Teaching Portfolio

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University of Akureyri
Faculty of Natural Resource Sciences

Foreword

January 2022 – post evaluation

Dear potential Kennslu Akademía applicant,

This is a slightly revised version of my application to Kennslu Akademía (KA) that was submitted in May of 2021. This application was successful as I was admitted to KA, which I must admit I thought was surprising (and even more surprising heaving re-read it a year after the fact!). Please note that it has been slightly modified from the original form; most of the changes are cosmetic (spelling and grammar errors, edits for clarity) although most of application has been left in its "warts and all" state. Some information has been removed for privacy reasons.

Finding a template and getting started

There are numerous suggestions available online for how to structure a teaching portfolio. Based upon my elementary understanding of Scholarship of Teaching and Learning (SoTL), I tried to find a portfolio structure that highlighted some of the core tenants of SoTL and underlined my **student-centric approach to teaching**, my **professional knowledge**, my current and future work relating to **pedagogical development** (both personally and within the institution where I work), and how I go about **participating in the broader conversation** related to learning. After spending several hours (more than I´d care to admit) going in circles trying to find the "best" approach (spoiler alert: there isn´t one!), I decided to structure this teaching portfolio based upon guidance from the University of Gothenburg´s Pedagogical Development and Interactive Learning Guidelines (which can be found here). If I had to do this again, I would have chosen a "simpler" portfolio structure.

Some notes and guidance on preparation

I spent around 80 hours preparing this application which was spread out over several weeks (although much of the time was more heavily weighted close to the application deadline, I'm just as bad as my students!). Much of the time that I spent on this application was time focused on trying writing around the gathered supporting material and reflecting on it and fit it into something resembling a cohesive narrative (I'll let you the reader judge if I actually accomplished that writing goal!). I would strongly urge future applicants to allow them ample time for revisions and editing.

I chose to use a style of writing that was more in line with prose rather than a more rigid style of academic or technical writing. The rationale for this was that it would make it easier to speak openly and honestly about the practice of teaching and my related experiences. Furthermore, I hoped that it would make it easier for evaluators (or even other readers in the future should I

need to submit a teaching portfolio when applying for a tenure track position) to read and engage with the text.

As I do my best to archive my teaching work (mostly to make it easier the following year), it was a fairly straightforward process to find ‘examples’ of how my teaching work aligns with SoTL principles (although this was slightly complicated with my work in multiple departments making telling a “cohesive narrative” a bit of a challenge”. I would suggest that applicants start by collecting together supporting documentation prior to deciding on a structure for their personal portfolios.

Sean M. Scully

15 January 2022

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1 Applicant background

I am employed as an adjunct at the University of Akureyri (UNAK) with my time divided between the Department of Natural Resource Sciences (80%) and the Department of Education (20%). As an educator, I am tasked with teaching courses within the biotechnology study line, namely microbiology, biochemistry, and microbial biotechnology; I am also the course supervisor for an introductory biotechnology course and currently supervise several master's students. Within the field of education, I teach within courses related to science education and scientific literacy at the undergraduate and graduate level and furthermore supervise a course on mathematics education. I am also the Head of Research and Development for Hemp Pack, a company aimed at developing sustainable bioplastics using bacteria.

As a researcher, my primary areas of focus include biocatalysis where I try to use microorganisms and their enzyme systems to do useful chemistry. I am also active in studying science literacy and serve on the Board of Directors of *Fine Focus*, an international undergraduate journal in microbiology. I am a member of UNAK's Environmental Council and serve as a representative for UNAK in Research Institute for Natural Science Education (Rannsóknarstofa um náttúrufræðimenntun) at the University of Iceland where we try to improve the quality of science education across educational levels in Iceland. I have also been active in science outreach in Northeast Iceland, and recently received funding from School Development Fund (Sprotasjóður, Ministry of Education, Science, and Culture) in order to develop multi- science educational materials ("Verkleg og vistvæn vísindakista") in cooperation with Lundarskóli, a primary school in Akureyri.

2 Higher education courses and study programs

Subject-related courses and experience As highlighted in my C.V. (which accompanied this application), I studied chemistry and biology at the undergraduate level at the University of Toledo (United States) from 2002 to 2006. During my time at UT, I worked as an undergraduate researcher before getting a job in the chemical industry at Perstorp Polyols as a lab technician where I worked for 4 years (2003-2007). After immigrating to Iceland in 2008, I completed a B.Sc. in biotechnology (2014) and an M.Sc. in natural resource sciences (2015) from the University of Akureyri. I then completed my Ph.D. in biology at the University of Iceland (2019) which focused on the amino acid and related catabolism of *Thermoanaerobacter* species. To date, I have published 21 research papers and 8 book chapters within fields related to microbiology and organic chemistry.

Pedagogy-related courses: I am currently working towards my M.Ed. (120 ECTS) at the University of Akureyri for which I have completed 70+ ECTS credits as of spring of 2021. I did my praxis at Akureyri Junior College under the supervision of Brynja Finnsdóttir (autumn 2020) during which I taught part of a module on cell biology to third year students and adapted practical experiments such that they could be performed at home (due to COVID restrictions). I have already started working on my M.Ed. project which is aimed at investigating the status of

scientific literacy in Iceland, particularly among educators. Additionally, I completed a 10 ECTS course for university educators at the University of Akureyri Centre for Teaching and Learning (Kennslumiðstöð, KHA) in the autumn of 2019.

3 Higher education teaching experience and supervision

Over the past decade, my teaching responsibilities have ranged between 60-75% of my time. Course supervisor stuff. The individual courses which I have been involved with are listed in **Appendix X.C** as are a list of the undergraduate and graduate students that I have supervised (**Appendix X.D**).

Teaching within the Faculty of Natural Resource Sciences

From 2009 to the spring of 2016, I served as a teaching assistant for the laboratory sections of a number of classes (mainly chemistry and microbiology) at UNAK's Faculty of Natural Resource Sciences. From 2016 onward I have held an adjunct position where my involvement at the undergraduate level spans all three years with me teaching at least one course in each academic year. In 2012, I co-developed the 2nd year undergraduate course in Biochemistry (LEF1106200) where I designed the laboratory part of the module and was responsible for the lectures relating to amino acid and protein chemistry, enzymology, carbohydrate chemistry, and lipids. After being formally appointed as an adjunct in 2016, my teaching load was 75% until it was reduced to 60% in the autumn of 2019. From the autumn of 2019 onward, I have served as the course supervisor for Biotechnology (LFT1106120), a first-year course for students entering the biotechnology program. For the autumn 2021-2022 school year, I am supervising Microbiology (ÖRV1106200), Biochemistry (LEF1106200), and Microbial Biotechnology (LÍÖ1106200). I have also developed and supervised a number of courses at the graduate level including several literature courses and a course focused on biocatalysis (SVA1106).

Teaching within the Faculty of Education

In the autumn of 2018, I started co-teaching undergraduate courses at UNAK's Faculty of Education as a collaborative effort with Brynhildur Bjarnadóttir; as a part of this effort, I developed hands-on course content to supplement teaching topics relating to chemistry and biology. Initially, this included Natural Science and Natural Science Teaching (NÁV0156160), and Natural Sciences in Study and Play (RVN0156160). In the autumn of 2020, I was additionally asked to formally join the department to supervise the course Math and Math Education (STÆ0156090). More recently, I have been involved in teaching science literacy-related courses in the Master's program in the teaching department – Reading for Education (LNÁ1510160) and Reading for Understanding (LES1505160).

Supervision

The supervision of undergraduate and graduate students is among my favorite aspects of educating and is of great importance to training the next generation of innovators. To date, I have been the primary-supervisor of 5 B.Sc. students completing their final projects (12 ECTS)

within the field of biotechnology. I have also served as the primary supervisor for 3 M.Sc. students conducting project work (90 ECTS) in fields relating to bioprocessing or biocatalysis. My first M.Sc. student (Pia Iloranta), carried out a project on the seasonal variation and bioprocessing of macro algae, with me as her sole supervisor from 2016-2018. Unfortunately, she has yet to defend her work. I currently have two M.Sc. students, Eva María Ingvadóttir (2019-present) and Lisa Wrogemann (2021-present) for whom I am the sole supervisor. I have also been a co-supervisor with Jóhann Örlygsson for an additional 3 M.Sc. students; in these instances I was primarily responsible for the direct supervision of their laboratory and writing tasks. I have also supervised over a dozen Erasmus undergraduate and graduate students from all over Europe doing practical placements in the laboratory (typically 3 to 6 months). A more detailed description of my supervision experiences can be found in **Appendix X.D**.

4 Pedagogic activities – description, reflection and development

In this chapter, I will primarily focus on my teaching journey with an emphasis on the evolution of my practice. I will highlight some of the challenges and moments that have influenced my teaching philosophy. In latter sections I will focus on my teaching work within the sciences with some exploration of my work with the intersection of science and education. A number of letters from my direct teaching supervisors and students, past and present, can be found in **Section X.E.**

Unlike many other university educators, I see teaching as a primary part of my job rather than something that I do out of obligation. When I was an undergraduate student at the University of Toledo, I floated the idea of doing a degree in education after completing my education in the sciences so as to be better equipped to teach at the university level in the context of an academic position. I found it rather odd that the department chair scoffed at such an idea and quickly brushed it aside with a comment like, "that's nonsense. Once you have a Ph.D. you'll be more than qualified to teach!". Given the highly variable quality of teaching that I have observed, I think that this attitude is ubiquitous and highlights a fundamental problem with teaching in higher education. Having a doctorate is not enough to be an effective educator and as such, I´ve strived to become a thoughtful educator with my students learning in mind as I´ve actively pursued becoming a more competent teacher as I outline herein.

4.1 My teaching philosophy

As an educator, I want to help ***every*** student learn, regardless of their background or challenges. One of my major goals as an educator is teaching the next generation of scientists and educators to become critically minded, responsible life-long learners. This requires an approach that nurtures strong critical thinking and problem-solving skills, with the aim of empowering students to take in and evaluate new information as active self-directed learners. I envision my role as an educator as more of a guide and a facilitator that helps students on their journey rather than an arbiter of arbitrary grades. I strive to guide students towards building a better understanding of problems, whether in the lab or in the classroom, and empower them to create solutions. My approach to this task is simple in principle: I try to be an authentic exemplar of curiosity by constantly asking questions aloud in an attempt to highlight the metacognitive processes that I use to solve problems and gather information. If I have done my job correctly, my enthusiasm for teaching and learning should be infectious.

My teaching style places a strong emphasis on my relationship with my students; it could be described as authentic, genuine, open, honest, helpful, and approachable. I set high standards that are both transparent and achievable. I am flexible and enthusiastic. I emphasize good communication with my students and take an interest in their academic and personal well-being, listening to their perspectives.

I use a wide range of activities. Lectures intermixed with demonstrations, hands-on practical courses that range from simple technique-focused lessons to open-ended semester-long projects, field work, etc. I try to invite experts from the field into the classroom and include real-world examples when introducing new topics. I set clear expectations on the “front-end” (e.g. in the form of detailed grading rubrics) while also supplying students with clear, robust, constructive and effective feedback on their assignments on the “back-end”.

My approach to teaching emphasizes curiosity and authenticity; both of these virtues are central to teaching and scientific inquiry. Education is not “one-size fits all” and I try to take a flexible approach and encourage students to take chances. One of my aims is to develop a culture of learning and cooperation between students, e.g. by encouraging them to help me craft the courses I supervise by adding their own experiences and ideas. A lot of my laboratory activities are designed to encourage and facilitate contact with the instructor and their peers, and frequently include references to my own research and other relevant real-world experiences.

I am of the opinion that teaching quality is best measured by student outcomes. I systematically collect student feedback (and have even started offering points for it, such as to send the message that both the time students take to complete my “end-of-semester” surveys and the information they pass on is valuable and represent a tool for course development) as well as informally soliciting student commentary and critique throughout the semester. Another way in which I measure my own success is by the successes of my students. I routinely have students from years past reach out for collaboration or consultation on problems that they are having in graduate school or in their careers.

Similarly, the continuous improvement of me as an educator is dependent on student feedback. I actively solicit feedback from my students, whether it be informal or anonymous. I try to demonstrate what students have taught me over the years by relaying anecdotes (like the students informing me that it is *retardation* factor NOT *retention* factor) or making it known how former students have made contributions to the learning environment (suggestions, etc). I have also started asking experienced students to write reflections and “advice” that I share with first year students at the start of the semester.

4.2 Pedagogical theories and background

As an undergraduate, I quickly came to realize that few educators at the tertiary level have any interest in teaching beyond ticking a box such that they can collect a paycheck. That said, there were a number of university faculty members that did strive to be good educators and even used the language of pedagogy to explain their aims and approach. This only served to reinforce my own interest in learning *about learning* such that I could hopefully one day help the next generation of learners.

When I started teaching at the undergraduate level, I came across The Seven Principles for Good Practice in Undergraduate Education (Chickering & Gamson, 1987). While many of these principles seem like common sense, I was struck by how often these concepts are not practiced in the classroom and not having a background in education at the time beyond my own experiences, this seemed like a logical place to start. When soliciting feedback from students, I often show them Figure 1 and ask them to reflect on how I have measured up against these pillars.

Figure 1 – The Seven Principles for Good Practice in Undergraduate Education

As an educator, I strive to set high, but achievable learning goals and work with students to actively achieve those goals, which often necessitates a flexible approach. I definitely stress the importance of student/instructor contact and try to develop a culture of cooperation and learning among students. The big question of course: how can this be accomplished organically?. Fortunately, some of the ideas pertaining to inquiry-based and cooperative learning below offer some insight into this issue.

The professional standards for educators in the UK (from *Becoming an Outstanding Primary School Teacher*) offer some criterion with which I try to hold myself in my effort to be an effective teacher (Grigg, 2015; p 7). I have found these to also be a succinct and useful framing of the metrics by which educators should be held.

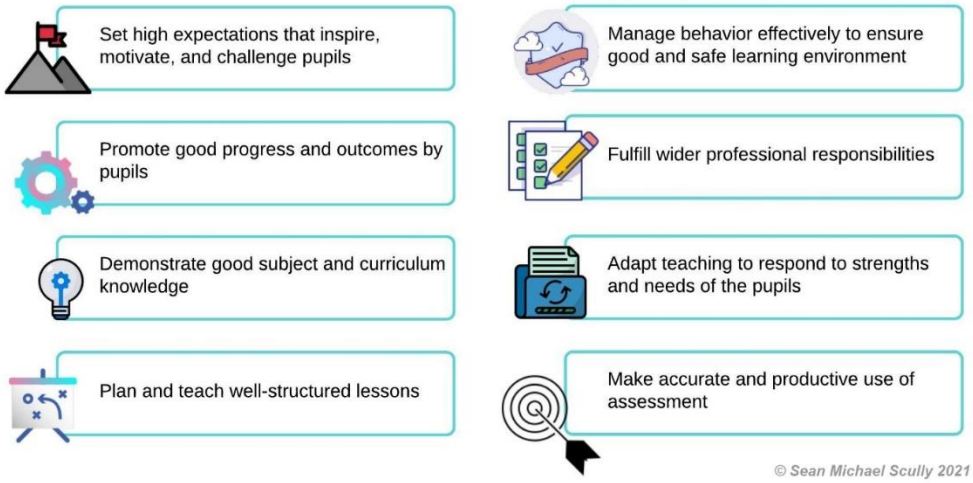

Figure 2 – UK Teacher Standards

While the these standards are primarily intended for primary and secondary school educators, I have found them to be a succinct reminder of my responsibilities as an educator.

Expanding on this, it was in my early 20s, a departmental colleague showed me a YouTube video that described Bigg's ideas regarding aligning teaching practices with the desired outcome to help students actively construct knowledge (i.e. Constructive Alignment). The language that Biggs used in his works describing constructive alignment was my first real exposure to pedagogy and proved to be gateway to the field. I was so impressed with Bigg's work, that I ordered *Teaching for Quality Learning at University* (Biggs & Tang, 2011).

