, & Yihdego, 2010). This movement is called mass flow and is the mechanism used to move resources from a resource-rich source to a resource-deficient sink. The rate of flow depends on the concentration gradient between source and sink. When the enzyme reaches the resource-deficient sink, it signals the presence of disease within the forest.

Data also suggest that enzymes released in one part of a network are transmitted through the network and can act as inoculants for individuals that reside within the entire network. Young trees are linked to the hub trees in a forest, also called “mother trees,” through the mycelium. Of particular interest for this classroom research project, transport of legacy information, including defense signals and information about how to best react and respond to a major disaster event, is a mechanism forests use to inoculate itself against setback. By sending low concentrations of warning compounds to alert
individuals within the ecosystem of a particular threat, response options are communicated so as to help the individual organisms in the forest disarm the threat (Simard, et al., 2012). Inoculation allows the individuals within the network to be more resilient in recovering from a particular danger because they are aware of and are ready to respond more quickly to a potential threat in the community (Song et al., 2010).

**Adolescent Academic Resilience**

All research projects conducted on resilience generally begin with a definition of the term resilience. Each researcher and each research study has a slightly nuanced way of defining the characteristic. The consensus is that resilience is an intrinsic personality trait that is related to personal confidence, control, and competence coupled with social support (Liu, Reed, & Girard, 2017; Luthar, Cicchetti, & Becker, 2000; Singh, 2016; Windle, 2011). In the classroom, a resilient student takes control of his/her learning, maintains a high level of confidence that success is possible, accepts responsibility, is able to manage stress, gets involved in learning activities, and seeks out solutions to problems (Martin & Marsh, 2008).

Adolescent resilience research indicates that resilience is the “presence of both risks and promotive factors that either help bring about a positive outcome or reduce or avoid a negative outcome” (Fergus & Zimmerman, 2005, p. 399). This means that an individual must have exposure to risks, the opportunity to work through those risks, and elements in his/her life that support a successful outcome. Individual resilience has been shown to be intricately connected to community and social supports. The quality of the connections in a child’s life is dynamic, but may provide protection against or even
prevention of negative outcomes (Greenberg, 2006). Resilient individuals are characterized as having a high self-esteem, a clear sense of purpose, and healthy expectations. They are also able to successfully plan, control their environment, problem-solve, and achieve learning success (Wang, Haertel, & Walberg, 1997). These positive personal assets coupled with supportive external resources, such as community organization participation, adult mentoring, and parental involvement, provide a framework that inoculates and provides protection to the child in overcoming negative risks (Fergus & Zimmerman, 2005).

Researchers warn that individual resilience should not be compared to a universal benchmark, but rather be evaluated as a function of the “capacity of the individual’s environment to provide access to health-enhancing resources in culturally relevant ways” (Ungar et al., 2007, p. 288). Each person exists within his/her own ecosystem of causes and effects. Expecting everyone to strive for the same level of resilience is unrealistic, especially since everyone has varying experiences, realities, and support systems. The small, rural high school where this classroom research project was conducted superficially appears to have a very consistent and uniform culture, but a wide variety of interests and belief systems are present. Students are predominantly Caucasian, come from middle-class working families, are well-adjusted and respectful. Of the 900 students, 30% have completed the formal process to obtain free and reduced lunch, but his number is likely suppressed due in part to an unwillingness to accept support.

For this classroom research project, academic resilience, which is characterized by a person’s ability to maintain engagement in the educational process, is the primary
focus. A person with a high degree of academic resilience understands that success depends on participation in the learning environment. Setbacks, such as poor grades, competing deadlines, exam pressure, and difficult schoolwork, are stresses that test a student’s ability to remain resilient (Martin & Marsh, 2008). Martin and Marsh developed a survey instrument to measure stress levels and capacity for bounce-back, or buoyancy, in the academic setting. A 13-question survey was developed, tested on a group of Australian students \((N=598)\), and implemented longitudinally beginning during middle-school (Year 8) and ending in high school (Year 10). Change in academic buoyancy over the time of the study was measured. No training or lesson was delivered between the first and second measurements, and correlation to actual achievement in content mastery was not evaluated. Findings indicated that male participants over female participants as well as older students over younger students displayed statistically higher levels of academic buoyancy. A finding of the 2008 research pointed to anxiety as a major limiting factor in a student’s ability to develop academic resilience. Additionally, confidence throughout the learning process, and positive teacher-student relationships were found to result in greater buoyancy in the older, Year 10 students. All 13 questions from the 2008 Academic Buoyancy survey were selected for use in this classroom research project due to Martin and Marsh’s rigorous instrument validation and use in a similar population. The researchers identified two issues that required further consideration and study: correlation of student academic achievement with resilience improvement as well as an evaluation of individual risk factors related to prior achievement, socioeconomic status, race, and prior adverse experiences.
A different 25-question Resilience Measure survey was validated by Wagnild and Young (1993) in response to a lack of research on adult resilience. The researchers developed a survey tool that could be used to measure resilience or the capacity for resilience in adults (Wagnild & Young, 1993). The questions were originally tested on 1,500 adults and subsequently have been used in various other studies to assign a resilience score between a range of 25 to 175, where higher scores reflect more resilience (Wagnild, 2009). The 1993 study focused on calculating the reliability and validity of the survey tool and each question. A subset of questions was selected from the 1993 Resilience Measure survey for use in this classroom research project due to rigorous validation completed by Wagnild and Young.

Another personality characteristic connected to resilience is grit. This characteristic is defined by the Merriam-Webster dictionary as a firmness of mind and character that allows unyielding courage in the face of hardship (Merriam-Webster, 2017). Grit is determined using two factors, passion and perseverance, in a person’s ability to stay committed to achievement of a goal. Resilience is a component of the perseverance factor in grit and was selected in this project to narrow and focus the scope of study. In order to develop an understanding of a person’s grit, a validated 12-question Likert-style grit survey (Grit-S) was developed to measure the passion and perseverance characteristic (Duckworth & Quinn, 2009). The Grit-S survey was tested on a large variety of participants (N=2,840), including adolescents, in an effort to identify the 12 questions that can most successfully predict the ability of a person to find a goal that they are passionate about and willingness to commit to seeing the goal achieved. Results of
the study confirmed that the structure of the grit scale did not produce significant
differences in response between genders but did produce significant variation with age,
suggesting that grit increases with life experience. The Grit-S survey was selected for use
in this classroom research project to support triangulation of reported resiliency in the
study’s participants.

Research Application

Both forest and adolescent communication tactics share some common
characteristics. Forests enhance resilience by sharing information through the complex
network of mycelium cords. People, especially adolescents, are constantly sharing
information through a variety of existing communication tools, including Snapchat,
Twitter, texting, Instagram, etc., outside the classroom. In the classroom, communication
comes in the form of hand-raising, direct and indirect questioning, seeking out extra help,
and talking to classmates in the classroom. Forests transmit enzymes through the network
to signal when danger may be coming. Students also transmit information through the
communication network available to them to signal when they are uncertain about a
concept.

The mechanism that fungi use to recycle biomass and to connect to a resource-
dense area was of particular interest for this project. To optimize a communication
network, teacher resource use (i.e., time, availability, money, curricular resource access)
must be optimized. The goal was to mimic the flexible communication network observed
in mycelium and thus to transmit information and receive feedback from students
continuously, to proactively prepare students, and to anticipate challenges. A feedback
loop was used to determine what concepts and methods for content delivery were most effective. The time and resources saved from rewording and restyling a message were then recycled into efforts to develop new communication strategies or strengthen existing pathways.

If the students are the individual trees within the classroom, the group as a whole is equivalent to the forest. The resource distributed in the classroom is knowledge. However, just like in a forest ecosystem, the best way of distributing this knowledge can vary. Some students require more challenges than others. Some students require more support to thrive. Urgent deadlines or upcoming assessments motivate some, but not all. Some students seek to learn and understand the material as their primary goal/reward. For some students, focused parent/guardian involvement in grade monitoring is their primary motivating factor. In the forest, concentration gradients from resource-rich areas to resource-deficient sinks are used to determine how resources flow through the mycorrhizal network. In the classroom, identifying the concentration gradients from knowledge sources to sinks helped to determine how knowledge transport and flow could facilitate each student's learning.