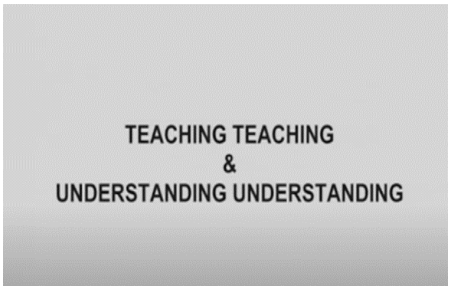

Figure 3 – The John Bigg's-inspired *Teaching Teaching & Understanding Understanding* ,produced by Aarhus University, which can be viewed on Youtube

Bigg's provided me with a lot of context and terminology to help me better understand the learning process (ideas such as metacognition, constructivism, reflective learning) to kick-start my journey to becoming a better educator, notably the SOLO taxonomy (Biggs & Collins, 1982) which has provided invaluable in helping to structure courses as I navigated the dizzying array of pedagogical theories and practices out there in search of a good fit for my own teaching.

Given the content areas in which I teach, the scientific method represents the “central dogma” of what I´m trying to teach. Unfortunately, at least in my experience, the underlying virtues of scientific inquiry, such as curiosity, are often lost in the format of a traditional lecture aimed at dispensing information to passive students. Reducing science education to “teaching facts” does little to prepare students for the realities of working in a science-related field as many of my non-education students end up in the industry or pursuing further education. Being cognizant of this, I have attempted to infuse my teaching efforts with authenticity and curiosity. I have found that a number of tools are helpful in these endeavors to give students a real look at how science unfolds “at the bench” and have been equally helpful in demonstrating how my education students can approach science.

The **inquiry-based learning model** closely mirrors the process of scientific inquiry (Figure 4) which is one of the characteristics that attracted me towards using it, particularly in my upper level classes. The ‘Evaluation’ phase is particularly relevant as it describes how students use their work to connect prior knowledge to new ideas while reflecting on their learning. Inquiry-based learning comes in several variations including problem-based learning, cooperative learning, collaborative learning, guided inquiry, among other variations. A variation of guided inquiry model is the 5E Model of Instruction (engage, explore, explain, extend, evaluate) formulated by Roger Bybee which, while not useful for my science students, is a highly useful tool that I use to teach my education students to use in the aims of teaching science (Bybee, 2009; Bybee, 2005, 2014; Bybee & Landes, 1990).

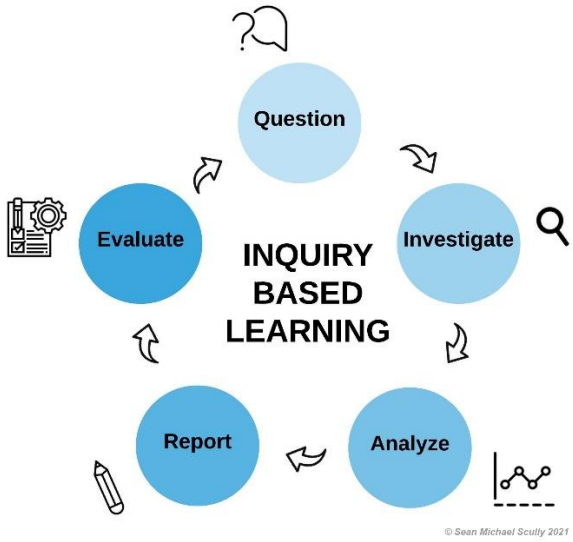

Figure 4 The inquiry-based learning model

A variant of inquiry learning that is, however applicable to teaching science to undergrads, at least in my context, is cooperative learning. Cooperative learning (CL) is a method of teaching and learning in which students team together to explore a significant question or create a meaningful project and I have tried to emphasize, especially in the laboratory "heavy" courses such as microbial biotechnology. As such, CL has evolved from a number of earlier pedagogical philosophies including constructivism, the zone of proximal development, and social theories such as positive social interdependence. Cooperative learning as described by Johnson and Johnson requires five key elements to be effective: positive interdependence, dynamic interaction, a combination of individual and group accountability, effective cooperation, and group processing (Barkley et al., 2014; Johnson et al., 1994).

One particularly interesting aspect is the role of student motivation in CL. In order to create a truly cooperative space where students meet learning objectives through a combination of individual and group activities, it is helpful to understand how students can be guided into learning. (Cohen, 1994) argues that motivating group members is among the most crucial elements to the overall success of the group and highlights the need for both resource and goal interdependence to achieve this. In science, one of the primary drivers of learning activities (i.e. experiments) is curiosity. Slavin´s work (1996) stresses the importance of social reinforcers, such as praise and encouragement, and the need for positive rewards structures as opposed to 'traditional' techniques such as grading or informal reward structures which can cause negative responses from poor performing students and create social issues for the higher performing students receiving the reward.

One of the critical elements of CL is creating positive interdependence; to this end, cooperative learning, and to a lesser extent collaborative learning, can be viewed as a form of social engineering. Johnson and Johnson repeatedly stress that the two crucial steps in creating positive interdependence involve having shared goals within the group and using social mechanisms to reinforce interdependence; these can include shared group identity, shared group rewards, resources, and so on (Johnson, Johnson, & Holubec, 1994, p 51). Studies have shown that positive reward interdependence leads to better outcomes (Buchs et al., 2011) with more positive peer group relationships and achievement being linked to cooperative (rather than individual or competitive) objectives. Resource interdependence is also a critical element to ensuring positive perceptions of mutual support (Bertucci et al., 2011).

The act of group processing involves persons within the group actively reflecting and making decisions about next steps (Johnson & Johnson, 2009). While not all proponents of CL include group processing as a function, a study conducted using university students demonstrated that CL conditions which included either teacher- or student-facilitated group processing resulted in higher achievement and better problem solving capabilities (Johnson, Johnson, Stanne, & Garibaldi, 1990). I would argue that the description of group processing provided by Johnson and Johnson insufficiently captures the value of reflection, particularly when groups are faced with complex problem-solving challenges. Johnson and Johnson strongly emphasize the social nature of group processing but ignore the fact that it is at this stage that students are actively engaging higher-order thinking skills (so-called "HOTS"). Studies also suggest that collaborative learning supports critical thinking skills (Gokhale, 1995).

Another highly useful concept that I've invoked in much of my teaching, particularly given the hands-on nature of science instruction, is David Kolb's Experiential Learning Cycle (Figure 5) which provides a framework for building a basis for crafting learning experiences as a tool for learning (Kolb, 1984, 2015).

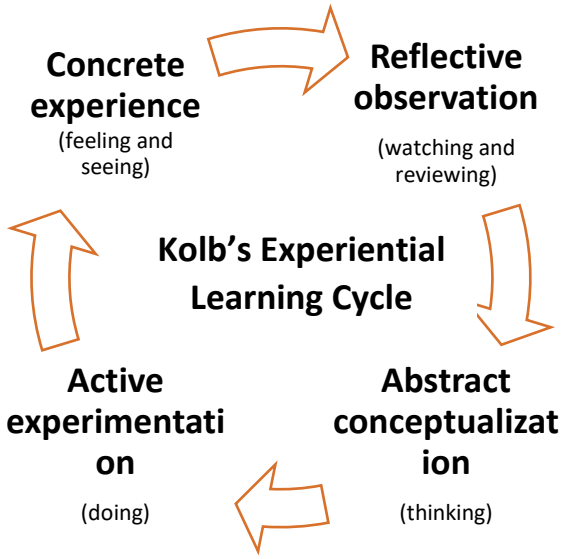

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Figure 5 – Kolb's Experiential Learning Cycle (modified from Baker et al., 2005)

By building on the knowledge and skills gleaned from their own experiences, they can build understanding while aiding knowledge transfer. Furthermore, by having students take their conceptualizations and make testable predictions through experimentation, they can transform "play" into actual understanding through reflecting on this process. Much like the previously mentioned inquiry-based learning models, this too mirrors the use of the scientific method. It goes without saying that critical reflection and discourse are incredibly important aspects of experiential learning and by incorporating these aspects into collaborative inquiry projects, students can help collectively build understanding.

One issue that has proven to be of importance is that of student engagement, particularly in the context of distance and asynchronous education. An early frustration that I experienced in my early lectures was a lack of attentiveness among attending students while data suggests that distance learners seldom engaged with lecture recordings. While I will not go into depth here on the nature of student engagement, research has shown that active learning strategies improve student engagement (as reviewed by Prince, 2004) and this has been among the chief aims of my pedagogical efforts.

An interesting concept in educational psychology that has shifted the way that I think about teaching is metacognition ("thinking about thinking" or awareness and control of one's own thought process). Since sharpening our cognitive skills is a part of higher education and very important in terms of developing critical thinking and problem solving skills, how do we *teach* metacognition to students? Johnson, Johnson & Holubec (1994) reason that the most effective way to assess thinking is "(...) by observing students *thinking out loud*". In the classroom, I´ve found that this is often best accomplished by asking students to reason through problems or questions verbally. I try to highlight my own metacognitive processes for students in a number of ways. I wonder aloud, I ask questions. I observe. I speculate. I formulate 'thought experiments'. Indeed, this seems to work and when done with groups of students seems to aid group processing.

4.3 Let´s get into it: course plans and student data

Student evaluation data (collected by the University of Akureyri) for the courses that I have been involved with are provided in Figure 6A. It should be noted that the number of responses and the overall percentage of participation has varied often resulting in a sample size that is not statistically useful. Additionally, some terms are missing data all together and student comments were not collected by the University in 201X and 201X. Student evaluation data for my performance as an educator is given in Figure 6B.

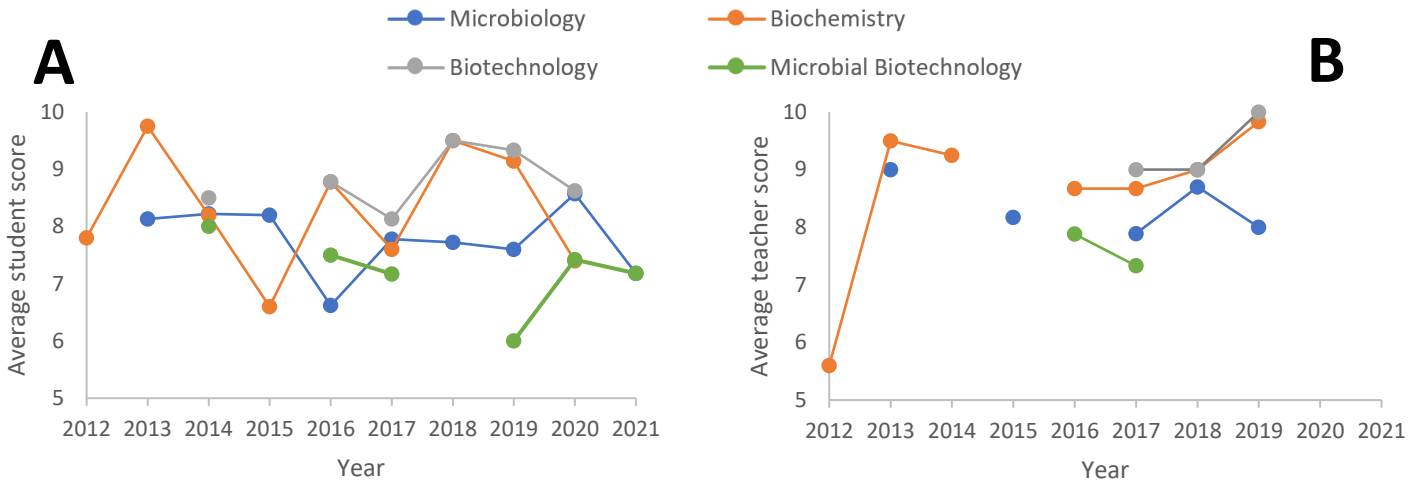

Figure 6 – Student evaluation data for selected courses with my involvement. A – course scores, B – instructor (SMS) score. Note that data from my work in the Department of Education is not shown due to lack of student response.

At the beginning of each term, I stress my commitment to continuous improvement in my teaching and encourage students to provide feedback as well as sharing prior critiques from students and how I have tried to address them. During instruction, I often check for understanding and openly reflect on how things are going and encourage students to openly share their comments and opinions.

My initial experiences teaching were problematic, as evidenced by the average score of 5 awarded as an instructor in biochemistry in 2012. I can attribute part of this as a mismatch between my education in the United States and failing to understand where my Icelandic undergraduate students where at. Students from my early attempts have certainly made clear that I had high expectations. Reflecting on the seven principles, I decided to emphasize three which greatly informed my own teaching philosophy: contact between students and faculty, active learning, and prompt feedback. To help bridge the gap between the expected objectives, I starting advertising an “open door” policy in which I would tell students that they could drop by at any stage of their writing process (particularly important for lab reports and projects) or just to discuss challenges with learning the material. I also encouraged students to work together and use each other as resources although this has often proven to a be a challenge with distance students.

Student comments have been an excellent source of constructive feedback, however, as student comments are no longer actively collected, I have been collecting data on student attitudes and background as well as their feedback on specific courses using Google Forms since 2017 with a strong emphasis on my first-year microbiology course and the mathematics course that I teach. At the end of each term, I encourage students to participate in an anonymous online survey for which I´ve now collected more than 5 years of data which also includes information about not only their course experiences, but also their confidence with lab techniques, scientific literacy, and so on.

Specific issues Early in my teaching efforts I found that students were often poorly prepared for practical work to the point that it created and unsafe learning environment. Additionally, many students had trouble completing laboratory tasks in the allotted time. To resolve this issue, I implemented pre-laboratory exercises selected for their learning level within their perceived zones of proximal development. In first year courses (i.e. microbiology), they complete a simple guided worksheet designed to get them to engage with the safety and procedural aspects of the work. At the second and third year levels, student must write their laboratory plans for their experiments directly into their lab notebook such that their notebook becomes the primary "go to" source of information rather than the directions.

Another issue that I´ve encountered is that many students are not familiar with the traditional lab report format and consistently making the same errors such as not italicizing Latin names, not placing the purpose statement at the end of the introduction, and not displaying numbers with an appropriate number of significant figures. In an effort to force students to review the comments and corrections made during grading, I made the decision to place the grading rubric at the end of returned lab reports.

Students, particularly high-achieving students, have often complained about poor partner performance for group assignments, namely laboratory-related assignments. This has resulted in adding a requirement of a "contributions" section at the end of reports and allowing students to work solo.

Over the past several years, I have noticed declining engagement with the course modules that I teach. This has manifested in several ways: decreased class attendance, showing up unprepared for laboratory practical, and decreased viewed hours of recorded lectures. Apart from taking on a full course load, students tend to work full or part time, and have other time-consuming obligations including family life. This causes me to compete for the student's attention and engagement with their other tasks. One of the ways that I´ve tried to combat this is by offering discussion sections and increasing the number of smaller deadlines ("chunking").

An often discussed topic in university education is highlighting the ‘cutting edge’ of research. I´ve found that this is often a useful engagement tool in its own right while also serving to talk about areas of active research. I often make a point of talking to my students about what is going on in the lab, typically in a very casual manner. Sometimes this is as simple as talking about a “cool” observation that I made or something that went horribly wrong (sometimes comically so!). I make an effort to talk about some of the challenges faced in the lab on a day-to-day basis and what I am currently investigating with my research group. This has lead to enhanced engagement with the students and sometimes students have provided invaluable suggestions for dealing with specific problems

4.4 Moving beyond “just” lecturing (Biochemistry)

My first major opportunity to develop pedagogical material at the university level was through developing the Biochemistry (LEF1106) course with professor Jóhann Örlygsson in 2012. Previously, my contributions had been limited to designing and implementing single experiments. I helped design the course from the ground including chapter selection and designing the laboratory (which is discussed in more detail a later section). As a student, I have never found the traditional lecture format to be a particularly good means for learning information. My own experiences as a student of biochemistry had been disappointing. The content was straight from the book with an emphasis on rote memorization with critically thinking about the material, which is incredibly important for understanding the chemistry of life, being completely non-existent. Reflecting on the instruction I actually *remember* from my own education, all had a common element: something *interesting* and *real* associated with them so I felt that this was an opportunity to make the content come alive. That is to say, the teacher created a memorable ***experience***.

Scaffolding is a critically important concept in appreciating how more advanced topics in chemistry need to be taught; fundamental principles of how atoms and molecules work are built upon and used as a basis for developing a deeper understanding of how the simple phenomenon that govern how molecules behave give rise to complex structures such as proteins which have emergent functions of their own but still have their very basis composed of those fundamental rules.

After my first few years of teaching this course, I found it necessary to heavily review many of the fundamental concepts from the first year chemistry courses (such as molecular forces) to make sure that students have a sufficient basis to build their understanding of protein structure and function upon. One way that I have done this is by dedicating lecture time to this review (not the most innovative approach) and coupling it with a computer program (called "Foldit") which walks students through the process of protein folding[1].

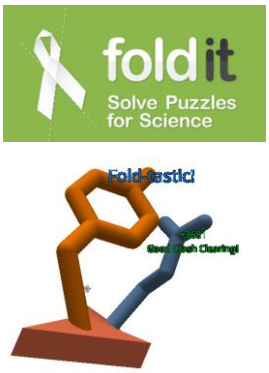

Figure 7 - A screenshot from Foldit during an initial task involving resolving steric clashing

Students have responded positively to this approach and if the exam responses over the years are any indication, it seems that this has greatly improved their understanding of these interconnected topics. The impact of this is most visible in the following academic year where students can apply the protein structure and function concepts to applied cases in the Microbial Biotechnology course.

On the topic of teaching protein folding and catalytic function, these subjects present an excellent opportunity to highlight real-world challenges and introduce a layer of critical thinking on to the basic concepts present. As an example, a discussion section strategically placed after the protein structure and enzymology chapters asks students to ponder some truly challenging and authentic problems. For instance, I'll remind students at the start of the discussion of how the knowledge covered up to this point is based upon our understanding of how the enzymes from mesophilic organisms (i.e. organisms that function at modest temperatures between 20-45 °C). But how do we explain how enzymes have adapted to environmental extremes like hot springs that are above the boiling point of water or those found in organisms that survive under the extreme pressures of the ocean floor? How much have these systems evolved in atmospheres totally different from ours (such as on Mars or some exoplanet)? How can we modify enzymes to function differently?

The questions touch on a lot of interesting questions relating to extremophiles, astrobiology, and the very origins of life! In my experience this discussion usually starts with a bit of silence for which I've prepare prompts. Every time I've done this discussion exercise, the class goes somewhere different. Students are often scared to venture beyond safe answers but I ask them to trust me and with time, I've watched them open up. Even when students come up with "crazy" ideas, I'm ready to push back by asking, "Okay. So how could we *test* that idea?".

[1] Which I maintain is still a lot more fun than folding laundry!

Over time, I wanted to integrate a greater variety of experiences into the "traditional" lecture setting to better engage the students by using ***active*** and ***experiential*** learning. Thinking back to the memorable experiences that I had in chemistry, they often had one thing in common: an educator that tried to bring the subject to life by pulling the content from the real world into the classroom through demonstrations, hands-on experiences, etc. Within the field of biochemistry, this is a little bit more challenging given the more esoteric nature of the subject, but I like a challenge. With each year, I have added a hands-on or visual demonstration to accompany each lecture theme.

The use of meaningful in-class demonstrations has proven to be a great **experiential** tool for helping students with particularly challenging concepts.

As an example, a concept which students often struggle with is the idea of chiral molecules. Responses on the exam on stereochemistry-related questions definitely highlight that this topic required action. So to provide a vivid and relatable experience of this phenomena that students could relate to, starting in the autumn of 2014, I started making cupcakes (Figure 8) and bringing them to lecture (distance students can collect their cupcakes when they show up for lab). Each student gets two cupcakes: one with caraway(dill)-infused frosting (*S*-(+)-carvone) and the other with spearmint-infused frosting ((*R)*-(+)-carvone).

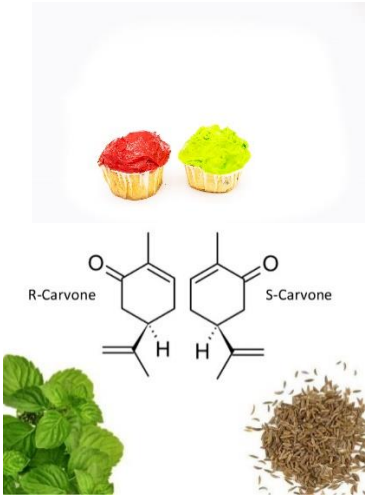

Figure 8 - Cupcakes infused with (R)- or (S)-carvone.

Interestingly, the spearmint-flavored cupcakes prove to be more popular with the students. Based upon the greatly improved quality of exam responses in this course (and indeed, this carries on into my high level courses), this experience seems to have an impact. I still have students fondly recall this experience when I come across them years later.

Building on these successes, I´ve introduced other (hopefully) useful and relevant experiences as summarized in the table below. Not only is each of these activities designed to reflect the lecture's content, it attempts to coax the students into using their observational skills.

Table 1 - Selected in-class demonstrations/hands-on activities that I use to teach undergraduate biochemistry

Activity	Chirality cupcakes	Fold it (Software/ game)	Egg white denaturation	Jello setting in the presence of pine apple	Action! On! starch!	Sugars are sweet?
Year introduced	2014	2013	2018	2017	2019	2015
Concepts	• Enantiomers	• Molecular interactins • Protein folding	• Protein denaturation/renaturation • Enzyme function	• Protein denaturation • Enzyme function	• Enzyme kinetics • Enzyme parameters	• Ligand-receptor interactions • Hydrogen bonding

Another useful tool that I've tried to apply whenever possible is **Teaching with Analogies (TWA)** method pioneered by Shawn Glynn and Mary Gick (Gick & Holyoak, 1980, 1983; Glynn, 1991). While the use of analogies is nothing new in teaching, with even the famed Robert Oppenheimer of Manhattan Project notoriety espousing their utility (Oppenheimer, 1956), their use is particularly useful for helping students visualize abstract concepts.

The textbook for this course, *Lehninger Principles of Biochemistry*, has a beautiful analogy to help students understand how enzymes function by encouraging the formation of the transition state of a substrate by squeezing it into a shape that permits a reaction to move forward. In this instance, the book uses the analogy of 'stickase', a hypothetical enzyme that speeds up the reaction of sticks breaking (Nelson & Cox, 2008, p 196) as shown at the right.

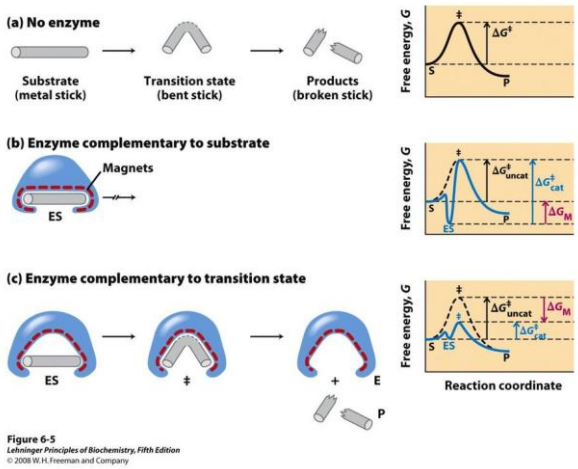

Figure 9 -The use of the 'stickase' analogy (Nelson & Cox, 2008)

I decided to use a more illustrative and 'hands-on' analogy as breaking sticks in this manner is not only quite difficult (and potentially embarrassing for the instructor), it can be dangerous. Furthermore, brining this analogy to life is quite challenging. Thus, I decided to use my own analogy using some Christmas tree decorations (which may or may not have been broken by the instructor) for which I can demonstrate a hands-on variation using plastic bulbs.

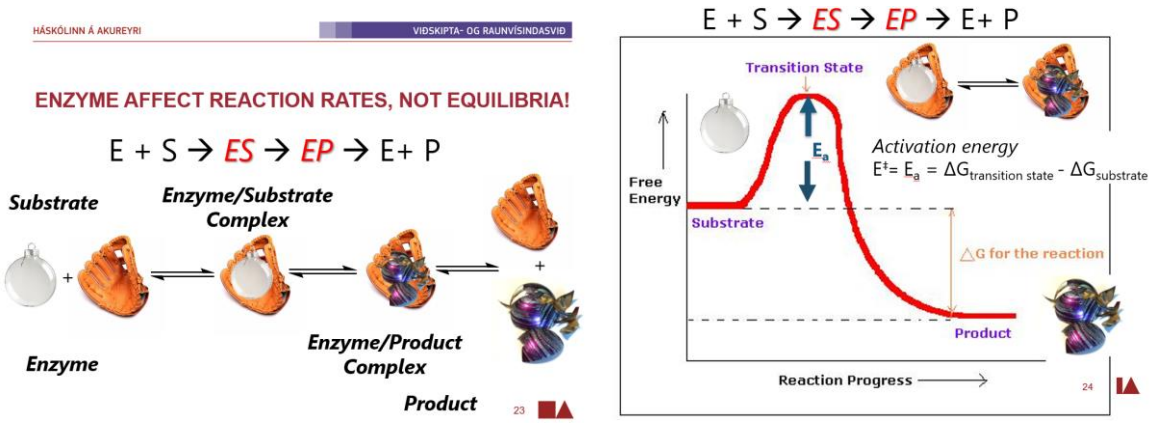

Figure 10 - "Christmas-bulb-decoration-ase" - an imaginary enzyme analog designed to destroy my significant other´s favorite decorations?

Students can “feel” the tension on the plastic Christmas tree bulb and understand how the enzyme “squeezes” its substrate to get it to break. Many students have remarked that this analogical approach has been extremely helpful.

4.5 Cooperative learning in Microbial Biotechnology

One of the aims that I have for my advanced undergraduates is to get them to become more independent in planning and executing their own work. An associated major challenges that a lot of students seem to struggle with is the idea that there is not just one correct answer in approaching a lot of lab work and when thrown into a problem where explicit step-by-step instructions are not provided for them is often jarring… and yet reflects the real-world and how science *actually* works.

To help students meet this bar, I began using a problem-based learning approach to their third year Microbial Biotechnology course in which they are presented with an authentic problem to solve. Some years ago, it was making bioethanol from lignocellulosic biomass or making chiral alcohols using baker´s yeast and ketones. This coming autumn (2021), the problem will be making bioplastic from industrial hemp using bacteria. While each of these tasks may seem incredibly different, they ultimately all share some basic elements. Each term, I start with a lecture on the topic, which I frame as presenting a real-world problem… and microbes (or their enzymes) are the answer! I tell them what´s available (such as microbes, protocols, equipment, etc) and what the goal is, which in this case instead of a lab report is an actual manuscript that could get submitted to a peer-reviewed journal. Students form small cooperative groups, often with a mixture of ‘local’ and ‘distance’ students.

At this point, I step back and let them plan. I´ll meet with groups informally and discuss ideas or offer suggestions. My goal here is to act more as a resource and facilitator as opposed

‘traditional’ teacher. Some students have required more guidance than others and I maintain an “open door policy” throughout the process.

The student response to this approach is usually a mixture of hesitation and anxiety at first but, at least in the handful of years that I´ve been doing this, students quickly come in to their own. Most students have told me that they enjoyed the challenge of getting to do something real and having a deliverable other than ‘just another lab report’. To date, at least one group of students even got their work published in an undergraduate journal, *Fine Focus*, although most groups fall short

4.6 Teaching how to teach: my first forays into education

As a scientist, I have always been taught that a part of my job also involves education, whether it is outreach to the general public, teaching in the classroom, or inspiring the next generation of teachers to bring science to life in the classroom. I began collaborating with Brynhildur Bjarnadóttir formally in the autumn of 2018 where she allowed me to restructure and update the biology and chemistry-related topics within her course, Natural Science and Natural Science Teaching (NAV0156, autumn 2018).

Unlike my previous attempts at teaching, the emphasis in this instance was as much on the science content as it was on being a good exemplar of effective science education. After reflecting on the positive science educators that I have had in my past, I decided to reach out to a few them of them. What I gleaned from these reflections and conversations was that there are a few essential elements to good/effective science education:

- Exploration/inquiry
- Enthusiasm
- Thoughtfulness
- Humility (just say you don’t know!)

With each lecture theme, I carefully crafted a hands-on component and demonstration that teachers could actually use in their own teaching. The initial assessment was quite disappointing. Students had a difficult time answering basic content-area questions and often struggled with applied content area questions (i.e. *how would you teach xxx?*). I reached out to a number of students who revealed that they lacked confidence. The following spring, Brynhildur insisted that I participate in her course Natural Science in Education and Play (RVN0156 spring 2019). It was during this course where I tried my now somewhat infamous “box of junk” activity.

A box of junk: doing science with bootstraps and shoe string

Teaching critical thinking and innovative approaches to teaching the scientific method can be a challenge for persons lacking content area knowledge. That said, the challenge of creating authentic, hands-on science activities for students using common items presents an interesting task that requires teachers to 'think outside of the box'. So to exploit this idea, I "designed" an in class activity for small groups of students to work collaboratively in small groups (3-5) that involved a box of items (Figure 11) that I put together from materials laying around and could be easily obtained by teachers with access to a grocery store. Given half an hour, the students were required to design an experiment with at least two variables and that could be accomplished using the box contents and whatever else might be around in the lab environment if and only if that item was likely to be something that a teacher could access.

Box contents

- The box (not shown)
- String
- Balloons
- Baker´s yeast
- Aluminum foil
- Dish soap
- 3% hydrogen peroxide
- Plastic cups
- Soil
- Fertilizer
- Seeds
- pH paper
- Assorted household chemicals
- And much, much more!*

Figure 11 – The "what´s in the box?" approach to teaching teachers experimental design on a literal shoestring budget

*Batteries sold separately

At the end of a collaborative planning phase, the groups of students meet and share. Watching this activity unfold over the past few years has yielded some interesting results. Some students, having seen my work elsewhere, designed experiments on getting hydrogen peroxide to breakdown using different given chemicals. One group even observed that the yeast can do this. Another group, much to my surprise, opted to put the table sugar in a balloon with some of the Baker´s yeast, seal it, and run it under different temperatures of water using the tap. Interestingly, no one to date has thought to use the seeds and soil to do some sort of experiment with growing plants and measuring them, which at least in my mind, is the most obvious experiment to design.

This exercise integrated many of the inquiry-based learning techniques discussed earlier. While this activity has been positively received by most students, with some even saying it gave them

ideas of their own, others found this exercise overwhelming or of little practical value. Particularly troubling is some participants failed to understand the point of control experiments even after discourse with the wider class and despite covering this concepts *prior* to coming to lab.

In the future, I´m considering preceding this activity with a simpler inquiry activity designed to get students of education to develop their observational and descriptive skills using a box with an opening covered by a cloth. Participants will have to grab one item in the box and describe it in sufficient detail that the group can ascertain what it the object is.

5 Development of teaching materials and learning resources

Over the years that I have been active in teaching in both the laboratory and the classroom, I´ve designed a number of experiments, resources, and activities for my students.

	Biotechnology	Microbiology	Biochemistry	Microbial Biotechnology
Level	Undergrad (1st year)	Undergrad (1st year)	Undergrad (2nd year)	Undergrad (3rd year)
Syllabus	[link]	[link]	[link]	[link]
Lab manual	N/A	[link]	[link]	[link]

As detailed in the subsequent section, I have used a diverse range of teaching approaches in my courses. I try to carefully balance the historical/basic/timeless methods with modern approaches to solving problems in the sciences as I've found giving students a mix of tools not only gives them an appreciation for the history of science, it shows them how sophisticated science can be done when resources are limited. A good example of this is my reliance on "old-school" colorimetric methods alongside more modern (and time consuming!) techniques such as gas chromatography, HPLC, and NMR. Several examples of the teaching resources that I have used can be found in **Appendix X.E**.