The teacher and willing knowledge-rich students are the sources of content and advice. Although chemistry knowledge is concentrated in the teacher, knowledge of what students do not know is concentrated in the students. Both sources, teacher and student knowledge, input information into the classroom network. Those who require knowledge are the information sink and take knowledge out of the pipeline for use. Although input
and uptake may be unbalanced, benefits to student resilience, grit, and content mastery within the entire classroom ecosystem were expected to be measureable.

METHODOLOGY

Inspiration for the methods in this research effort was drawn from techniques that forests use to inoculate themselves against disturbance events. The students involved in this research, the metaphorical trees in the forest, were connected to other students and the teacher through a network of communication strategies during a unit that centered on the electron and the periodic table’s organization. The hypothesis of this classroom research project was that by increasing communication connectivity within the classroom, resilience, grit and content understanding would also increase. Students used strategies to communicate levels of confidence, a heads-up about a misconception they had, and general advice on understanding the material being taught. A culminating whole-class inquiry project was used to require students to work together on finding the solution to a problem. The study was implemented over the course of nine weeks. Academic resilience and content understanding were measured before and after the unit to determine growth. Grit was surveyed at the beginning and end of the course. A summary of research questions and methods is presented on Table 2.
Primary Research Question: “To what degree can growth in academic resilience be facilitated in the classroom?”

Secondary Research Question

<table>
<thead>
<tr>
<th>Methodology</th>
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<tbody>
<tr>
<td>What indicators can be used to predict the area of individual resilience a student needs most support in developing?</td>
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<tr>
<td>Each student’s individual resilience ecosystem map was drawn to identify areas of strength and weakness in self-identity, family, friend, school, and community connections.</td>
</tr>
<tr>
<td>To what extent did academic resilience improve in students who were more connected in information-sharing activities?</td>
</tr>
<tr>
<td>Classroom network maps were drawn to identify student-student and student-teacher connections and node students within each class.</td>
</tr>
<tr>
<td>Multiple communication mechanisms (i.e. Schoology discussion boards, one-on-one teacher support, and small group work) were used to encourage student-student and student-teacher interactions on a daily basis.</td>
</tr>
<tr>
<td>A culminating, challenge project was implemented to require students to collaborate.</td>
</tr>
<tr>
<td>To what extent did content understanding improve in students who were more connected in information-sharing activities?</td>
</tr>
<tr>
<td>Classroom network maps were drawn to identify student-student and student-teacher connections and node students within each class.</td>
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<td>Multiple communication mechanisms (i.e., Schoology discussion boards, one-on-one teacher support, and small group work) were used to encourage student-student and student-teacher interactions on a daily basis.</td>
</tr>
<tr>
<td>A variety of instructional activities (i.e., direct instruction, laboratories, process oriented guided inquiry activities, textbook concept previewing, games, demonstrations, practice problem sets, and student-led 3D model development) were used to teach the electron and periodic table organization unit.</td>
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</table>

Sample

Students participated in the classroom research project as part of normal day-to-day classroom activities. Students who did not complete the pre-study survey on resilience were not included in the classroom research project due to data unavailability.
Students from five sections of general-level chemistry \((N=62)\) and one section of honors-level chemistry \((N=21)\) provided enough information about their resilience ecosystem, and completed the pre- and post-study resilience surveys so that they could be included in the final data analysis. Additional students \((N=15)\) with resilience data but no pre-unit content test data were included in the data analysis, but their pre-unit content test was assumed to be 0\%, which may have skewed the final content knowledge growth calculations toward positive growth.

Most students take chemistry in 10\textsuperscript{th} grade. Of the 83 participants in the classroom research project, 37 (45\%) were male and 46 (55\%) were female. Twelve students (14\%) have individualized education plans (IEPs), and two students had recently exited from the English Language Learner program. Each of these students required some accommodations and/or supports to be successful in understanding the material presented in the classroom. The individuals that made up each section varied widely in aptitude and motivation toward learning.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix D). Compliance for working with human subjects was maintained throughout the course of the study.

**Treatment**

Student-student and student-teacher connections were fostered in the classroom to mimic the forest’s mycorrhizal network. Students, who were more connected in the classroom community, were identified as nodes, and were encouraged by the teacher to help other students who were demonstrating difficulty with the content material. Daily
rounds were made to touch base with each student in the classroom, to ensure any questions could be answered or misunderstandings in the beginning phase could be swiftly identified and clarified. General and resilience information was collected through casual conversation and added to the resilience ecosystem concept map developed for each student. Anecdotal comments and the frequency of the same question being asked were noted and used to tailor lesson delivery in subsequent class periods.

The school-promoted learning management system, Schoology, was used to facilitate dialogue through the use of discussion board posts where students performed write-to-learn activities, asked additional questions, and provided insight into any budding misconceptions (Schoology, 2018). Additionally, preferred methods and modes of communication (teacher-to-peer, peer-to-peer, independent, verbal, on-line, during study hall, and during after-school help sessions) were identified for each student and used to facilitate student-student and teacher-student communications. A culminating activity was used at the end of the unit to require students to work together on finding the solution to a problem using a whole-class inquiry style project. Each class identified a leader and then the team orchestrated the development of a controlled experiment, collection of data, and development of one presentation to summarize their findings.

**Instrumentation**

Instruments used to collect data to measure student connectedness, academic resilience, grit, and content understanding included surveys and questionnaires, conversations, observations, student-generated discussion posts, and formative/summative content assessments. Each step in the research process involved
data collection. Validity and reliability were ensured in the collection of resilience and grit survey data through the use of pre-published instruments. Table 3 summarizes the instruments used to collect data by research question.

Table 3
Data Triangulation Matrix

<table>
<thead>
<tr>
<th>Primary Research Question: “To what degree can growth in academic resilience be facilitated in the classroom?”</th>
<th>Data Collection Instruments</th>
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</thead>
<tbody>
<tr>
<td>Secondary Research Question</td>
<td></td>
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<tr>
<td>What indicators can be used to predict the area of individual resilience a student needs most support in developing?</td>
<td>Student academic data mining</td>
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<td></td>
<td>Teacher-student conversations</td>
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<td></td>
<td>Teacher observation log</td>
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<td></td>
<td>Resilience Measure Pre-Study Survey Results</td>
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<td></td>
<td>Grit Pre-Course Survey Results</td>
</tr>
<tr>
<td></td>
<td>“Getting to Know You” Pre-Course Questionnaire</td>
</tr>
<tr>
<td>To what extent did academic resilience improve in students who were more connected in information-sharing activities?</td>
<td>Node and Non-node Student Identification by Class</td>
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<tr>
<td></td>
<td>Teacher observation log</td>
</tr>
<tr>
<td></td>
<td>Resilience Pre- and Post-Study Survey Results</td>
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<tr>
<td></td>
<td>Grit Pre- and Post-Course Survey Results</td>
</tr>
<tr>
<td></td>
<td>Inquiry Activity Opinion Survey</td>
</tr>
<tr>
<td>To what extent did content understanding improve in students who were more connected in information-sharing activities?</td>
<td>Content Pre- and Post-Unit Assessment Results</td>
</tr>
<tr>
<td></td>
<td>Schoology Discussion Board Posts</td>
</tr>
<tr>
<td></td>
<td>Teacher Observation Log</td>
</tr>
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Student Academic Data Mining

Throughout the classroom research project, data were collected to develop an understanding of individual student characteristics related to their personal resilience ecosystem. The effort to understand individual risk factors was undertaken to provide a
broader context and was included since prior research findings indicated doing so may support a deeper level of data understanding and evaluation (Martin & Marsh, 2008).

The school district where this classroom research project was conducted uses an integrated educational data management system called EdInsight that compiles data from various data sources, such as attendance, demographics, state exam result data, IEP goals, and current grades onto one platform (On Hand Schools, 2018). EdInsight was used to mine the following general information about each student participant (N=83):

- 45% were male and 55% were female.
- 80% were in 10th grade.
- 12 have IEPs that require accommodations and in some cases differentiation techniques to be used in the delivery of instruction.
- 76% are Caucasian, 6% African-American, 12% Hispanic, and 1% Asian/Pacific-Islander.
- 30% passed the Pennsylvania state Keystone exam in biology; 43% passed the algebra Keystone exam; and 30% passed the English and Language Arts Keystone exam.
- The average weighted grade-point average (GPA) was 2.63 for general chemistry course participants, while the same ranking averaged around 3.90 for honors-level students.