5.1 Laboratory manuals and laboratory reports

When I began my work overseeing the practical portion of the microbiology course in the Spring of 2013, I had spent the previous six months thinking about how to improve the course outcomes based upon a number of problems that I had observed with students working in the laboratory on research projects, namely poor aseptic technique (the cornerstone of all work in microbiology), problems following multi-step directions, problems troubleshooting problems (critical thinking), and problems working with datasets. Up to this point, the microbiology laboratory was a collection of themed activities designed primarily to teach techniques.

One of the areas in which I have been most active is the development of laboratory manuals to accompany the courses which I have been involved in, namely Microbiology and Biochemistry. Both manuals are quite large and not included here although several examples are included in the appendix specifically in context of adaptations made for performing experiments at home.

The design philosophy of the laboratory sections that I teach is intended to shift students away from 'cookbook' style teaching towards more open-ended inquiry. The approach that is taken for each of the lab sections that I am involved in depends upon the year of study; students within first year courses have laboratory practicals which focus primarily on teaching techniques with some sprinklings of inquiry, while laboratory activities in the second year focus more on

multicomponent projects which require the use of multiple techniques, while courses in the third year are open-ended and fully built around inquiry.

Concepts which I routinely emphasize throughout the laboratory careers of my undergraduates are the importance of controls and reference materials in experiments, proper documentation, laboratory safety, experimental design, and Good Laboratory Practices. The ultimate purpose of laboratories is to teach students how to approach real-world science, whether in the context of research or in the industry.

Writing scientific text is a major objective for all of my laboratory course and to help students with the task of writing, I provide an 'template' document designed to help students through the writing process (**Section X.F**); included is a detailed rubric to help students reconcile what they write with the marks they receive. I also stress to students the importance of coming to terms with writing as a process and **high-quality feedback** has been identified as among the most important factors for effective learning (Hattie, 2009). As such, I´ve stressed to the students the importance of carefully reviewing comments. I remind the students that writing is a *process* that requires rounds of reflection and revision. The students that stick with the program often show great gains in the quality of their writing with at least one student reaching out to thank me as it now pays dividends in her job working in the biotech industry where she is required to write.

5.2 Biochemistry: development and pandemic challenges

This course is a second year 6 ECTS course offered to students within the Biotechnology study line although at least a dozen international students have enrolled in the course over the past decade. I co-developed this course in biochemistry at the University of Akureyri along with Jóhann Örlygsson in 2012. Since its inception, this course has been offered simultaneously as a distance or traditional course although the laboratory portion requires in person attendance (weekly for local students, twice per term for distance students). Although he has been the supervisor for the course until recently, I was tasked with developing half of the lecture material as well as the practical portion of the class.

The crafting of the laboratory was discussed in the previous section although I would like to note that I am especially proud of the laboratory portion of the course as when I took biochemistry at the University of Toledo there was no laboratory associated with the course at the time. As this is a second year course, the laboratory was designed with a purposeful shift away from the more "technique" oriented activities often associated with first year laboratories in favor of experiments which are more project based and require students to use multiple techniques.

5.3 Microbiology … @Home

My development work in microbiology started in 2014 with completely overhauling the laboratory portion of the class including crafting a new laboratory manual. I have tried to integrate more elements resembling actual research work (such as having student characterize and work with bacteria that have been isolated from around Iceland´s unique environments, I would rather focus on the development work that had to take place to work around the challenges associated with not having to work in the laboratory due to the pandemic.

Unsurprisingly, the 2019 pandemic had a significant impact on multiple courses that I teach that are highly depending on teaching students practical laboratory skills. While my microbiology course in the spring of 2020 was spared much of the disruptions that plagued many of my other courses, I realized that the following spring of 2021 was going to present a major challenge. While some teachers have opted to rely on "alternative" activities, it is my opinion that "virtual laboratories", writing essays, and so on do little to increase student confidence and fully address the major intended learning objectives of the practical side of the course.

Fortunately, the class could meet for half of the laboratory sessions (with 1 m of social distancing) so I carefully chose established laboratory exercises focusing on sterile technique and some other basic tasks in microbiology. Three experiments were adapted for the students to do home using materials sent with the students. The directions for these three experiments can be found in **Appendix X.G**.

Some student feedback regarding the @home microbiology experiments

"I wasn't very fond of them because of lack of experience which lead to not having much confidence in preforming them"

"I really liked performing the experiments and writing the reports. It was good to get a chance to perform some lab work while not being in a lab."

"I like doing at home experiments it increases my interest even more for this field of study than if I was doing them in the lab at the university so I think even after lockdown it should be a part of the studying process."

"I would feel more comfortable doing this at school with someone to help."

"Some of it was fine, but I have no prior experience with labs so I feel like I would have needed someone to hold my hand"

"haha, i already said it. It was difficult and lots of mistakes were made, but i guess we learn from our mistakes"

"It was very hard and bad information about how to do these experiments."

"it was difficult and took a long time"

"I loved them! I had major anxiety going to practical's for the first time this semester and being able to finish the rest of the experiments in the comfort of my home was nice. It also helps that Sean responds ASAP and offers help if there are any questions or concerns with the lab."

"i hated it. I dont like doing experiments alone without the support of a fellow student"

"I felt like they were to hard for us because we havent done anything like that before, and if I couldnt have asked a lot of people for help I wouldnt have been able to do them."

These comments represent the roughly even split between "positive' and "negative comments. Interestingly, the "negative" comments seem to highlight a lack of confidence among the students due in part to a lack of prior experience (which they were deprived of due to lockdowns in the autumn of 2020) or a lack of being able to rely on a group for information or guidance. While I did strongly urge many students to work collectively, a common response from the students was that they did not know whom among their peers to reach out to because they had been isolated. This really underscores the social nature of learning and highlights a real challenge with not only asynchronous distance learning, but also the hardships associated with being forced into social isolation. In the future, I will attempt to find ways of organically getting the students to come into greater contact if "normal" teaching does not resume in the 2021-2022 academic year.

5.4 Overall student feedback on teaching resources

A common complaint from students is the delay in returning written assignments; departmental policy allows me 10 working days to returned graded assignments. Given the nature of the feedback on reports that needs to be given, this is often impossible with more than one session per week. In order to at least partially address this issue, I've more vocally advertised an "open door policy" in which I will provide students with editorial feedback on report drafts prior to the deadline. I have also tried to more strategically place deadlines such that reports are returned before the next deadline.

Another common complaint, particularly among first year students, is that laboratory directions are not clear enough. After these comments, I asked several colleagues of mine to review my directions and they found only minor flaws. After reflecting on this a bit, I came to the

conclusion that students' lack of experience is a problem and directions, not matter how clear, may be abstract if they are not acquainted with the basics and lack confidence.

To better help the students visualize procedures, I've started to implement more flow charts into the pre-lab work or suggest that they use this type of visualization tool in their own pre-lab planning in more advanced course in the second and third year. Another addition has been to deliver short (5-10 minute) "pre-lab lectures" covering major topics and safety points; this has actually resulted in laboratory sections being completed by most students much more efficiently. Recently, I have begun making supplemental videos linked within the laboratory manual which provide a link to a YouTube video demonstrating critical procedures. This will be implemented in Microbiology in 2022.

6 Experience of leading and developing courses

Over the course of my teaching career, I´ve developed the laboratory practical aspects of many courses within the Department of Natural Resource Sciences. Here I am going to focus on my recent development work with an emphasis on developing and restructuring courses as the course coordinator.

The course Introduction to Biotechnology (LFT1106; 6 ECTS units), detailed in **Appendix X.G**, was established about 5 years ago and developed as an introductory course for students within the biotechnology study line at the University of Akureyri within the Department of Natural Resource Sciences. The course was adapted from an earlier course, Marine Biotechnology, which had come to serve the same introductory function. I inherited supervision of the Introduction to Biotechnology course (LFT1106) in the autumn of 2019.

I restructured 30% of the course using a **blended learning** approach to allow time for deeper discussion on specific topics of interest within biotechnology. Four lectures on the topics of proteins, biocatalysis, microbial biocatalysis, and bioethics were “flipped” in order to create time in class for discussion, using alternative media, and hands-on demonstrations of key concepts (such as column chromatography and stereochemistry). Additionally, a **focus on academic writing** was also woven into the course similar to the “writing across the curriculum” (WAC) model used at universities in the United States. Three biotechnology-centric writing assignments of increasing complexity were used to better develop student´s academic writing. Four mini-lectures on paragraph structure, writing flow, essay structure, and finding references were provided.

The changes to the course were received positively by the students whom especially enjoyed the greater flexibility offered by taking this approach balanced against the direct contact with the instructor. This was reflected in the end of term evaluation of the course as well as from positive remarks from students made in passing. Future work to improve the flexibility of the course will include the addition of self-guided laboratory experiments that can be accomplished at home that will reinforce vital skills introduced in other courses.

In an effort to diversity the course activities, I decided to use media to provide a foil for discussing the bioethics chapter in the textbook. In this instance, I selected the 1990 film, *Awakenings*, based on a book by Oliver Sachs which focuses on the dilemma of using untested drugs on patients. For the past few years, I´ve hosted screenings of the film while the students are on site during the distance weeks. Not only did this provide an organic method for getting the students to identify potential partners for future project work, the discussion that occurred

were surprisingly robust. Sadly, few students have caught on that the protagonist in the film is actually a re-named character portraying Oliver Sacks himself.

This past autumn (2020), I wanted to provide more guidance on scientific writing. To accomplish this, I added a small module in which the students worked remotely in pairs to do a small experiment aimed at identifying which types of enzyme chemistries are available in specific fish organs (liver, pancreas, etc). Students completed a short laboratory report based on several positive examples and some detailed guidance from me. A brief report that was submitted as a part of my annual evaluation for the 2019-2020 school year can be found in **Appendix X.F.2**.

Overall the changes to the course have been well received by the students and faculty alike. I would like to continue to introduce more variety by inviting guest lecturers with interesting jobs within biotechnology related fields to offer their firsthand perspectives on the subject. As always, the struggle will be to balance pedagogical value and class hours.

7 Development projects and dissemination

I have been active in discussion science and science education at conferences and seminars as listed in **Section X.H**. Unfortunately, I´ve been rather slow to publish much of my pedagogical work. I´ve submitted several articles to *Science in Schools*, and a number of manuscripts are in a draft state. Much of the development work that I´ve done in my courses may be of interest to other educators. It is my intention to publish a number of the experiments that I've designed for my undergraduate course in relevant teaching journals such as the *Journal of Chemical Education* and the *Journal of Biological Education*. The experiment involving the isolation of lysozyme has a number of novel elements and with the recent "modifications" to be done at home, these details could be of interest to those teaching courses in biochemistry or separation sciences.

A particularly interesting piece that I´m working on related to science literacy is the impact of the pandemic on student confidence with related lab tasks which is part of an on-going study that I´ve been doing for the past five years. Another nearly ready manuscript details some of the practical aspects of 'engagement' related to Bybee´s 5E instructional model (which can be made available upon request!).

One of my major "hobbies" is revitalizing the old-fashioned colorimetric methods used to quantify molecules using smart phones. I am also actively working on a problem-based learning modification of the classic ethyl acetoacetate reduction experiment that is typically seen in undergraduate organic chemistry courses. I've adapted a number of old-fashioned colorimetric techniques that greatly expand the possibilities for real-time monitoring of the this type of yeast-mediated reaction. Similarly, the facile colorimetric method that I've recently optimized and given to students to do fermentations at home may warrant writing up to relevant publications.

8 Pedagogic activities outside the university

I have been involved in a variety of activities outside of the university; a partial list can be found in **Appendix X.I**. Please note that I have not kept detailed records of my outreach work.

I am of the opinion that public science education is the responsibility of every practicing scientist and is something that I have been active in since high school. When I was in high school, I was a part of the *SciQuest* (a student-led science outreach program in Northwest Ohio within the Sylvania School district) outreach program for 3 years during which time my fellow students and I designed, prepared, and executed a series of six modular science lessons in chemistry, physics, and biology aimed at first grade students in the Sylvania area. These experiences gave me firsthand experience working with young students and seeing the power and ease with which their curiosity and enthusiasm for science can be exploited and built upon. As a student at the University of Toledo, I was a member of the local American Chemical Society chapter and participated extensively in planning and executing outreach activities such as demonstrations and chemistry summer camps for high school students. Even though this work is 20 years in the past, I have endeavored to keep the spirit of science outreach alive as a part of my professional life and weave the lessons learned from these experiences into my own teaching as well as keeping these activities going.

I have been active in communicating beyond the university environment by engaging in a variety of activities aimed at the general public as well as at primary and secondary school students. Since moving to Iceland, I have conducted over 25 public events which typically consist of a science demonstrations and/or a hands-on activities for youngsters (and adult-sized youngsters). I have developed a modular 20-45 minute science demonstration "act" which consists of several well-known chemistry demonstrations (Elephant Toothpaste, Ethanol drum, colored flames, hydrogen balloons) as well as several novel biology demonstrations (biofluorescence, "Enzymes at work", etc). Since 2009, I have performed an hour long chemistry demonstration at the town of Akureyri´s annual festival (Akureyrarvaka). I have also used this opportunity to do various hands-on science activities, with the help of my students and other volunteers, with the public, typically making "slime" or flubber although I have used other hands-on activities.

I have also been involved in several dozen classroom visits, primarily for early primary school students, where I do a short hands-on experiment with students (such as "Slime" or something involving culturing bacteria on agar plates) although have not kept a detailed account of these activities.

"The most immediate way to nurture interest in science among students with less supportive home environments may be to increase early exposure to high-quality science instruction in schools." (OECD, 2005)

In an effort to train and encourage broader science outreach to schools and increase cooperation between departments, I started a pilot outreach program. During the autumn 2017 term, I organized a student-led outreach program at the University of Akureyri that involved students from both the Natural Sciences and Education Departments; the students named this program “Vísundur” (which is a bit of a pun in Icelandic as it translates to both “science”/”wonders”/”wonders of science” **and** “buffalo” . I’m told it’s very clever!).

*Figure 12 – UNAK students that participated in the **Vísundur program** in a primary school classroom*

The UNAK students designed or adapted science lessons, prepared them, and then spent six 45 minute sessions per school during the autumn of 2017. During this time, the students used some basic items to teach lessons that they developed collaborative to teach lessons in biology, chemistry, and physics. One such lesson involved learning about physical properties by using those properties to separate a mixture of sand, iron fillings, plastic beads, salt, and water (Figure 13).

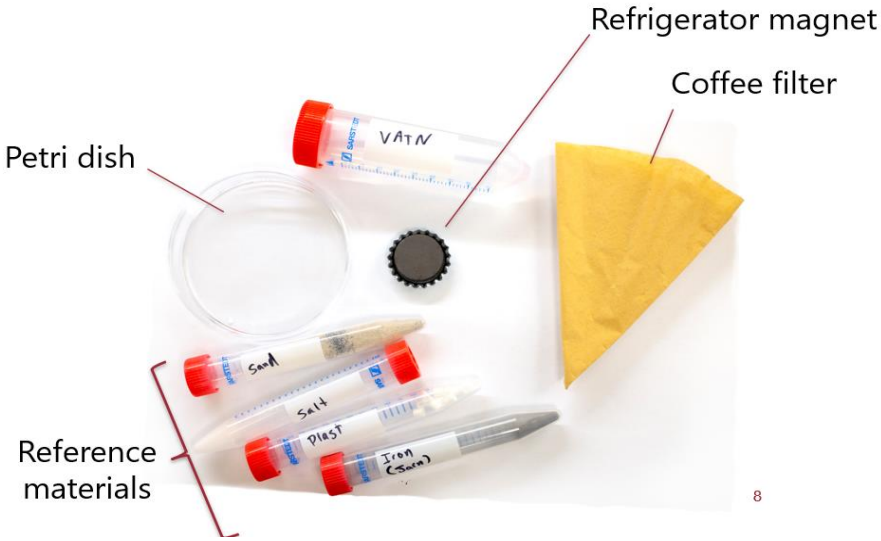

Figure 13 - Teaching physical separations to elementary school children (and by extension, students of education) can be accomplished using some very basic materials

Many of the university students involved were initially skeptical about the abilities of the 1st and 2nd grade students but quickly realized that they were very creative problem solvers and very adept at learning. The response of this pilot program was overwhelmingly positive among my own students, the primary school students and their teachers alike. It is my hope to restart this program in the 2021-2022 school year and make it a regular opportunity for our university students to enrich the early science experiences of students.