A risk score is calculated by EdInsight, which is used to alert teaching staff of students who may need additional support in the classroom to be successful. Student participants had an immense range in risk scores, from 1 to 129, where a higher score indicates higher
risk. The average score was 33 for general-level and 19 for honors-level chemistry course student participants. The data and information were compiled onto a concept map, similar to that shown in Figure 2, to depict each student’s resilience landscape, for use in quick reference by the teacher.

![Concept Map](image)

**Figure 2.** Template for the individual student resilience ecosystem concept map.

**Student Generated Information**

Just like a natural ecosystem that has a complex network of connections that allow it to be flexible in its response to stress, students also have a network of supports. Flexible, spontaneous conversations were facilitated throughout the course of the project to develop a deeper sense of understanding of each student’s personal reality. From these
conversations, observations made in the classroom, and data provided in the first days of school “Getting to Know You” questionnaire (Appendix A), information was added to each student’s resilience landscape (Figure 2), for use in quick reference by the teacher. An effort was made to collect information within each of the five areas of resilience (self identity, family, friends, community, and school) so as to better understand student capacity for resilience growth.

Teacher Observation Log

Throughout the research project process, a teacher journal was kept to document qualitative data, including anecdotes, student comments and quotes, general observations, and teacher reflections. The journal allowed the impromptu synthesis of ideas and concepts and was maintained on an as-needed basis. Throughout the culminating whole-class inquiry activity, a log of student quotes was maintained to develop a chronology detailing student involvement and chatter.

Pre- and Post-Course Grit Survey

The validated 12-question Likert-style Grit-S survey (Appendix A) developed by Duckworth and Quinn was used to measure the grit characteristic, of which resilience is a component (Duckworth & Quinn, 2009). The survey was used to determine students’ perceptions of their grit at the beginning of the course in the first few days of school or when a new student joined the class as well as in the final weeks at the end of the school year. The results of these two surveys were collected to gauge students’ perceptions on how their grit may have changed as a result of personal growth over the course of the
school year, either directly or indirectly as a result of their participation in chemistry class.

**Pre- and Post-Study Academic Resilience Measure Survey**

Questions from the Academic Buoyancy survey and the Resilience Measure survey were combined to develop the Academic Resilience Measure Survey for use in this classroom research project (Appendix A). The questions, already validated for reliability in previous studies (Martin & Marsh, 2008; Wagnild & Young, 1993), were grouped into three question types: dealing with setbacks, pride in accomplishments, and coming up with solutions. A 21-question survey may disenfranchise students from full participation, so questions were grouped together by type to allow students to take a visual rest between response sections. Open-ended questions were also included in the survey to allow students to elaborate upon and clarify answers provided. The Academic Resilience Measure Survey was conducted prior to the beginning of the project and again at the end of the project following treatment. The post-study survey used the same questions, but verb-tense and directions were changed to prompt students to respond to the questions keeping the previous nine-week period in mind.

**Inquiry Activity Opinion Survey**

Following the culminating whole-class inquiry activity, students were encouraged to provide feedback about other team members that was shared anonymously to help them not only see the things that could use improvement, but more importantly, the positive and helpful qualities that helped to make the project successful. The team project survey, also included in Appendix A, was conducted using Google Forms at the end of
the inquiry project after feedback on the project was provided by the instructor. Data were aggregated in an Excel spreadsheet and used to pull student quotes and general information about the level of community networking and willingness of the survey respondent to connect into the network.

**Classroom Network Involvement/Node Identification**

The forest mycelium develops cords that transport information and resources throughout the ecosystem. For this classroom research project, a node student is characterized as someone who is highly interconnected, has high content understanding and confidence, and is willing to disseminate information within the network. Node students mimic the forest mycelium mechanism via their interpersonal behavior. Student activities were conducted individually, in small groups, and in whole-group settings. Students were required to participate in the conversation and work together with other students. The quality of participation, as well as how connected each student was to the group as a whole, was evaluated using a simple rubric (Appendix B). Students who met four of the six criteria for node students were classified as such.

**Schoology Posts**

Throughout the treatment’s implementation, an on-line discussion board on the school-district’s learning management system Schoology was used to support student synthesis of information learned in class as well as to write about confidence levels, areas of misunderstanding, and tips for other students to support learning. Dialogue was encouraged between students, and comments were provided by the teacher to encourage deeper reflection.
Pre- and Post-Unit Content Understanding Assessment

A goal of this research is to develop methods a teacher can use to inspire students to be more willing to make an effort to learn. A student who displays academic resilience will approach a challenge and dive in to try to understand and move toward mastery of the subject matter. The question is whether increased resilience translates into increased content understanding. To track growth in understanding, pre- and post-unit content tests was undertaken to provide insight into how growth in content understanding may be connected to change in resilience. Prior research findings indicate studying whether or not content knowledge growth was connected to academic resilience could provide a deeper understanding of a student’s resilience overall (Martin & Marsh, 2008). Pre-test questions were identical to post-test questions, but the question order and an additional option on the multiple choice questions for “I don’t know” was provided on the pre-unit content test to discourage guessing.

DATA AND ANALYSIS

All data were compiled using Excel and cross-checked by student ID number to ensure accuracy and analyzed via R Project (The R Foundation, 2018).

Confidence and Trust

Self-efficacy, or confidence in personal ability, has been linked to student ability to do well in their schoolwork (Martin & Marsh, 2008). Evidence was collected during this classroom research project using surveys, Schoology discussion board posts, and teacher observation log notes to track student confidence levels in themselves as well as their confidence and trust of class team-mates.
Students reported their perception of personal ability to do well in the chemistry course at the beginning, middle, and end of the study. “Well” was typically defined by both honors-level and general-level chemistry students to mean understanding the material and earning at least a B average. While a majority of students reported no change in confidence in their ability to do well in science, 35% of student participants reported a decrease in confidence over the course of the study. The general-level students tended to report greater anxiety and doubt in their ability to do well compared to the honors-level students. The general-level node and non-node students shared similar distributions in confidence levels at the end of the project, as shown on Figure 3.

Figure 3. Reported confidence at course-end in ability to do well in science of general-level, (N=58) and honors-level students, (N=21).

Comments from general-level chemistry students revealed insight into level of personal confidence. Students relayed stories of success with a tone of surprise that the accomplishment was even possible. One student noted that she was most proud of “being able to do the math part in chemistry, because I never thought I could do something that
hard, but I did.” Another noted, “I really struggled last year with science, but this year
I’m trying and I’m doing good.” Many sources of positive feelings and attitudes were
identified through the whole-class inquiry project. One student noted, “I just enjoyed the
sensation of being heard and having a voice.” Some students took on a leadership
position in the class for the first time. One student noted, “I was proud of myself because
I got up in front of the class to talk to everyone. I had to be confident in my work because
I had to tell others how to do the lab.” Another student leader commented that it
sometimes “seemed as if no one was listening and everyone was doing their own thing.
With a few loudly spoken words, (I was able to get) the team got back on track.” Specific
eamples of a time when students felt pride in their accomplishments was communicated
using the open-ended response feature of the survey.

Whole-class collaboration was a big challenge and revealed insecurities in some
students in their confidence and trust in their classmates. General-level students do not
seem to have been afforded as much freedom to explore and work in whole-class teams
in the past. This may be due to more raucous student behavior and a lower level of trust
between the teacher and the class in general-level sections. Figuring out how to work in a
big group and how to communicate with everyone on the team was a major challenge for
students. Comments like, “To be honest, this project hasn’t been much fun for me. There
are just a bunch of people in this class that I do not like” and, “I’m not trying to fail this
because of you,” “My partner just sat there and didn’t do anything,” and, “I don’t want to
collaborate with people. They’re nasty!” were very common across all five of the
general-level classes, and showed an entrenched distrust of classmates a student did not
already know. This deep level of distrust was surprising to uncover and indicated that a more focused intervention in team and community building earlier and throughout the school year may result in more fruitful and collaborative growth.

Students in the honors-level section were more adept at jumping into the whole-class challenge, as they have had previous experience with whole-group inquiry work in this course. Positive and supportive comments of their teammates were common, such as “(I contributed) a drive to get things done the correct way,” and “(our team lead) was a good leader and urged us to keep going,” and “(one of my team members had) creative ideas regarding the analysis of our results and why some trials didn’t work.” The collaboration demonstrated by the honors-level student team was inspiring to watch unfold.