Figure 14 - In the experiment involving separating a mixture of plastic beads, sand, and iron fillings, students received no instruction on how to use the tools they were give. They quickly figured it out anyway.

To spread awareness of my research-related interested (such as extremophiles, biocatalysis, sustainability, etc), I've written several articles that have appeared in journals such as *Science in School* of which one has been published and two have been submitted. Post pandemic, I´d like to be more involved at giving science lectures aimed at teachers and the general public rather than just talking to an 'academic' audience.

I have been actively involved in planning the annual conferences Vísindi í námi og leik (held at UNAK in 2019 and 2020) as well as helped plan and execute the bi-annual Ráðstefna um náttúrufræðimenntun (held at HÍ in 2021). In the Spring of 2021, I co-organized the 1st Sustainability Workshop at the University of Akureyri with Yvonne Höller. Associated with this event, I organized an associated workshop with Brynhildur Bjarnadóttir aimed at primary and secondary school teachers in the area looking for hands-on sustainability lessons.

In keeping with the theme, I´ve also been working with local teachers and like-minded professionals to expand the amount of science in elementary schools. Some of these activities include:

- Development projects (workshops with Jón Aðalsteinn Brynjólfsson, a primary school teacher at Lundarskóli), 2020 we successfully applied for funds from Sprotasjóður with a proposal titled "Portable Science Kits for Science and Sustainability Education"
- Building a professional learning community in the North of Iceland

I have also made an effort to increase the visibility of my work, both pedagogical and scientific, on social media although I have not been as active as I perhaps should be. I have been active in science teacher groups on Facebook in an attempt to support the teaching activities of other educators

9 Other pedagogical qualifications

Aside from receiving the University of Toledo American Chemical Society Service Award in 2003 for my public outreach work during my time as an undergraduate, I do not possess any additional pedagogical qualifications at this time.

10 Future vision

Going forward, I would of course like to continue to improve the quality of my teaching. After completing my M.Ed., I´d like to find a way to stay active through continuing education programs even if it means developing those programs by establishing some sort of professional development community for science educators (which is something I´ve discussed with teachers in the area). Develop greater opportunities that connect the studies with practical and real-world applications as well as finding

With regard to my own teaching, I must strive to make my materials more flexible and accessible. One way that I´m pursuing this is by making short lab tutorial videos that students can access via QR code in the manual or on Canvas to aid their confidence coming into the laboratory or to provide assistance to them while conducing procedures. I would also like to increase the diversity of activities that I use in my 'lectures´ by continuing to supplement my lectures or offer alternative activities so long as they are meaningful. This is something that I will continue to experiment with and refine with the help of my students (probably my number one resource when it comes to quality feedback!). In my teaching, I´d also like to better highlight possibilities for undergraduate research and other extra curricular opportunities to hone their science skills.

I´m quite keen on finding a way to promote greater internal and external collaboration in the area of science and science education. I´m currently exploring ways to do collaborative teaching with a number of educators in the United States on areas of mutual interest. If the pandemic has taught us anything, it´s how to use video conference software to facilitate real-time interaction. Also, I would like to work on increasing the avenues for student engagement and assistance to train students to teach science by actually teaching science; to accomplish this, I´m working on making the aforementioned Visindur program offered by the university.

One area that I am really excited to develop further is the a series of laboratory activities in chemistry and biology topics that can be performed (safely) at home. I would like to create a framework outlining the principles that should guide the creation of such activities and create a pool of resources, procedures, and other ideas to support the development of these types of activities. I think activities such as this can not only be a useful way to supplement and expand current 'in lab' activities, but may also provide content that can be used by educators that lack access to resources.

11 Acknowledgements

First and foremost, I´d like to thank Oddur Vilhelmsson for supporting me in my teaching over the years and providing a positive exemplar when it comes to being a thoughtful and enthusiastic educator. Additionally, I would like to give a special thanks to Professors Jóhann Örlygsson and Brynhildur Bjarnadóttir (University of Akureyri). My students also deserve tremendous credit for helping me shape my teaching and for their patience as I try new things. Their feedback and support has been instrumental in my journey as an educator.

I would like to express my sincere gratitude to Penny Cobau-Smith (Adrian College, MI, USA) for her years of support and service. She has not only been an inspiration to me as an exemplar of fantastic teaching, she has been a willing mentor throughout my educational journey.

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X Appendices

X.A. Higher education courses and study programmes (subject specialization)

Term	Institution	Course title	Course designation	Level	Credits

Redacted

X.B Higher education courses and study programmes (pedagogic specialization)

Term	**Institution**	**Subject**	**Course title**	**Course designation**	**Level**	**Credits** (ECTS

Redacted

X.C Experience of teaching and supervision within higher education

Orange courses are within the Department of Education.

Academic term	Course title	Designation	Level (year)	Credits (ECTS)	Students (*n*)	Applicant´s involvement		
						Supervision	Lab	Lecture
2009 (Autumn)	Organic and Biological Chemistry	EFN1313000	Undergraduate (2nd)	6				
2010 (Autumn)	Organic and Biological Chemistry	EFN1313070	Undergraduate (2nd)	6	10			
2011 (Autumn)	Organic and Biological Chemistry	EFN1313100	Undergraduate (2nd)	6	16			
2012 (Autumn)	General Chemistry	EFN1116120	Undergraduate (1st)	6	34			
2012 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	7			
2013 (Spring)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	32			
2013 (Spring)	Applied Chemistry	EFN1216120	Undergraduate (1st)	6	30			
2013 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	7			
2013 (Autumn)	Microbial Biotechnology	LÍÖ1106110	Undergraduate (3rd)	6	7			
2013 (Autumn)	General Chemistry	EFN1116120	Undergraduate (1st)	6	42			
2014 (Spring)	Applied Chemistry	EFN1216120	Undergraduate (1st)	6	34			
2014 (Spring)	Fish as food	MAT1106110	Undergraduate (2nd)	6	17			
2014 (Spring)	Food Science	MFR1106110	Undergraduate (2nd)	6	9			
2014 (Spring)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	41			
2014 (Summer)	Arctic ecology	ÖVN1108110	Graduate (1/2)	8	3*			
2014 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	11			
2014 (Autumn)	Biotechnological microbiology	LÍÖ1106110	Undergraduate (3rd)	6	6			
2014 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	19			
2014 (Autumn)	General Chemistry	EFN1116120	Undergraduate (1st)	6	49			
2015 (Spring)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	35			
2015 (Spring)	Food Science	MFR1106110	Undergraduate (2nd)	6	12			
2015 (Spring)	Fish as food	MAT1106110	Undergraduate (2nd)	6	21			
2015 (Spring)	Applied Chemistry	EFN1216120	Undergraduate (1st)	6	32			
2015 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	14			
2015 (Autumn)	Biotechnological microbiology	LÍÖ1106110	Undergraduate (3rd)	6	13			
2015 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	18			
2015 (Autumn)	General Chemistry	EFN1116120	Undergraduate (1st)	6	53			
2016 (Spring)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	43			
2016 (Spring)	Applied Chemistry	EFN1216120	Undergraduate (1st)	6	48			
2016 (Summer)	Sub-Arctic Microbial Ecology Field Trip	ÖVN1108110	Graduate (1/2)	8	4*			
2016 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	14			
2016 (Autumn)	Biotechnological microbiology	LÍÖ1106110	Undergraduate (3rd)	6	14			
2016 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	12			
2017 (Spring)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	25			
2017 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	8			
2017 (Autumn)	Biotechnological microbiology	LÍÖ1106110	Undergraduate (3rd)	6	11			
2017 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	24			
2017 (Autumn)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	38			
2018 (Spring)	Special assignment in natural resource science - Literature review	SVA1103060	Graduate (1/2)	6	13			
2018 (Summer)	Sub-Arctic Microbial Ecology Field Trip	ÖVN1108110	Graduate (1/2)	8	2*			
2018 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	13			
2018 (Autumn)	Biotechnological microbiology	LÍÖ1106110	Undergraduate (3rd)	6	9			
2018 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	15			
2018 (Autumn)	Natural Science and Natural Science Teaching	NÁV0156160	Undergraduate (2nd)	6	6			
2019 (Spring)	Natural Science in Learning and Play	RVN0156160	Undergraduate (1st)	6	25			

2019 (Spring)	Special assignment in natural resource science - Literature review	SVA1103060	Graduate (1/2)	6	15
2019 (Spring)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	33
2019 (Autumn)	Biochemistry	LEF1106120	Undergraduate (2nd)	6	13
2019 (Autumn)	Biotechnological microbiology	LÍÖ1106110	Undergraduate (3rd)	6	9
2019 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	20
2019 (Autumn)	Natural Science and Natural Science Teaching	NÁV0156160	Undergraduate (2nd)	6	7
2019 (Autumn)	Special assignment in natural resource science - Literature review	SVA1103060	Graduate (1/2)	6	15
2020 (Spring)	Natural Science in Learning and Play	RVN0156160	Undergraduate (2nd)	6	45
2020 (Spring)	Microbiology	ÖRV1106110	Undergraduate (1st)	6	32
2020 (Spring)	Teaching Natural Sciences and Mathematics to Younger Children	NSY0156130	Undergraduate (1st)	6	3
2020 (Autumn)	Biochemistry	LEF1106200	Undergraduate (2nd)	6	12
2020 (Autumn)	Biotechnological microbiology	LÍÖ1106200	Undergraduate (3rd)	6	17
2020 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	29
2020 (Autumn)	Natural Science and Natural Science Teaching	NÁV0156160	Undergraduate (2nd)	6	9
2020 (Autumn)	Literacy for Comprehension	LES1505160	Graduate (1)	5	69
2020 (Autumn)	Mathematics and the Teaching of Mathematics	STÆ0156090	Undergraduate (2nd)	6	21
2020 (Autumn)	Special assignment in natural resource science - Literature review	SVA1103060	Graduate (1/2)	6	14
2021 (Spring)	Microbiology	ÖRV1106200	Undergraduate (1st)	6	57
2021 (Spring)	Applied Chemistry	EFN1216120	Undergraduate (1st)	6	63
2021 (Spring)	Literacy for Learning	LNÁ1510160	Graduate (1)	10	34
2021 (Autumn)	Biotechnology	LFT1106120	Undergraduate (1st)	6	TBD
2021 (Autumn)	Mathematics and the Teaching of Mathematics	STÆ0156090	Undergraduate (2nd)	6	TBD
2021 (Autumn)	Biochemistry	LEF1106200	Undergraduate (2nd)	6	TBD
2021 (Autumn)	Microbial Biotechnology	LÍÖ1106200	Undergraduate (3rd)	6	TBD
2021 (Autumn)	Literacy for Comprehension	LES1505160	Graduate (1)	5	TBD
2022 (Spring)	Microbiology	ÖRV1106200	Undergraduate (1st)	6	TBD
2022 (Autumn)	Natural Science and Natural Science Teaching	NÁV0156160	Undergraduate (2nd)	6	TBD
2022 (Spring)	Natural Science in Learning and Play	RVN0156160	Undergraduate (1st)	6	TBD

X.D. Supervision experience within higher education

Redacted

Student Name	Year graduated	Level	Credits (ECTS)	SMS role	Subject	Thesis Opponent

*Tentative

X.E. Documents of educational skills from supervisors

X.E.1 Letter from Oddur

Oddur Vilhelmsson is the Dean of the Department of Natural Resource Sciences and has also been responsible for several courses (Microbiology, Biochemistry, and microbial biotech when Johann Orlygsson was on sabbatical during the 2017-2018 school year) as well as the microbial ecology course offered in the summers of 2014, 2016, and 2018.

X.E.2 Letter from Johann Orlygsson

Johann Orlygsson is a professor of biotechnology at the University of Akureyri and has been the course supervisor (Umsjonakennari) for a number of courses that the applicant has been heavily involved in, namely Microbiology, Biochemistry, and Microbial Biotechnology.

X.E.3 Letter from Byrnhildur Bjarnadóttir

Byrnhildur Bjarnadóttir is an Associate Professor in the Department of Education and a biologist by training. She has been the been the course supervisor (Umsjonakennari) for a number of course that the applicant has been involved in, namely courses relating to science education.

X.E.4 Letter from (student)

X.E.5 Letter from (student)

X.E.6 Letter from (graduate student)

X.E.1 Letter from Oddur Vilhelmsson (Dean of Department of NRS)

Redacted

X.E.2 letter from Johann Orlygsson

Redacted

X.E.3 Brynhildur Bjarnadóttir

Redacted

X.E.4 letter from Eydís Sigurðardóttir Schiöth

Redacted

X.E.5 Letter from (student)

Redacted

X.E.6 Letter from (Graduate student)

Redacted

X.F. Development of teaching materials and other resources for student learning

	Biotechnology	Microbiology	Biochemistry	Microbial Biotechnology
Level	Undergrad (1st year)	Undergrad (1st year)	Undergrad (2nd year)	Undergrad (3rd year)
Syllabus	[link]	[link]	[link]	[link]
Lab manual	N/A	[link]	[link]	[link]

Háskólinn á Akureyri

VIÐSKIPTA- OG RAUNVÍSINDADEILD
ÖRV1106
SEAN M. SCULLY

Experiment X

Experiment title

Date

Author 1 (e-mail address) (Note: right-click and remove e-mail´s hyperlink)

Author 2 (e-mail address) (Note: right-click and remove e-mail´s hyperlink)

Remove red text and instructor comments from the report prior to submission

1 Inngangur (Introduction)

The introduction should be 2-3 pages in length and contain some background information that is necessary and relevant for the reader to understand the experiment(s) that you are going to describe. What you describe in the introduction should also come up again in the discussion section to help you put YOUR experimental work into context for the reader.

Be sure to clump ideas into paragraphs that share a theme. I recommend using the "sandwich" method (link to a YouTube video about that here). Generally speaking, the first sentence of a paragraph should „introduce" the theme of that paragraph followed by 2+ sentences which contain content. The last sentence of a paragraph should attempt to link the theme of the current paragraph to the theme of the following paragraph.

- *Use signposting to create subsections (i.e. 1.1 Listeria innocua; be sure to set style to Heading 2 or Heading 3 for subsections and sub-subsections, respectively)*
- *Use authoritative sources of information (i.e. peer-reviewed journal articles, books, etc)*
  - *Here are some suggested places where you might begin to look for authoritative information*
    - *The Textbook*
    - Wikipedia *(do not cite Wikipedia… but check out those sources!)*
    - *The Library (yes, it still exists!)*
    - Hvar.is
    - Google Scholar
    - Google Books
    - ScienceDirect
    - WebofScience
    - NCBI PubMed

- *Do not plagiarize text*
  - *I use Turn it in to check for plagiarism*
  - *Make sure that all information is reworded „in your own words" and is cited in text*
  - *Avoid direct quotations! It is a cheap and lame tactic*
  - *If you have trouble "rewording" things, try…*
    - *Using a thesaurus*
    - *Consdier using a "paraphrasing tool" (such as the following* link*)*
  - *Do not copy/paste/google translate your work. You'd be surprised how easy this is to spot!*
  - *If more than FIVE continuous words are identical to you source, it could be considered plagiarism!*

- *Be sure to cite your sources in text using APA 6th or 7th Edition*

- *The last paragraph should contain the purpose of the experiment and a testable hypothesis (i.e. what you expect to find)*

- *Do not forget to italicize latin names (for example: E. coli, Bacillus subtilis, Homo sapiens)*

2 Framkvæmd (Methodology)

- ***Do not*** include a list of reagents and other materials (everything that is worth mentioning is mentioned in the text of the procedure)

- Consider using signposting to split multi-part experiments into chunks. (Just do not over do it with making overly small sections)
- Make sure that you include all experimental details written in a clear and succinct way such that someone can easily repeat what was done

Avoid including extraneous information (i.e. stuff you did that the reader doesn't need to know in order to repeat what you did)

- **Be sure to emphasize any deviations from the procedure in the laboratory manual**
  - **changes in volume**
  - **using modified procedures**

3 Niðurstöður (Results)

- *Be sure to write a sentence introducing each table or figure before the table/figure appears in text. Do. Not. Put. Table/figures. In. Your. Report. WITHOUT. Referring. To. IT. IN. TEXT.*
- *After each table/figure, be sure that you provide a brief written summary and highlight key results in text without providing an interpretation*
- *Be sure to add captions to tables/figures using the „caption“ function*
- *Refer to tables and figures using the „cross reference“ feature in text when referring to a table or figure for the first time*
- *Do not report results in both tables and figures; any tables reporting raw data should be included in the appendix*
- *Figures: Make sure that X- and Y-axis are labeled and contain relevant units*
- *Do not discuss results in this section*
- *Mention any statistical results (i.e. ANOVA or t-Test results in this section)*

4 Umræður (Discussion)

Now you interpret your results. Tell me what your results mean.

- Did you find what you expected (i.e. was your hypothesis correct?).
- Discuss the implications of your results (for example, you found *E. coli* in the salad at your local grocery store. So what?).
- How do your results relate to other similar data?
- How do your results relate to the scientific literature?
- Do your results bring up any new questions which might be investigated in the future?

5 Samantekt (Conclusions)

Writing a conclusions section is often difficult for new students. I generally recommend that you follow the following formula to „fake it" until you get a feel for it. Give it a try. It is not too difficult once you get a feeling for it.

- One sentence introduction
- One or two sentences summarizing what was done
- Two sentences of result highlights
- One or two sentences of major implications of findings

Example conclusions section: *Escherichia coli* is a facultative anaerobe commonly associated with fecal matter. The optimum growth conditions of *E. coli* strain DH5α was evaluated between 15 and 45°C, from pH 4.0 to 9.0, and from sodium chloride concentrations between 0 and 9% (w/v). The strain grew from X to Y °C, pH Z to X, 0 to X% (w/v) NaCl with the optimum conditions being 40°C in pH 8.5 and 1% (w/v) NaCl. These results are in good agree with what is known about the strain. The range of growth for *E. coli* suggests that it can thrive in a wide range of environments which could have implications for human health.

Acknowledgments – Optional *(Did someone help you? Here is the place to thank them. Remember that getting assistance with your work is not a bad thing; in fact, it shows me that you are taking this seriously and are trying to do good work)* The authors wish to gratefully acknowledge Berglind D. for assisting with the statistical analysis.

Contributions – *(write who did what)* ***Mandatory!*** **Each author needs to have contributed something to the report or their name should not appear on the report. Reports that do not have an adequate description of author contributions will be returned without grading.**

Example: SMS and JÖ performed the laboratory work; SMS counted the plates. Both authors drafted the introduction section, SMS wrote the Methodology and results section. JÖ processed the data in

Excel and performed the statistical analysis. Both authors wrote the Discussion and Conclusion section and revised the report.

6 Heimildir (References)

Do not provide hyperlinks to print articles that are available online.

I'd recommend reference management software such as Mendeley. It's easy to use and learning it now will save you PAIN and SUFFERING.

Use the APA 6th edition for formatting references. Rumor has it 7th edition is now available. Whatever you do, do it correctly and consistently.

External Evaluation

Introduction (15%)	**Points Awarded**	**Possible Points**	**Criteria**	**Comments from Reviewer**
Background	X	**9**	• Brief overview, hits key features and concepts of the experiment • Relevant • Good use of literature	
References and their quality	X	**4**	• Textbooks and authoritative texts • **4+ Peer-reviewed articles** • Avoid websites • Items are cited correctly in text • Items are correctly referenced (APA)	
Purpose and hypothesis statements	X	**2**	• Clearly stated; includes hypothesis • Describes scope of experimental work	
Materials & Methods (15%)	**Points**	**MAX Pts**	**Criteria**	**Comments**
Concise	X	**5**	• Is the procedure written as briefly as possible?	
Completeness	X	**5**	• Can I repeat what you did based solely on what you wrote?	
Clarity	X	**5**	• Clear, succinct and as written as simply as possible?	
Results (25%)	**Points**	**MAX Pts**	**Criteria**	**Comments**
Body paragraph text	X	**8**	• Body text should introduce relevant tables/figures and key data • Describe key data points after table/figure • Describe the results without interpreting the results • In-text references to tables and figures	
Tables/figure captions	X	**2**	• Table/Figure titles should "stand on their own"	
Data Presentation	X	**10**	• Is data presented clearly? • Axis labels and units • Avoid redundant presentation • Use of appendices • Significant figures • Basic statistics (Average, standard deviation)	
Statistics	X	**5**	• t-Tests, ANOVA	
Discussion (40%)	**Points**	**MAX Pts**	**Criteria**	**Comments**
Explanation of results	X	**10**	• What were the expected results? • Experimental problems • What is going on at the molecule level • Implication of results	
Putting your results into context				
Comparison with other groups' data	X	**10**	• Are your results similar? • Statistical comparison between data sets	
Comparison to literature	X	**10**	• Do your results fit with established results in the literature?	
Implications of results			• What do you results mean?	
Overall quality of discussion section	X	**5**	Points to be awarded at grader's discretion.	
Conclusions (5%)	**Points**	**MAX Pts**	**Criteria**	**Comments**
	X	**5**	• Brief summary of experiment • Highlights of key results • Implications of results	
Total	**X**	**100**	→	

X.F.2 Development of hands-on at home laboratory exercise for teaching enzymology

Note: this was a short report that I submitted to the University of Akureyri as a part of my annual evaluation for the 2019-2020 academic year.

Háskólinn á Akureyri
University of Akureyri

Innovation in Education

Introduction to Biotechnology (LFT1106) – Development of hands-on at home laboratory exercise

Keywords: flexible learning, hands-on, remote learning

The course Introduction to Biotechnology (LFT1106; 6 ECTS units) was established 6 years ago and developed as an introductory course for first year students within the biotechnology study line at the University of Akureyri within the Department of Natural Resource Sciences. The course was adapted from an earlier course, Marine Biotechnology, which had come to serve the same introductory function. Sean M. Scully took over responsibility for the course in the autumn of 2019 and has been responsible for its supervision since.

Building on an earlier promise to improve the flexibility of the course and introduce self-guided laboratory experiments, Sean introduced a number of innovative elements during the autumn 2020 academic term. These activities were designed to increase student engagement, which has been an issues of amplified importance due to the current and on-going SARS-CoV-2 pandemic, and reinforce the key concepts relevant to biotechnology. Most critically, Sean **designed an authentic, multi-part experiment that could be accomplished at home to provide a hands-on experience relating to the applications of enzymes in various industries using a combination of inexpensive laboratory items and household items.**

The purpose of this experiment was to expose students to basic concepts related to the intersection of enzymes and their applications, a topic covered within the scope of this course. The experiment involved students examining the action of enzymes found within specific organs from waste fish viscera. Students were provided with fish viscera and an array of enzyme substrates for which the action could be judged visually (either by a visible change in turbidity or a color change using an indicator). In all cases, students were sent the required materials via mail.

Figure 15 – From left to right: fish viscera donated by a company in the West Fjords being segregated prior to homogenization, Eppendorf tubes containing selected enzyme substrates, a YouTube video prepared by the instructor (link)

In addition to the materials and instructions required to complete the experiment, the students were also given a demonstration video via YouTube which navigated students through the experimental procedure. Additionally, students were assisted via Zoom (or Skype) in small groups which allowed for enhanced student-instructor contact during a period when isolation was the norm.

Figure 16 - Scully assisting students via Zoom individually or in small groups

Ultimately, the addition of this remote experiment to the course were received positively by the students who especially enjoyed the opportunity to experience hands-on science at home and at their own convenience. Students also commented that this opportunity for direct contact with the instructor, as well as an opportunity to engage with other students, was a welcome change in a semester otherwise characterized by isolation.

Based upon the report which students had to deliver as well as a surprise question on the course's final examination, students demonstrated a basic understanding of the experiment which suggests that this alternative use of laboratory experiment delivery was efficacious. Greater than 80% of the

students received full marks for the relevant exam question which was separated from the experiment by approximately four weeks.

This work highlights that there are options for students to do authentic laboratory activities remotely which is a topic that has been poorly explored with respect to “traditional” distance education but has become even more important in light of the current circumstances.

Sean M. Scully 31 December 2020
Adjunct
Department of Natural Resource Sciences
University of Akureyri

Oddur Vilhelmsson 31 December 2020
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X.F.3 Development of hands-on at home laboratory exercise for teaching protein separation

Note: this was a short report that I submitted to the University of Akureyri as a part of my annual evaluation for the 2019-2020 academic year.

Innovation in Education

Development of hands-on at home elements for Biochemistry (LFT1106)

Keywords: flexible learning, hands-on, protein separation, enzyme assays

The Biochemistry (LFT1106; 6 ECTS units) course was established in 2012 and developed as a course for second year students within the biotechnology study line at the University of Akureyri within the Department of Natural Resource Sciences.

The 2020-2021 academic year posed an interesting problem for both traditional and distance students which both attend practical laboratory experiments in the University labs which was not an option due to the ongoing SARS-CoV-2 pandemic. Given the need for students in the sciences to develop “bench skills”, this is particularly problematic and poses a unique challenge. As an example, traditional experiments involving the separation of proteins via column fractionation and subsequent analysis by UV-Visible or fluorescence spectroscopy often require direct access to facilities with this equipment which is often costly. In order to circumvent these problems but ensure that students had access to an experiment involving the separation and analysis of proteins, Sean carefully **adapted an experiment that he had previously designed which involved the fractionation of lysozyme from chicken egg whites which used commonly available items that could be sent to students via the postal service and could be analyzed using a smart phone as a spectrophotometer.**

Figure 17 -Laboratory materials were prepared in advance and mailed to students via the postal service

Of particular interest was the creation of functional chromatographic columns using 10 mL syringes, large gauge needles, and stopcock adapters. All of these materials are inexpensive and easily obtainable and safe for transport while functioning nicely for their intended purpose.

Figure 18 - Syringes and needles repurposed to function as chromatography columns

Laboratory sessions were facilitated via Zoom in with small student groups (4-6 students). The experiment took approximately 4 hours to complete, which is comparable to the time that it has historically taken in a “genuine” laboratory setting.

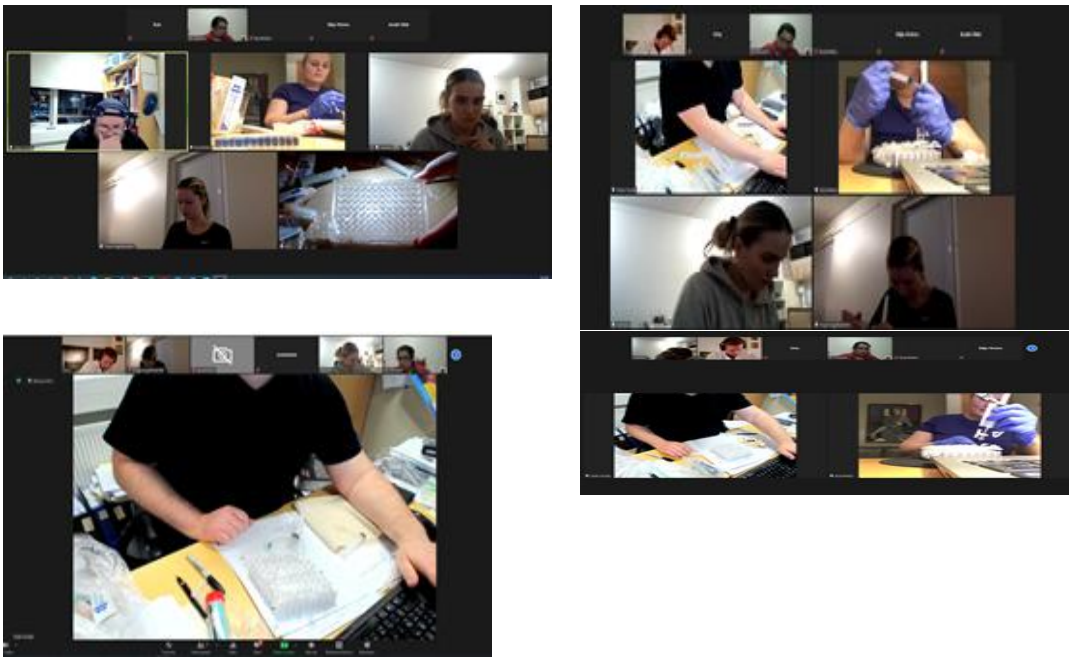

Figure 19 – Facillitating the experiment via Zoom proved to be a useful means of interacting withe students and providing real-time feedback and support

Students reported no significant problems in setting up the materials and following the procedure for the preparation of egg whites and subsequent separation via column chromatography as written with a few minor exceptions. In some instance, column clogging was an issue although this was traced back to inadequate filtration of the diluted egg white solutions.

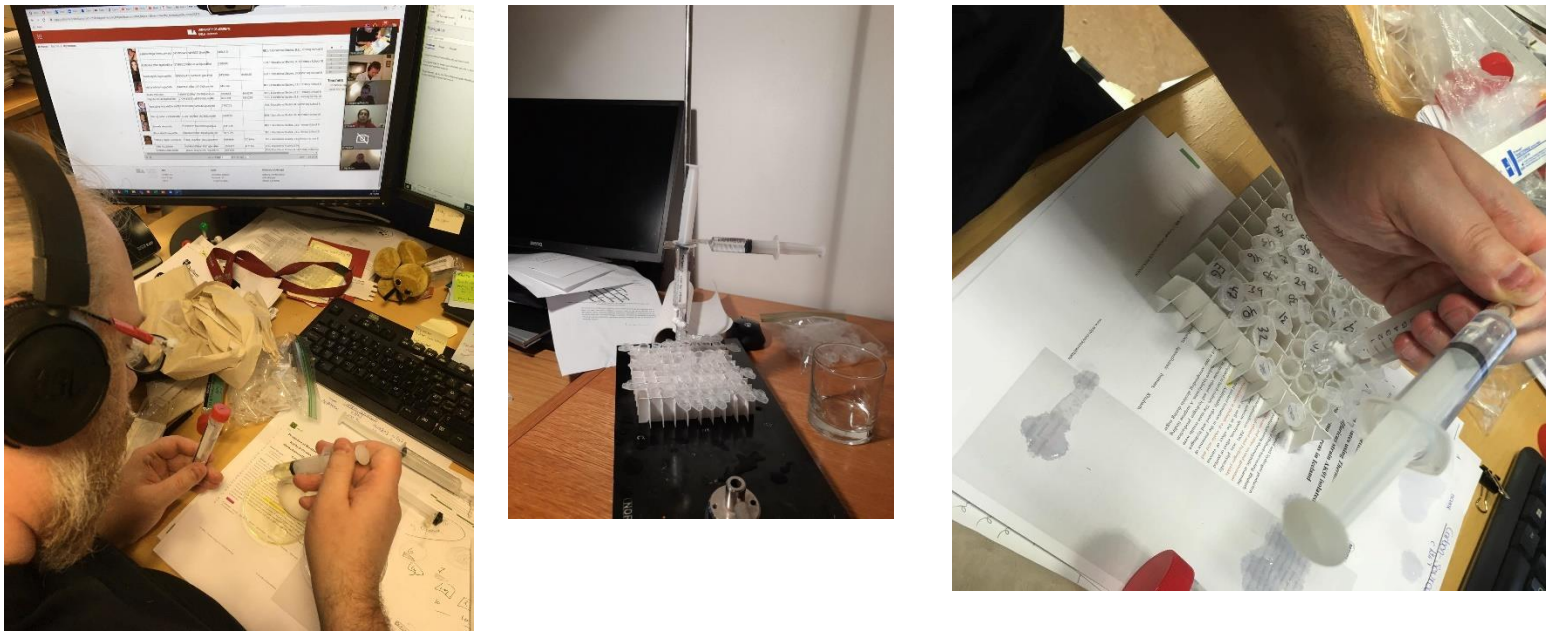

Figure 20 -

In order to analyze the experiment, students were required to quantify both the amount of enzyme activity as well as the concentration of protein in their fractions using a lysozyme assay and Bradford

protein assay, respectively. To accomplish this, students performed the assays on a microscale in a microtiter plate. To generate standard curves for protein, students were provided with suitable protein standards.