Growth in Resilience

Resilience was evaluated using surveys, student-supplied information, and teacher observation log notes to understand each respondent’s perception of individual resilience. Resilience scores range from a minimum score of 0 to a maximum score of 147. Results from both pre- and post-study Academic Resilience Measure Surveys were used to calculate the change in resilience to uncover student perception of how their ability to recover from setback changed over the course of the unit on the electron and the periodic table’s organization. Results were converted into percent change to facilitate ease of comparison. While positive growth in resilience was expected, a number of students recorded responses that resulted in a decline in self-perceived resilience. Overall, 57% of study participants reported a positive increase in resilience.
Consolidation of the five general chemistry sections was statistically evaluated. While variance was detected between the class sections, the students were randomly assigned to a section by the guidance department during the 2016-2017 school year course scheduling process. Sections are not leveled in any other way than through the designation as general or honors.

A check was conducted to ensure the combined general-level student change in resilience data was normally distributed. Accordingly, a parametric independent sample \( t \)-test was conducted to determine if the change in resilience observed in the honors-level was commensurate with the change in resilience observed in the general-level students. The independent sample \( t \)-test revealed a statistically insignificant difference between honors-level and general-level change in resilience over the length of the project, \( t(30.078) = -1.6203, p < 0.1156 \). A boxplot showing the changes in resilience scores reported by both honors-level and general-level chemistry students is shown in Figure 4.

![Boxplot](image)

**Figure 4.** Change in resilience as reported by honors, \((N=21)\) and general chemistry students, \((N=63)\).

While not statistically significant, the pre-study resilience survey scores between the honors-level and general-level students indicate the two groups did not start with the same level of resilience. Honors students reported an average resilience score of 77.9\% (114 points) in the pre-study survey, whereas general-level students reported an average
score of just 71.6% (105 points). Post-study survey scores, however, indicate both groups finished the project with an average resilience score of 75.5%. On average, the honors-level students reported a decrease in resilience by 2.4% (3 points), whereas the general-level students reported an increase of 3.9% (6 points).

While honors-level students had a large number of students who reported a decrease in their perception of academic resiliency, a number of comments from honors-level students indicated a great deal of resiliency in their mindset. For example, one student reported,

I was really confident about my unit test and really thought I got an A but I did a lot worse than expected. I felt like all of my hard work didn't pay off. Then I realized that I did learn a lot in this chapter and a few wrong multiple-choice questions don't define my ability.

Another student commented, “I received a few poor grades on things, but I dealt with those by studying more and applying what I learned to better understand it.” The discrepancy between the comments provided and scoring results indicates the possibility that a disconnect between student perception of resilience and actual resilience exists. A possible reason for this disconnect may stem from an inability for students to see their own strengths. Students, especially honors-level students, are hyper-aware of and sensitive to the competition within the classroom to the point where some retreat from the discussion. Some evidence for this idea is supported by the number of peer-to-peer comments suggesting that students take more credit for their gifts. Comments like, “She should speak up more because she has really good ideas” and “She doesn't give herself enough credit; she is very hard on herself and I think some positivity would go a long
“way” were common among the responses in the survey conducted following the whole-class inquiry activity.

**Resilience Ecosystems by Class**

Characterizing the resilience of a group of students as a class is useful to help characterize the general feel of the class as a whole and the work ethic of the group. Educators have a sense of the importance of the group mentality, but quantification of this characteristic is difficult. The culminating activity in the classroom research project was an activity that helped to illuminate the level of cooperation and communication developed between members of each class. A log of student quotes was documented to develop a chronology of student involvement and chatter. A network map showing connections of individuals within each classroom ecosystem was developed and is included in Appendix E. The maps were drawn based on student comments and connections during the unit and culminating whole-class inquiry project, resilience survey data, and teacher observation log notes. Students were categorized as connected to the teacher, somewhat connected, and indirectly connected. To show connection types on the network maps, a solid line connecting student to teacher was used to indicate the student sought help from the teacher on a regular or semi-regular basis. A somewhat connected student (i.e., connection shown as a dashed line) would indicate he/she needed teacher support only when the teacher directly asked the student if he/she needed help. An indirectly connected student did not seek teacher help and/or rejected help from the teacher and is shown as connected to the teacher only through other members of the class.
Nodes became apparent quickly. A node, for this project, is characterized as a student who is highly interconnected, has high confidence, and is willing to disseminate information within the network. Node students for each class are designated on the network maps shown in Appendix E. In the honors-level section, six students regularly took on node roles within the class. In the general-level sections, at least one but no more than three students took on node roles within each class section. Since general-level and honors-level change in resilience were statistically similar, node student data and non-node student data were consolidated. A parametric independent sample \( t \)-test was conducted to determine if the change in resilience observed in node students was commensurate with the change in resilience observed in the non-node students. The independent sample \( t \)-test revealed a statistically insignificant difference between node and non-node students’ changes in resilience over the length of the project, 
\[
t(36.879) = 0.4163, \ p <0.6796.
\]
A boxplot showing the changes in resilience scores reported by both the node and non-node students is shown in Figure 5.

![Boxplot showing change in resilience](image)

*Figure 5.* Change in resilience as reported by node, \((N=20)\) and non-node, \((N=62)\) students.
Results indicate that no statistical difference was present between node and non-node student populations in their perceptions of change in resiliency.

**Resilience Ecosystems by Individual**

The internal resilience ecosystem is deeply personal, and generalizations are difficult. Resilience is built and grown within the individual, and rate of growth is personal. Each student’s resilience ecosystem was mapped, which included understanding student perceptions of supports available to him/her at home, at school, and within the community. The quick “Getting to Know You” questionnaire (Appendix A) was completed at the beginning of the school year and was used to initiate conversation and relationship building. Additional impromptu conversations occurred organically and information gleaned was added to each student’s ecosystem resilience map. The mapping exercise supported efforts to understand areas of strength and weakness in each student’s resilience ecosystem, but the process was cumbersome and is unrealistic to continue use in its current form. Development and use of a Microsoft Access database to manage the information could streamline data input and accessibility.

Development of a deep understanding of family and community connections was difficult, as connections with some families never occurred. Community connections were even more difficult to track, as part-time jobs, friends from other schools, volunteering and church group activities were ever-changing over the course of the school year. Self-identity, classmate interactions, and to some degree, school activity involvement were easier to study because those indicators are more readily available to observe and get information about in the classroom.
The electronic survey process was extremely useful in collecting large amounts of data in a time-efficient way. Based on data collected during data mining, from student conversation, and in the teacher observation log, student strengths and weaknesses within the five characteristic areas of self-identity, family, friends, school, and community were identified. The selection of one area of greatest strength and one area where improvement may be warranted was completed based on teacher understanding and knowledge of information associated with each of the five characteristic areas for each student. Strength in family support appeared more frequently in data associated with the honors-level students, whereas strength in self-identity appeared more frequently in general-level students (Figures 6 and 7).

Figure 6. Teacher-perceived honors chemistry node (left) and non-node (right) student strengths.
Figure 7. Teacher-perceived general chemistry node (left) and non-node (right) student strengths.

Growth in Grit

Grit scores range from a minimum score of 0 to a maximum score of 5. Results from both pre- and post-course Grit-S surveys were used to calculate a change in grit. The change indicated overall student perception about whether their personal passion and perseverance characteristic had changed over the course of the school year. Results were converted into percent change to facilitate ease of comparison. A positive growth in grit was expected, but only 39% of study participants reported a positive increase.

All of the five general-level chemistry sections were combined into one population group. A check was conducted to ensure the data were normally distributed. Accordingly, a parametric independent sample $t$-test was completed to determine if the change in grit observed in the honors-level student population was commensurate with the change in grit observed in the general-level student population. The independent sample $t$-test revealed a statistically significant difference between honors-level and general-level change in grit over the length of the course,
\( t(26.137) = 2.2898, p < 0.03035 \). Growth in grit was found to improve in honors-level students on average about 4%, resulting in an average 0.2149-point increase in grit score. General-level students’ perception of grit characteristic decreased on average by 2%, resulting in an average 0.1063-point decrease in grit score (Figure 8).

**Figure 8.** Comparison of change in grit scores between honors and general chemistry students.

Since the honors- and general-level groups of students showed statistically different changes in grit, further evaluation of the node and non-node student populations in each group was also completed. The node data in both honors-level and general-level datasets were not normally distributed; therefore, a nonparametric Wilcoxon rank sum test was conducted to determine if the distribution in change in grit observed was commensurate between the respective node and non-node datasets. A two-sample rank sum test revealed a statistically significant difference between the honors-level node and non-node groups over the course of the school year, \( W=15.5, p < 0.04312 \). Honors-level node students reported an overall negative, or decreasing, grit score (-0.16 points) compared to the overall increasing grit score (+0.39 points) reported by non-node students (Figure 9).
Figure 9. Comparison of honors node, \(N=6\) and non-node, \(N=13\) student change in grit.

The same two-sample rank sum test was completed on the general-level node and non-node groups and revealed a statistically insignificant difference between the two populations over the course of the school year, \(W=387, p < 0.1528\). While not statistically significant, general-level node students reported an overall positive, or increasing, grit score (+0.023 points) compared to the overall decreasing grit score (-0.15 points) reported by non-node students (Figure 10).

Figure 10. Comparison of general node, \(N=14\) and non-node, \(N=44\) student change in grit.

Activities and efforts completed over the course of the school year seem to have improved honors-level non-node students and general-level node students’ perceptions of
grit more positively than their corresponding counterpart groups within each leveled course.

**Growth in Concept Understanding**

The goal in any classroom is to grow and deepen student understanding of content. A pre-test was implemented before instruction began on the electron and periodic table organization unit. A post-test was completed following the end of the unit’s active instruction and review lessons. Overall, 91% of all student participants demonstrated at least a 20% improvement in content understanding. Pre-test scores were compared to post-test scores, and the difference was calculated to estimate growth in knowledge, as shown on Figure 11.

![Figure 11. Growth in content understanding of honors, (N=23) and general, (N=80) chemistry students.](image)

A check was conducted to ensure changes in content understanding were normally distributed. Accordingly, a parametric independent sample $t$-test was conducted to determine if the change in content understanding observed in the honors-level student population was commensurate with the change observed in the general-level students. The independent sample $t$-test revealed a strong, statistically significant difference
between honors-level and general-level content understanding growth during the electron and periodic table organization unit, \( t(46.34) = 5.7925, p < 5.786 \times 10^{-7} \). Growth in content understanding over the course of the project was shown to be statistically one and a half times greater compared to general-level student knowledge.

Further analysis of the data was conducted to determine if the node students in the honors-level and general-level populations demonstrated a greater knowledge growth based on the unit pre- and post-tests. A node for this project is characterized as a student who is highly interconnected, has high confidence, and is willing to disseminate information within the network. Since changes in content understanding were not normally distributed among the node and non-node groups, a nonparametric Wilcoxon Rank Sum Test was conducted to determine if the change in content understanding observed in the honors-level node student population was commensurate with the change observed in the honors-level non-node student population. The test revealed a statistically insignificant difference between node and non-node growth in content understanding, \( W=55.5, p < 0.4346 \). Likewise, the same test was run for general-level node and non-node students. The test also revealed a statistically insignificant difference between node and non-node growth in content understanding in the general-level sections, \( W=398.5, p < 0.294 \). Results indicate that there is no difference in growth in content understanding between node and non-node students in both types of classes, general and honors. Growth in content understanding is plotted in Figures 12 and 13 for those who took on a node responsibility against those who did not in the honors and general populations, respectively.
In addition to growth in content understanding, post-test data were evaluated to determine if node students ended up with a deeper understanding of content. Since post-test raw scores were not normally distributed among the node and non-node groups, a nonparametric Wilcoxon Rank Sum Test was conducted. The test revealed a statistically insignificant difference between node and non-node students’ content understanding (Honors-level: $W=52, p <0.6074$; General-level: $W=431, p<0.11$). Node students did not demonstrate greater knowledge of content compared to their non-node peers.
Connecting Academic Resilience with Content Knowledge Improvement

Evaluation of both change in resilience and resilience levels at the beginning of the study were found to be statistically similar between honors-level and general-level student populations. Honors-level students were shown to have a one and a half times greater increase in content understanding compared to general-level students. Comparison of change in academic resilience and change in content understanding levels was completed to determine if a correlation between the two measures could be shown. It was expected that a direct relationship would exist, where increases to one measure would result in an increase in the other measure proportionally.

Prior to conducting correlation analysis, scatterplots (Appendix C) were developed to compare resilience growth and content understanding growth for both the honors-level and general-level populations. A linear relationship between the two variables was not apparent in either population, and since data were also not normally distributed in the honors-level datasets, a nonparametric procedure, the Spearman’s rank order correlation coefficient, was performed to determine if resilience growth and content understanding growth were correlated using student paired data. For the honors-level population, the Spearman’s rho revealed a statistically significant negative relationship between resilience and content understanding growth ($r_s[2255.7] = -0.4648$, $p < 0.03$), indicating a decrease in resilience resulted in an increase in content understanding. For the general-level population, the test revealed a statistically insignificant positive relationship between resilience and content understanding growth.
(rs[34747] = 0.1250, p<0.333), indicating an increase in resilience resulted in an increase in content understanding.

The statistically significant negative correlation between resilience and content understanding in the honors-level student population is most likely due to the unexpectedly large number of honors-level students (48%) who reported a decrease in their perception of academic resiliency over the course of the unit. These students are suspected to have a larger degree of resilience than reported. Correlation between academic resilience and content understanding could not be established.

Connecting Academic Resilience with Grit

The change in resilience and the resilience levels at the beginning of the study were found to be statistically similar between honors-level and general-level student populations. Honors-level students were shown to have a 6.4% greater growth in grit compared to general-level students. Comparison of change in academic resilience and change in grit levels was completed to determine if a statistically significant correlation between the two measures could be shown. Resilience is a component of the grit characteristic, so it was expected that a direct relationship would exist, where increases to one measure would increase the other measure proportionally.

In order to compare grit data with resilience data, both resilience and grit scores were converted to percent changed over the time period over which data was collected. On average, grit in all students tended to decrease over the course of the school year, whereas resilience slightly improved over the course of the project (Figure 14).
Figure 14. Percent change in grit and academic resilience characteristic in chemistry students, \((N=77)\).

To evaluate statistical significance between change in resilience and grit data, scatterplots (Appendix C) were developed to compare change in resilience and change in grit for both the honors-level and general-level populations. A linear relationship between the two variables was not apparent in either population, so a nonparametric test, the Spearman’s rank order correlation coefficient, was performed to determine if resilience and grit were correlated using student paired data. For the honors-level population, the Spearman’s rho revealed a statistically insignificant negative relationship between resilience and content understanding growth \((rs[1199.7] = -0.0524, p < 0.8313)\), indicating no observable correlation between resilience and grit. For the general-level population, the procedure revealed a statistically insignificant negative relationship between changes in resilience and grit \((rs[32755] = -0.0076, p<0.9551)\), which also indicates no correlation between changes in resilience and grit. Based on the data collected as part of this project, correlation between academic resilience and grit could not be established.
INTERPRETATION AND CONCLUSION

The goal of this research was to mimic the mechanisms that forests use to share information and proactively prepare for potential disaster so as to enhance resilience. The mycorrhizal network provides a multi-branched, highly integrated way to connect various forest individuals and species over long distances. The forest network allows sharing resources, which includes instructions, through the use of enzymes, for improving resilience. Within the classroom, an intricate communication network is used to promote the dissemination of information and sharing of understanding between individuals. Sending out signals and messages is only one component of the process. Individuals must be able and willing to receive the signals and messages and interpret them for their own use. The hypothesis of this classroom research project was that by encouraging communication connectivity within the classroom, resilience, grit, and content understanding would increase.

The biggest challenge in applying biomimicry in the classroom is mimicking the urgency present in a natural system. The survival of a forest may depend on the ability of the individual organisms to communicate and share resources, but the value of learning chemistry is not perceived with as much urgency by students in the classroom. Making learning authentic and using a variety of activities to engage the learner in the learning process were the primary strategies used to promote student engagement during this classroom research project. A culminating challenge experience was used to create a sense of urgency and require communication between all members of the class. While significant measurable improvement in resilience was not observed as a result of this
project, content understanding improved by at least 20% in more than 90% of student participants. Throughout the project, opportunities to capitalize on the successes and trim away inefficient practices were noted for future continuation of this research and are detailed in the following subsections.