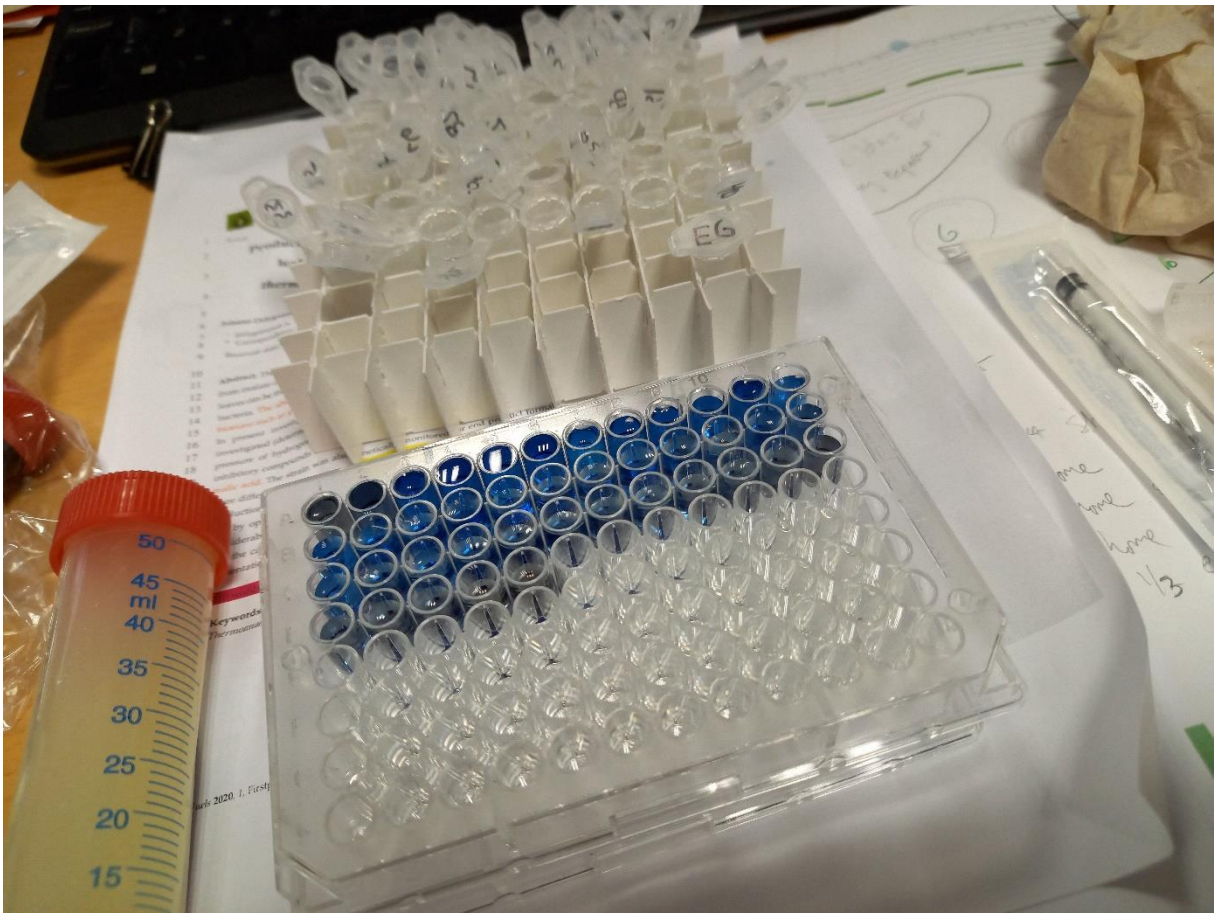

Figure 21 - Analysis of egg white fractions using the Bradford protein assay adapted to a microplate scale

To quantify the amount of protein or the change in absorption due to the action of the enzyme (lysozyme), student measured the absorption of the solutions by holding their microplate against a colored background and determining the amount of absorbed light using a smart phone app used for color detection.

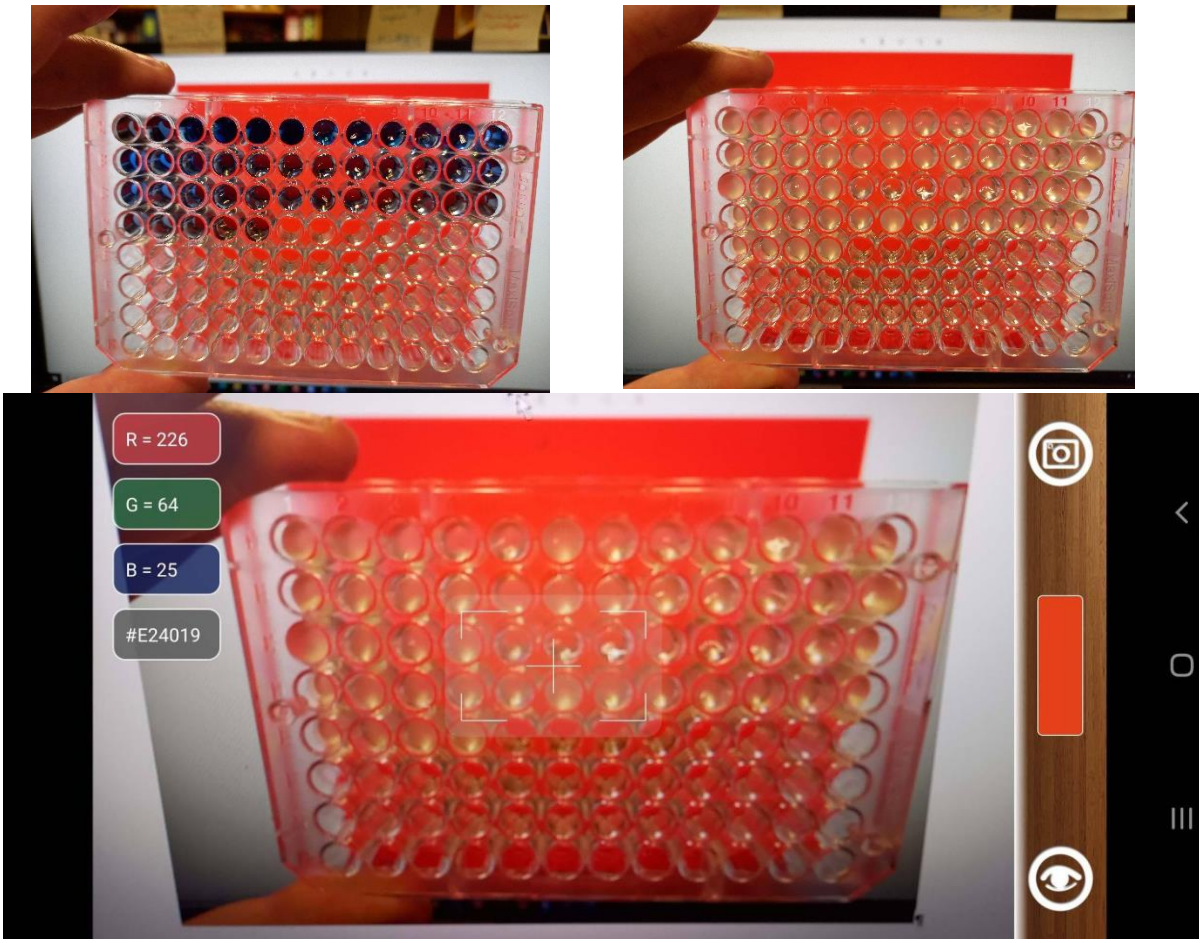

Figure 22 – Analysis of the Bradford protein assay and the lysozyme assay using a smart phone app

Ultimately, the addition of this remote experiment to the course were received positively by the students who especially enjoyed the opportunity to experience hands-on science at home and at their own convenience. Students also commented that this opportunity for direct contact with the instructor, as well as an opportunity to engage with other students, was a welcome change in a semester otherwise characterized by isolation.

This work highlights that there are options for students to do authentic laboratory activities remotely which is a topic that has been poorly explored with respect to "traditional" distance education but has become even more important considering the current circumstances.

Sean M. Scully 31 December 2020
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III

Experiment III – Environmental Variables and the Growth of *Saccharomyces cerevisiae*

Number of class periods: 1

Weight: 2 of 10

Keywords: Reading: Staley Chapter 6 (Microbial Growth), 8 (Cellular Energy)

Experiment 3 –the Growth of *Saccharomyces cerevisiae*

Groups of 1
1 Lab period
Concepts and Techniques: Kinetics, Growth curves, high-throughput screening, pipette usage
Hand-in: Full Report

Introduction

Modeling Microbial Growth

In order to better understand how bacteria (and other microorganisms) behave, the growth of a culture is often monitored as a function of time and total number of bacteria present (typically the log of the total bacteria concentration since large numbers are involved!).

The resultant growth curve (see Section 2.6.5 on Canvas) can be divided into several phases: lag phase, exponential phase, stationary phase, and the death phase. The exponential phase can be further scrutinized to reveal the "early exponential phase" in which the growth rate is accelerating, the "actual" exponential phase during which the growth rate is relatively constant, and the "late exponential phase" where the growth rate decelerates prior to reaching the stationary phase.

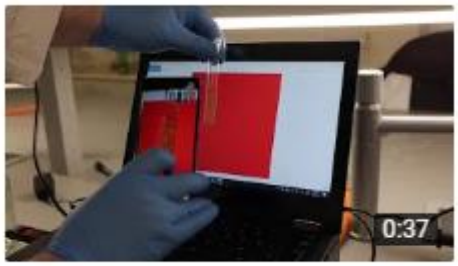
Experimental Objectives

The purpose of this exercise is to use basic spectroscopic techniques to generate a growth curve for a yeast culture which will be used to measure the length of the lag and stationary phases of the growth curve and determine the maximum growth rate (μ_{max}), (which is described in Section 2.6.5 on Canvas).

Materials and Methods

Inoculate three tubes containing 5 mL of 1/10 Yeast-Peptone-Dextrose (YPD) media with 0.5 mL of *S. cerevisiae* culture using good sterile technique. The time of inoculation is time = 0 hours.

At various time intervals (see the table below), measure the absorption of light at ~620 nm. This can be done by swirling each tube and measuring the **intensity of red light** through the tube by holding it against the red background (see the last page for the red background) using your computer screen as a light source and by using the Colormeter Free App (iPhone users should try the Colorimeter RGB App).



How to measure red intensity through a cuvette (link)

Record the red light intensity from the app in the table below for each replicate tube (i.e. #1, #2, #3) over a period of roughly 48 hours.

Note that the specific times are not critical. However, you should record the time to the nearest quarter hour and adjust the table accordingly.

Time (h)	**Red light intensity** (~620 nm) #1	#2	#3	**Transmittance** (%T) #1	#2	#3	**Absorbance** (~540 nm) #1	#2	#3	Average	Standard deviation
0											
4											
8											
12											
18											
24											
36											
48											

After measuring absorbance in the sample tubes, the tubes maybe cleaned with soapy water with no special precautions.

Calculations

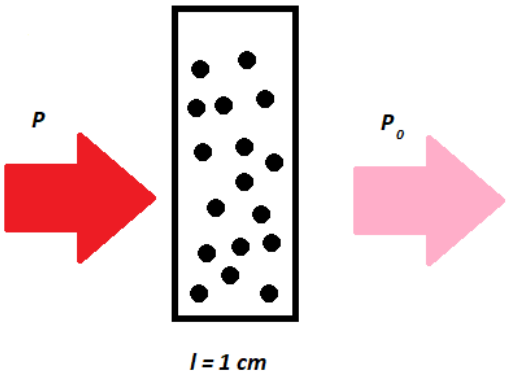
To complete these calculations, you will need to convert the "red" value read by the app on your phone to percent transmittance (% T) which we can then convert to absorbance and use to prepare a concentration versus absorbance plot.

In this instance, the P_0 value is the red light intensity at time zero.

$$\%\, Transmittance = \frac{P}{P_0} \cdot 100\%$$

Where *P* is the amount of light allowed to be transmitted (i.e. not absorbed) through the culture at each given time and P_0 is the amount of light let through a "blank" (in this case the tube before inoculation).

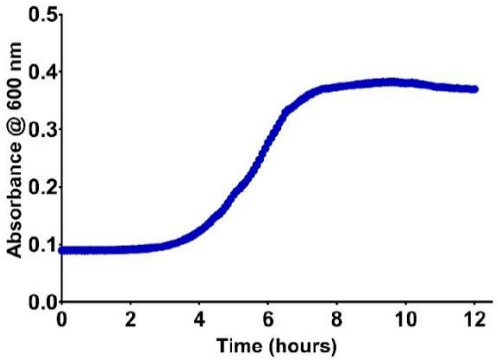
If we think about a solution in a cuvette, such as the one at the right, we are measuring the amount of light absorbed by the solution and how much light actually makes it through said solution (that is to say how much light is transmitted through the solution).

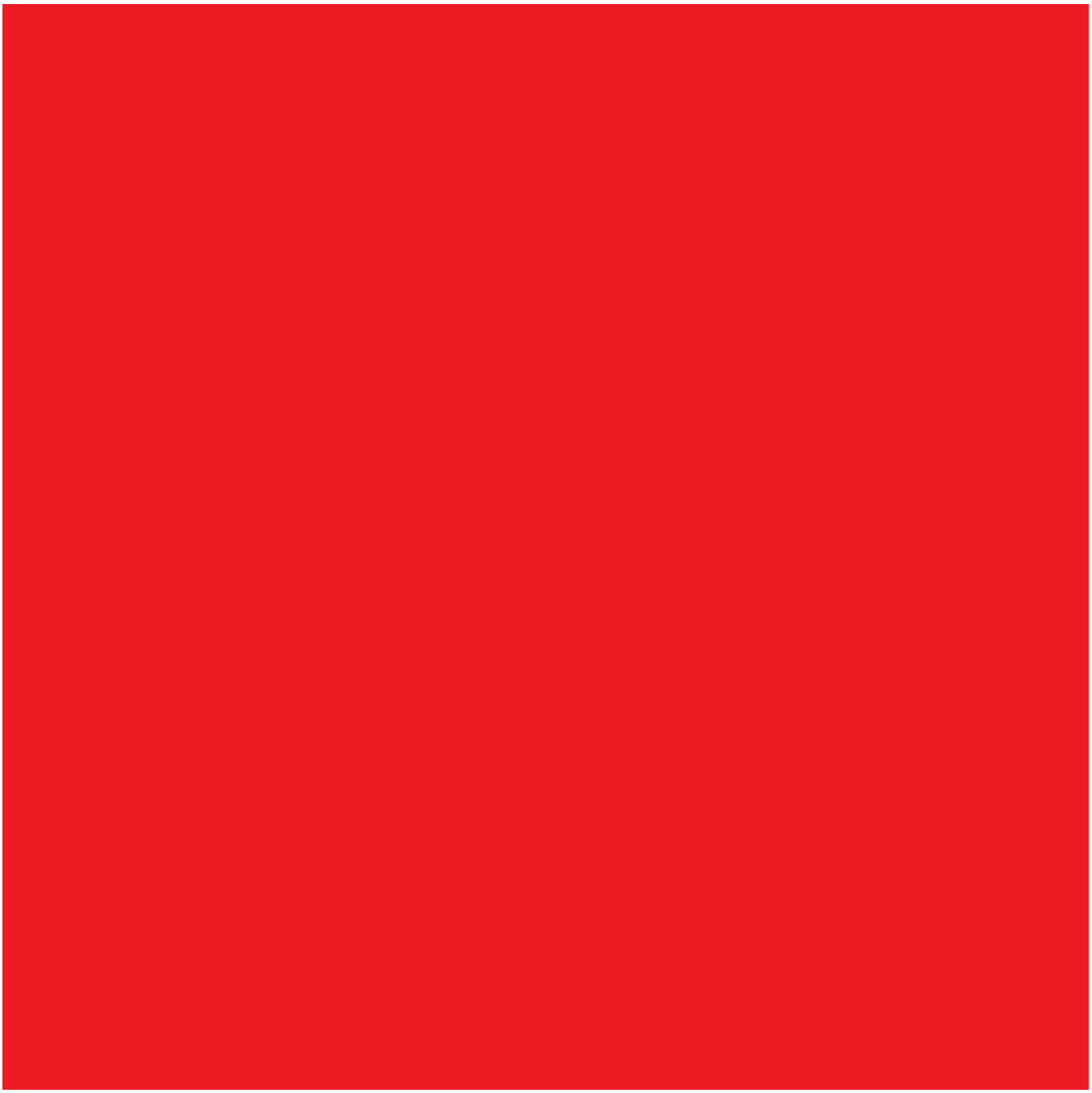


In many instances, absorbance is a much more convenient measurement to work with. Fortunately, absorbance can be calculated from the amount of transmitted light using Beer-Lambert's Law as follows

$$Absorbance(A) = 2 - \log(\%T)$$

Prepare a plot of time (x-axis, independent variable) versus the average absorbance at 620 nm with the standard deviation shown as error bars. Finally, calculate the growth metrics (μ_{max}, generation time, lag phase) for the set of wells that you inoculated as outlined in **Section 2.6.5 on Canvas**.