**Resilience Ecosystem Mapping**

One question this project sought to answer centered on developing a technique that can be used as a quick way to map and identify areas where individuals may need extra support in developing resilience. This effort sought to include data from a robust number of locations, with an eye for developing a method that could be quickly employed in future years to predict student capacity for academic resilience. The amount of data available and the limited time a teacher has to comb through data made the individual mapping methodology cumbersome. As a result of the effort, it was determined that the main data points used in identifying student strengths and weakness related to three areas: student-offered information gleaned during conversation; family pro-active/reactive participation in the student’s educational experience; and teacher awareness of student involvement in after-school activities. Narrowing the scope of data collection to focus on tracking these areas as well as including an opportunity for students to identify and discuss their perception of personal strengths and weaknesses within the resilience landscape may help to streamline and reduce time required to develop the understanding. Addition of a question on the “Getting to Know You” questionnaire (Appendix A) used at the beginning of the school year could give early insight into student resilience ecosystem. The question “Who/what inspires you the most to do well in
school? Rank the following in order of greatest to least: self, family member, friend, community member, school activity eligibility, class rank, and other.” The individual ecosystem maps, while a nice way to visualize and centralize student data, were not easy to flip to for quick reference. Some data collected did not necessarily help to understand a student’s resilience capacity but contributed more to teacher understanding of the student’s personal reality. Continuation of the individual mapping practice is not recommended.

In contrast to the individual maps, the whole-class ecosystem maps (Appendix E) were a very helpful way to summarize the connections observed within the classroom. This mapping activity would be useful to conduct early on and then throughout the course of the school year to document the changing communication network within the classroom community. Even though a statistically significant difference in content understanding or resilience was not observed in node versus non-node students, teenagers can be fickle. Understanding the dynamics between individuals and groups within the classroom could help promote more proactive classroom management and communication networking. Increasing the number of connections within the classroom as well as tracking changes in network connections would be a meaningful goal of future efforts. Continuation of the whole-class mapping practice is recommended.

One of the biggest lessons learned was discovery that levels of resiliency in students from similar life situations varied widely. Some students who have very difficult personal situations seemed to have a greater capacity for resilience, whereas others in
similar situations did not. Reflecting on the data collected indicates that no stereotypical characteristic can be identified as providing for greater capacity in resilience growth.

Students did provide insights into their perspective on willingness to participate in the class. Responses to the Likert-question “I get along with my teacher,” provided on several occasions an indicator that a student was struggling. In some cases, it seemed that the student would select an answer to see what the teacher’s reaction would be, while others seemed to simply want to report a fact. Student responses, particularly those who disagreed or disagreed strongly, helped create conversation starters, and in some cases resulted in a dramatic change on a future survey response. Use of this question within a larger survey effort is recommended as it could be a bellwether indicating student willingness to persist.

**Resilience Measure Growth**

The main question this classroom research project sought to answer was related to understanding the degree to which resilience growth can be facilitated in the classroom. Even though the difference is not statistically significant, at this particular high school, honors-level and general-level students did report differing levels of academic resilience. This difference in resilience is apparent in the classroom when observing student learning practices, self-talk, and interactions in the classroom. Students in the honors-level section tended to be more tenacious and actively engaged in learning, put extra time in to their learning outside of the classroom, and were quicker to raise their hand when unsure. Only 5 out of the 21 (23%) honors students came after school for extra help during the classroom research project period, but the most common comment made in the post-study
resilience survey indicated 52% put more time into self-study of the course materials to improve content understanding. Students in the general-level section tended to get frustrated and give up more easily, had a harder time managing work deadlines, and spent less time outside of class reviewing concepts, completing assignments, and studying. For general-level students, 38% came for extra help during the project period, but the most common type of comment made in the post-study resilience survey, made by 29% of general-level study participants, was related to working harder to turn in late work for partial credit.

Based on the pre- and post-study resilience measure survey results (Figure 15), an estimation of projected increase in academic resilience for any type of chemistry student was projected. An interesting future use would be to use the following function to estimate the increase in academic resilience that a student may expect to experience and then to compare projected change to actual change:

\[
\text{Final Resilience Score} = 0.03059 \times \text{Initial Resilience Score} + 49.724
\]

*Figure 15. Post-study resilience results vs. pre-study resilience results: projecting future increase potential of academic resilience for chemistry students.*
The connection between resilience growth and level of connectedness a student experiences in the classroom was thought to be important in the development of resilience, but node and non-node students reported statistically similar changes in resilience. The reason for this is not clear but may be that these students have less room for growth, since they already view themselves as fairly resilient. For example, the node student who volunteers to lead a team is much more willing to take an academic risk than the student who would rather sit and wait to be told what to do. That same node student may not perceive an increased ability to handle leadership of a team, since they were willing to take on the challenge from the beginning. Honors-level node students reported an average 81% resilience measure score prior to the start of the unit compared to the average 76% resilience measure score of non-node students. In the general-level node students, a 72% average resilience measure score was reported prior to the start of the unit in node students, compared to an average 71% average resilience measure score of non-node students.

Although some students reported a decline in resilience, a number of these same students indicated great pride in their accomplishments in the narrative responses they provided as part of the survey process. One honors-level node student who registered a -8.16% decline in resilience noted, “I was trying to help direct the group and help lead the class. I think this is somewhat special because I wouldn't have done that in years past.” Another node student admitted to taking more academic risk by trying new things to see if they helped or not but registered only a 0.68% increase in academic resilience.
Based on comments students provided, a general inability or unwillingness to give themselves credit for growth appears to be present. The saying, “you are your own worst critic” may apply to these situations. An example of this sentiment was demonstrated when a general-level node student who recorded a negative growth in resilience (-10.8%) commented that there was no time that she had come up with a solution to a problem during the last unit. This student had been asked by the class to lead them in the whole-class challenge and had been instrumental in pulling everyone together to develop the whole-class presentation. Arguably, without her, the entire team project would have fallen apart. If more timely individualized praise given directly to this student and other students from the teacher more favorable changes in resilience may have been observed. Development of a recognition program that very clearly praises examples of resilience in action could be a way to mitigate this perception disconnect in the future.

Content Understanding Growth

Honors-level students grew in content understanding one and a half times their general-level counterparts. When the data were further refined to separate node students from non-node students within each of these populations, node students were determined to have statistically similar content knowledge compared to their non-node counterparts. While the findings are not significant, the honors section node students outperformed their non-node counterparts on the post-test by an average by 5.8%. For general-level students, node students outperformed their non-node counterparts by about 6.4%.

Students in general-level chemistry classes tend to put less effort into using time in class wisely and are bolder about making negative proclamations, such as “This is
stupid, when am I ever going to need to know this?”, which gives the teacher an impression that the class as a whole does not care about learning. This teacher misconception has the potential to impact the ability of students to move the pace of learning forward and keep momentum high. Awareness that the growth potential for honors and general chemistry students is statistically similar and that node students do not necessarily have deeper content understanding is a mindset shift that must be understood to ensure individualized attention and support is being provided to all students. This finding would be an important data point to communicate and bring awareness to teaching staff especially to those who instruct both honors-level and general-level sections.

**Grit**

While this study focused mainly on resilience, grit is a personality characteristic that requires a great deal of resilience. The 12-question Grit-S survey was conducted as part of this research project at the beginning and end of the school year. Results showed a statistically significant greater change in growth in grit in the honors-level student population compared to the general-level students. Within the honors-level population, non-node students reported the greatest increase in grit (0.39 points; 7.8%) over the course of the school year. Willingness to see a challenge through and to persevere was evident in some of the comments received from this student population: “I had a team member who has the tendency to get easily distracted. Instead of ignoring them, I had to find ways to keep them focused and engaged,” and “I had to come up with a way to actually focus on studying and understanding the material… I decided to address (it)
myself;” and “Memorizing things and studying are weak areas for me, but I came up with tricks to help me remember (things).” These students recognized a challenge and made a conscious decision to address it. Each met these challenges with great success.

A reason why honors-level node and general-level students did not perceive improvement in personal grit could not be determined. The Grit-S survey does not include open-ended follow-up questions to help dig deeper into the through process and reasoning for scoring. Modification to the survey by adding open-ended prompts is recommended for future use, so that a more comprehensive understanding of student perspective on their grit characteristic can be achieved.

**Next Steps**

As this research in student resilience continues and is replicated in the future, several changes to the methodology and instructional strategy are recommended based on the findings of this project. Resilience ecosystem mapping should be pared down and include more direct methods for collecting student input. Surveying for resilience and general course feedback should be used on a regular basis. Identifying the node students early in the course is important, but it is important that the teacher remember that node students may have a slightly better command of the content, but they do not necessarily recognize their own inner strengths. All students must be supported to help them recognize and appreciate all of the hard work they put forth. A possible strategy for coaching students on what resilience looks like would be to set up a recognition program to highlight examples of those who are putting resilience into action. For example, an award or classroom privilege could be offered to a student who noticed that he/she
needed help with a particular concept and signed up for after school help. Development of non-node students into node students could also be a useful focus for further research in accelerating the intensity and challenge that the entire class experiences. Content knowledge growth was excellent in all groups of students during this project. The variety of methods used to deliver the content appeared to be successful, but more individualized feedback throughout the whole-group inquiry project activity may have helped to foster a stronger sense of community and dispel some of the mistrust observed.

While transmission of data and information was assumed to primarily be from the teacher to the student for this project, collection and understanding of the data and information that students send to the teacher would be another way to evaluate communication mechanisms in a classroom. Several instances where a common misconception or misunderstanding of a question’s wording were identified during the first couple of times the lesson was delivered. Modifications were made to deliver the content more efficiently and to prevent misconceptions or misunderstandings from the beginning. Understanding how the teacher adjusts and improves communication and teaching strategies with increasing number of times the lesson is delivered could also be beneficial to ensure lessons learned are captured and retained for use in the immediate and distant future.

Additionally, a larger sample size may yield different results. Given the relatively small number of honors-level students and several p-values < 0.15, it is possible that this research was underpowered and could benefit from a larger sample.
Enhancing communication, improving academic resilience, and increasing content mastery is a noble goal in all educational pursuits. Student perception of resilience can vary from day to day. High school teenagers often are not self-aware and can quickly feel defeated or become self-critical. Teachers understand that cheerleading to establish and maintain confidence is an integral part of the learning process, since confidence is a necessary component of success. General-level students enter the classroom with a more hesitant perspective of their capacity for success. Fostering positive connections and celebrating small successes is an important role the teacher must embrace in the classroom. By developing highly interconnected networks within the classroom, greater support can be provided in developing student growth in content knowledge, resilience, and grit.

One of the most beneficial outcomes of this classroom research project to the teacher was the development and use of a regular survey process. Use of the existing resilience measurement instruments streamlined the development process. Use of Google Forms made implementation and data analysis time-efficient. Outreach and management of a working relationship with all students is important but setting aside time to develop relationships is difficult to fit into the schedule. All students were able to provide greater insight into their mindset and personal opinions through the use of open-response survey questions. Comments gave insight into students’ perspectives, work process, and sometimes even revealed an entrenched distrust between classmates. The information gleaned during the survey process was used to modify classroom practices, be sensitive to
student tendencies, and to keep an eye out for distress signals. Uncovering perspectives early on and often throughout the school year allows for a quick and focused response.

The fundamental hypothesis for this classroom research project was that if mechanisms for enhancing forest resilience were replicated in the classroom, student academic resilience, grit, and content understanding would increase. The effort to create a networked community of learners was challenging but encouraging students to interact and become a more cohesive group resulted in development of a more collaborative and positive energy in the classroom. Building trust and fostering relationships between students may not have the obvious life or death urgency that forest resilience requires, but flow of information throughout these two types of networks is similar. This classroom research project revealed an excellent increase in content understanding. Students also showed improvement in their ability to recognize personal strengths and weaknesses both in themselves and in the contributions of others in the class.

This research has had a powerful and positive impact on me, the teacher. The process has been extremely enlightening. We hope that our young generation of students will want to persevere and learn always. This mindset is unsustainable though if the student does not have a support network. I experienced a number of setbacks while implementing this project, and in many cases, a kind word from a professor or a technical reviewer was all I needed to get back on track. Experiencing difficulties that stem from being challenged is an important reminder that learning is supposed to be a process that involves setback. Encouraging students to embrace and seek challenge is my duty as a
teacher, but I must keep in mind that students need extra support, kind words, and lots of encouragement when trying to be resilient.
REFERENCES CITED


APPENDIX A

DATA COLLECTION SURVEYS
## Getting to Know YOU!

Following is a list of informational questions that will be helpful for me to get to know you. Please fill out the information completely to the best of your knowledge for an easy 5 participation points!

<table>
<thead>
<tr>
<th>Full Name:</th>
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<tbody>
<tr>
<td>What do you want me to call you?</td>
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<tr>
<td>Who do you live with?</td>
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<tr>
<td>Parent/Guardian’s Phone Number</td>
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<tr>
<td>Parent/Guardian’s Email Address</td>
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</tbody>
</table>

### What are your interests?

(check all that apply)

- Play Sport(s)
- After-School Club(s)
- Community Organization
- Part-time Job
- Hobbies
- Other

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<thead>
<tr>
<th>What are your interests?</th>
<th>Fall_______ Winter _________ Spring ________</th>
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</thead>
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<tr>
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<td>Which One?__________________________________</td>
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<td>Which One?__________________________________</td>
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<td>Where?______________________________________</td>
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<td>What are they?_____________________________</td>
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<td>Tell me about it:____________________________</td>
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<tr>
<th>List your top 3 favorite music artists</th>
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<td>1. __________________________________________________________________</td>
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<td>2. __________________________________________________________________</td>
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<tr>
<td>3. __________________________________________________________________</td>
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</tbody>
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<tr>
<th>Do you have internet at home?</th>
<th>Yes ☐ No ☐</th>
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Tell me anything you like:

Photos/Videos:
Mrs. Rapone periodically will take photos and videos of the class for use in providing feedback. The photos and videos will NEVER be posted to the internet and if a use outside of the classroom is expected, additional permission will be requested.
I consent to photos and videos being taken of me during class **ONLY** for use in providing feedback:

________________________________________________________________________(sign here)
12-Question Grit Survey

Directions: Please respond to the following 12 items. Be honest! There is truly no right or wrong answer!!

1. I have overcome setbacks to conquer an important challenge.
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

2. New ideas and projects sometimes distract me from previous ones.*
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

3. My interests change from year to year.*
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

4. Setbacks don’t discourage me.
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

5. I have been obsessed with a certain idea or project for a short time but later lost interest.*
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

6. I am a hard worker.
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

7. I often set a goal but later choose to pursue a different one.*
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

8. I have difficulty maintaining my focus on projects that take more than a few months to complete.*
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

9. I finish whatever I begin.
   A. Very much like me
   B. Mostly like me
   C. Somewhat like me
   D. Not much like me
   E. Not like me at all

10. I have achieved a goal that took years of work.
    A. Very much like me
    B. Mostly like me
    C. Somewhat like me
    D. Not much like me
    E. Not like me at all

11. I become interested in new pursuits every few months.*
    A. Very much like me
    B. Mostly like me
    C. Somewhat like me
    D. Not much like me
    E. Not like me at all

12. I am diligent (steady, earnest, and energetic effort).
    A. Very much like me
    B. Mostly like me
    C. Somewhat like me
    D. Not much like me
    E. Not like me at all
Academic Resiliency Measure Pre-Study Survey

Think about your life and academic experience up until this point in time. Please respond to the following questions in the most truthful way possible. There are no right or wrong answers!

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

* Required

1. Name (first and last) *

2. Class Period *
   Mark only one oval per row.

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<tr>
<th>1</th>
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</table>

Period

3. How confident are you in your ability to do well in science class? *
   Mark only one oval per row.

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Very</th>
<th>Slightly</th>
<th>Moderately</th>
<th>Not at all</th>
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4. Define what "well" means to you from the previous question. *

5. Dealing with Setbacks *
   Mark only one oval per row.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Mostly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Mostly Agree</th>
<th>Strongly Agree</th>
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   When I make plans, I follow through with them.
   I am good at dealing with setbacks (i.e. negative feedback, bad grade, etc.)
   I intend to complete school.
   If I try hard, I believe I can do my schoolwork well.
   If I can't understand my schoolwork at first, I keep going over it until I do.
   I don't let stress get on top of me.
   Learning at school is important to me.

6. Can you share with me a time that you had a major academic setback? How did you handle it? *

   |               |               |               |               |               |               |               |
   |               |               |               |               |               |               |               |
7. **Pride in Accomplishments**

Mark only one oval per row.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Mostly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Mostly Agree</th>
<th>Agree Strongly</th>
</tr>
</thead>
<tbody>
<tr>
<td>When I am in a difficult situation, I can usually find my way out of it.</td>
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<tr>
<td>I enjoy being a student.</td>
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<tr>
<td>I feel proud of my accomplishments.</td>
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<tr>
<td>I get involved in the things we do in class.</td>
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<td>I get along well with my teacher.</td>
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<td>Keeping interested in what I am learning is important to me.</td>
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<td>I feel that I can handle many challenges at a time.</td>
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8. Can you share with me an academic accomplishment that you are particularly proud of? Why is it particularly special to you? *

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9. **Coming up with Solutions**

Mark only one oval per row.

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<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Mostly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Mostly Agree</th>
<th>Agree Strongly</th>
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</thead>
<tbody>
<tr>
<td>I take things one step at a time.</td>
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<td>I do not dwell on things that I can't do anything about.</td>
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<tr>
<td>When exams and assignments are coming up, I worry a lot.</td>
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<td>I can usually look at a problem in a number of ways.</td>
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<tr>
<td>I don't let a bad mark affect my confidence.</td>
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<td>I'm often unsure how I can avoid doing poorly in this class.</td>
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<tr>
<td>I think I am good at dealing with schoolwork pressures.</td>
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10. Can you share with me a time that you had to come up with a solution to a problem you had in a class (i.e. with the teacher, another student, the material being learned, etc.)? What did you do to solve it? *
Academic Resiliency Measure Post-Study Survey

Think about your academic experience over the last month as we learned about how the periodic table is organized, electron configurations, energy, electromagnetic radiation wavelengths and the team challenge. Please respond to the following questions in the most truthful way possible. There are no right or wrong answers!

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way.

* Required

1. First Name *

2. Last Name *

3. Class Period *
   Mark only one oval per row.

<table>
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<tr>
<th>1</th>
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<th>8</th>
</tr>
</thead>
</table>
   Period

4. How confident are you in your ability to do well in science class? *
   Mark only one oval per row.

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Very</th>
<th>Slightly</th>
<th>Moderately</th>
<th>Not at all</th>
</tr>
</thead>
</table>
   Confidence Level


5. Dealing with Setbacks *
   Mark only one oval per row.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Mostly Disagree</th>
<th>Somewhat Disagree</th>
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<td>When I made plans, I followed through with them.</td>
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<td>I intend to complete school.</td>
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<td>When I tried hard, I was able to do my schoolwork well.</td>
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<td>When I couldn't understand my schoolwork at first, I kept going over it until I did.</td>
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<td>I didn't let stress get on top of me.</td>
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</table>

6. During this past unit, tell me about a time that you had a major academic setback. How did you handle it? *

7. Pride in Accomplishments *
   Mark only one oval per row.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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<td>I got involved in the things we do in class.</td>
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<tr>
<td>I was able to handle many challenges at a time.</td>
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8. During this past unit, tell me about an academic accomplishment that you are particularly proud of. Why is it particularly special to you? *
9. **Coming up with Solutions**

*Mark only one oval per row.*

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Mostly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Mostly Agree</th>
<th>Agree Strongly</th>
</tr>
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<tbody>
<tr>
<td>I took things one step at a time.</td>
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<td>I did not dwell on things that I couldn't do anything about.</td>
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<td>When exams and assignments were coming up, I worry a lot.</td>
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<td>I approached a problem from a number of different ways.</td>
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<td>I didn't let a bad mark affect my confidence.</td>
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<tr>
<td>I was often unsure how I could avoid doing poorly in this class.</td>
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<tr>
<td>I was good at dealing with schoolwork pressures.</td>
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</tbody>
</table>

10. **During this past unit, tell me about a time that you had to come up with a solution to a problem you had in class. What did you do to solve it?**
Can Recycling Company of America Project

Think back on your experience figuring out what strategy made the best crush.

* Required

1. Name: *

2. How did your team work together during this activity? *
   Mark only one oval.
   - Excellent
   - Well
   - Okay
   - Fair
   - Not So Well

3. Was there a superstar on your team? *
   Mark only one oval.
   - Yes
   - No

4. Was there anyone who didn't pull their weight?
   Mark only one oval.
   - Yes
   - No

5. What special skill or talent did you bring to the table that your team was able to use? *

Your Team

Think back on how your team was run.

6. What was your team leader's leadership style?
   Mark only one oval.
   - Laissez-faire leader: everyone sort of did their own thing and there wasn't much group cohesion
   - Authoritative leader: made all the decisions and told everyone what to do
   - Democratic leader: asked for input from team, but ultimately made the final decision on what to do
   - Transactional leader: gave good jobs to the people they like
   - Transformational leader: delegated tasks so that everyone was included, motivated team to stay focused

7. Did you enjoy working with your team leader?
   Mark only one oval.
   - Yes
   - No

8. Did you have any issues with any of your teammates? (Is there someone you would prefer not to work with again)
Chemistry Concoctions Lab Kit - General Survey

Think back on your experience investigating the effects of changing variables on water moved into the graduated cylinder.

* Required

1. Name: *

2. How did your team work together during this activity? *
   Mark only one oval.
   - Excellent
   - Well
   - Okay
   - Fair
   - Not So Well

3. Was there a superstar on your team? *
   Mark only one oval.
   - Yes
   - No

4. Was there anyone who didn't pull their weight?
   Mark only one oval.
   - Yes
   - No

5. What special skill or talent did you bring to the table that your team was able to use? *

Your Team

Think back on how your team was run.

6. What was your team leader's leadership style?
   Mark only one oval.
   - Laissez-faire leader: everyone sort of did their own thing and there wasn't much group cohesion
   - Autocratic leader: made all the decisions and told everyone what to do
   - Democratic leader: asked for input from team, but ultimately made the final decision on what to do
   - Transactional leader: gave good jobs to the people they like
   - Transformational leader: delegated tasks so that everyone was included, motivated team to stay focused

7. Did you enjoy working with your team leader?
   Mark only one oval.
   - Yes
   - No

8. Did you have any issues with any of your teammates? (Is there someone you would prefer not to work with again)
Chemistry Concoctions Lab Kit - Team Lead Survey

Think back on your experience investigating the effects of changing variables on water moved into the graduated cylinder.

* Required

1. Name

2. How did your team work together during this activity? *
   Mark only one oval.
   ○ Excellent
   ○ Well
   ○ Okay
   ○ Fair
   ○ Not So Well
   ○ Terrible

3. Was there a superstar on your team? *
   Mark only one oval.
   ○ Yes
   ○ No

4. If so -- Who is it and would you recommend them for a raise/promotion?

5. For each member of your team (including yourself), write a positive comment about their contribution to the team's effort. *

6. For each member of your team (including yourself), write a comment about how they can improve their contribution to the team's effort next time. *

7. Do you enjoy working with your team? 
   Mark only one oval.
   ○ Yes
   ○ No

8. Did you have any issues with anyone on your team? *
   Mark only one oval.
   ○ Yes
   ○ No

9. Are you interested in changing your team? Would you like to hire someone from another team?

10. Being a team leader is more challenging. Is it worth it for you? 
    Mark only one oval.
    ○ Yes
    ○ No
APPENDIX B

NODE RUBRIC
Node or Non-Node?

1. Is there a frequent and open communication of understanding from this student to teacher?

2. Does this student coach others in their learning?

3. Do other students gravitate to this student to work together with during small group work?

4. Does this student actively seek out opportunities to help others with their understanding?

5. Does this student enjoy success in understanding the material on a regular and consistent basis?

6. Does this student actively participate in lessons?

If 4 or more of the answers to the above questions are YES – student identified as a Node student.
APPENDIX C

DATA
Figure A. Honors-Level Node Content Understanding Growth (%) vs/ Resilience Growth (%), \((N=6)\).

Figure B. Honors-Level Non-Node Content Understanding Growth (%) vs/ Resilience Growth (%), \((N=15)\).
Figure C. General-Level Node Content Understanding Growth (%) vs/ Resilience Growth (%), (N=14).

Figure D. General-Level Non-Node Content Understanding Growth (%) vs/ Resilience Growth (%), (N=48).
Figure E. Honors-Level Grit Growth (%) vs Resilience Growth (%), (N=19).

Figure F. General-Level Grit Growth (%) vs Resilience Growth (%), (N=58).
APPENDIX D

IRB EXEMPTION
INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

MEMORANDUM

TO: Marcia Rapone and Walt Weilbaugh
FROM: Mark Quinn
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 13, 2017

RE: "Facilitating Growth in Academic Resilience" [MR111317-EX]

The above research, described in your submission of November 13, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

(b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

(b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

(b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

(b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.
APPENDIX E

CLASSROOM NETWORK MAPS
Honors Class Network

Period 2 Network
Period 3 Network

Period 5 Network
Period 7 Network

Period 8 Network