IV

Experiment IV – Fermentation with *Saccharomyces cerevisiae*

Number of class periods: 1

Weight: 2 of 10

Keywords: Reading: Staley Chapter 6 (microbial growth), 8 (cellular energy), 23 (Eukaryotic microbes), 31 (industrial microbiology)

Experiment IV –Fermentation with *Saccharomyces cerevisiae*

Groups of 1
1 Lab period
Concepts and Techniques: Fermentation
Hand-in: Worksheet

Introduction

Fermentation

Organisms use either aerobic or anaerobic respiration (or a combination thereof) for their energy metabolism. In the case of aerobic respiration, oxygen serves as the terminal electron acceptor. Under anaerobic conditions, however, oxygen is not available and the electrons must be disposed of using other means such as the reduction of pyruvate, nitrate, or some other alternative electron acceptor.

The transfer of energy in the bonds of an energy source such as glucose involves the transfer of that energy into the bonds of adenosine triphosphate (ATP) which is the energy currency of the cell. The ATP yields of two common processes - aerobic respiration using oxygen as the terminal electron acceptor and alcoholic fermentation in the absence of oxygen - are shown in the figure below.

Aerobic respriation

$C_6H_{12}O_6$ (aq) + $6O_2$ (g) —(Many, many enzymes)→ 6 H_2O (l) + 6 CO_2 (g) + 36-38 **ATP** + Heat

Glucose

Alcoholic fermentation

$C_6H_{12}O_6$ (aq) —(Many, many enzymes)→ 2 CH_3CH_2OH (aq) + 2 CO_2 (g) + 2 **ATP** + Heat

Glucose ***Ethanol***

The complete oxidation of glucose in the presence of oxygen yields much more ATP than in the absence of oxygen. A consequence of this is that cultures grown aerobically typically have greater biomass yields (and as a result, higher optical density) as compared to those cultivated under anaerobic conditions.

Regardless of oxygen availability, the process by which cells gain energy is glycolysis (the Embden-Meyerhof-Parnas (EMP) pathway). For a hexose (6 carbon sugar) such as glucose, glycolysis yields two molecules of pyruvate. In the presence of oxygen, these pyruvate molecules are oxidized completely to CO_2 with oxygen being reduced to water molecules. The dominant end products of glucose metabolism under fermentative conditions, however, include lactic acid, acetic acid, butyric acid, ethanol, butanol, carbon dioxide, hydrogen, and so on – see Figure 23.

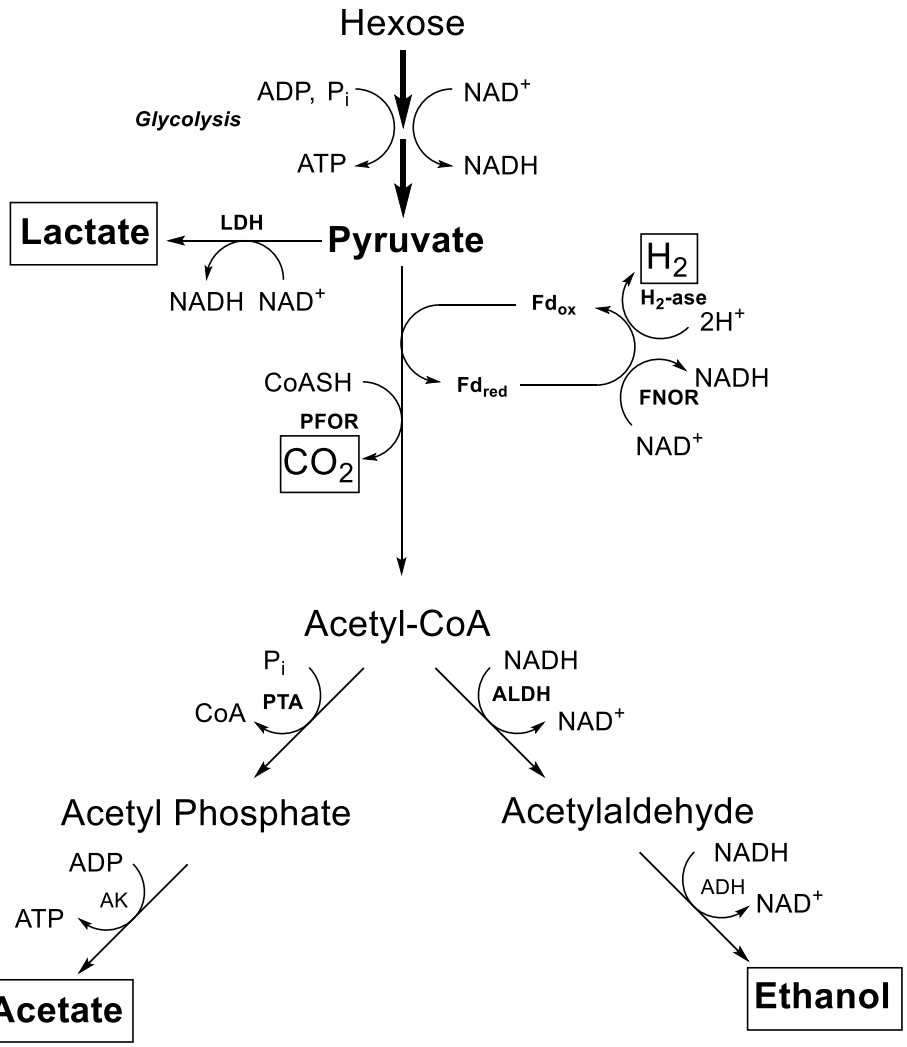


Figure 23 - The fate of the pyruvate generated from glycolysis when oxygen is not available often leads to a mixture of reduced and oxidized end products

Inquiring minds might wonder "why" cells produce ethanol as an end product when oxygen is not available. For glycolysis to quickly metabolize glucose into useable energy, the glucose molecule must be oxidized which is accomplished with the "help" of NAD^+ (which gets reduced to NADH). The availability of NAD^+, which is often only present in trace amounts in the cell, is a major bottle neck as to how quickly glucose can be catabolized. Thus, in the case of ethanolic fermentation, the whole point of ethanol production is to "dispose" of reducing potential or the electrons carried by NADH that have been removed from the glucose molecule using NAD^+ as an oxidant. So, these electrons (NADH) are used to reduce pyruvate (to lactic acid) or acyl-coenzyme A/acetaldehyde to produce ethanol, thus making NAD^+ available again to oxidize more glucose. This is sometimes called "NAD^+ recycling".

Question: what happens if ethanol is present and then oxygen becomes available?

It should be mentioned that molecules other than carbohydrates such as glucose can be fermented in this manner. Since fermentation media often include substrates other than carbohydrates, such as proteins and fatty acids, fermentation products other than ethanol such as glycerol, "fusel alcohols", and sugar alcohols, are possible and may contribute other flavors to fermented products. *Saccharomyces cerevisiae* is

a good ethanol producer as it lacks the enzymatic machinery to utilize ethanol as a carbon source.

Some organisms produce other end products (acetic acid, lactic acid, propionic acid, etc.) in what is called mixed acid fermentation. Many organisms and animals are also capable of producing lactic acid yielding 2 ATPs.

Practical Aspects of Fermentation

In order to maintain anaerobic conditions, it is necessary to exclude atmospheric oxygen. Since yeast often need oxygen to produce membrane sterols, it is often the case that yeast cultures are started with no special precautions to remove oxygen and the vessel is allowed to go anaerobic as carbon dioxide is produce. To prevent atmospheric oxygen from entering the fermentation vessel, a special trap (called and "airlock" or "fermentation lock") is used – see Figure 24. This allows carbon dioxide to escape by bubbling through the water yet prevents oxygen from entering the vessel.

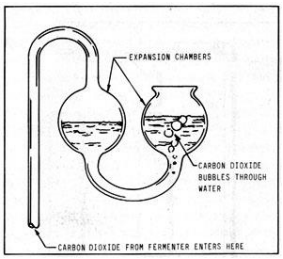


Figure 24 - A common fermentation lock (or "airlock") used for the cultivation of facultative anaerobes.

In practice, airlocks look something like the ones below; the airlock on the left is a glass airlock made from a glass rod and a test tube, while the one at the right is made from a few plastic pipette tips and a syringe (which is what you will be making). When brewing at scale, however, it is common to simply vent gasses through a hose submerged in a bucket of water.

Figure 25 – Two examples of airlocks used for fermentation to allow the escape of fermentation gasses while restricting the diffusing of oxygen back into the system

Experimental Objectives

The purpose of this exercise is to determine the effect of substrate concentration on the ability of *S. cerevisiae* to produce ethanol under fermentative conditions.

Materials and Methods

Several preparation steps are required prior to starting the fermentation. Be sure to leave yourself ample time. You will need to prepare a set of fermentation airlocks, prepare YPD medium, setup the fermentation, and then analyze the fermentation products (in this case ethanol) after a period of time. Note that **YPD Medium** is a commonly used non-selective liquid medium for yeasts including *Candida, Pichia, Saccharomyces*, and *Zygosaccharomyces*. YPD contains 20 g/L peptone, 10 g/L yeast extract, and 20 g/L glucose although another carbon source may be used. In this experiment, however, YPD media containing 1/10 the amount of peptone and yeast extract will be used and sucrose (table sugar) will be used as the carbon source.

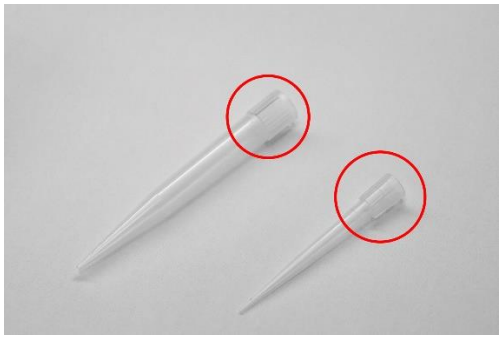
Preparation of airlocks (~1 hour not including intermediate drying step)

To complete this experiment, you will need 12 airlocks which can be prepared using the materials at the right and following the step-by-step direction below.

A YouTube video demonstrating the procedure can be found at the right.

(link)

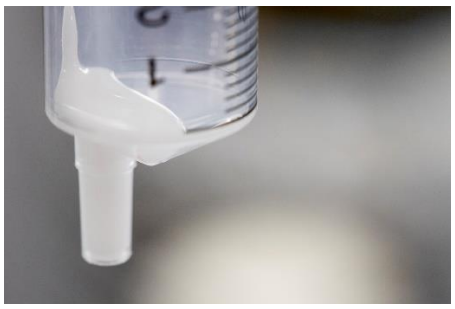
1. Cut off the bulky ends of the 1 mL and 250 µL pipette tips



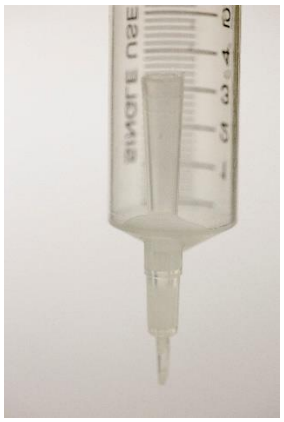
2. Melt the tip (the small end) of the 1 mL pipette tip to seal it closed (caution! Melted plastic is hot!) and place aside to cool.

3. Remove the plunger from the 10 mL syringe.

4. Add a drop of glue to the outlet part of the syringe. If you slobber, do not worry too much as long as the glue gets in the hole.

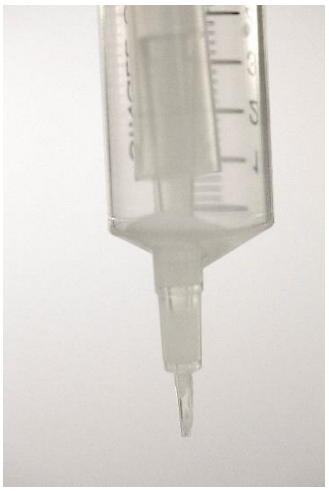


6. Place the 250 µL pipette tip inside of the 10 mL syringe and maneuver it into the opening. Maneuver it into the hole and push it firmly into place using a pen or other object (try not to block the hole of the pipette tip!).



6. Add a few more drops of glue to cement the 250 µL pipette tip in place. Remove any excess glue that ended up in the tip of the 250 µL pipette tip.

7. Air dry in an upright position (for however long glue takes to dry).



8. Maneuver the unsealed end of the 1 mL pipette tip *over* the open end of the 250 µL pipette tip inside of the syringe.

Media preparation **(~1.5 hours)**

The provided tube of YPD base contains enough material to make 2 L of 1/10 YPD base. You will need to prepare four different variations of this medium to achieve different sucrose concentrations.

Dissolve the contents of the tube containing the YPD base in 2 L of cold water (tap water is fine). Divide the YPD base into four 500 mL portions.

To each 500 mL portion, add the required amount of sucrose to get the desired final concentration. Note that 1 teaspoon (tsp) of sucrose weights approximately 4 grams.

$$\frac{g\ Sucrose}{1\ L} = \frac{x\ g\ Sucrose}{0.5\ L}$$

	Control	A	B	C
Desired final [Sucrose] (g/L)	0	16	48	96
Volume (L)	0.5	0.5	0.5	0.5
Grams of sucrose to add per 0.5 L	0	x	x	x
# teaspoons needed	0	(calc)	(calc)	(calc)

Add the required amount of sucrose and swirl to dissolve.

For each sucrose concentration, dispense ~150 mL to three soda bottles (be sure to label them on the neck of the bottle). Secure an airlock into the mouth of the soda bottle. If your airlock does not fit snuggly, wrap the syringe body with aluminum foil until a secure fit is achieved. Fill the airlock with water, no higher than the top of the 250 µL tip.

Sterilize the media by heating in boiling water for 30 minutes. **Slowly cool to room temperature.**

Important note!

Make sure that you handle the hot glass media bottles with care. Do not cause stress on the glass by changing the temperatures.

Inoculation and cultivation

Inoculate each soda bottle (near a flame and using good aseptic technique!) with 500 µL (0,5 mL) of S. *cerevisiae* (DSM 1334) from the provided Eppendorf tubes (be sure to mix before use!). Incubate the bottles for 2-3 days at room temperature or until bubbling stops.

Analytical Methods

At the end of the fermentation, transfer approximately 1 mL of cultivation broth out of *each* bottle into an Eppendorf tube. Add a small scoop of calcium carbonate, close the tube, mix its contents and transfer it to a refrigerator to all the cells to sediment out of solution (you should end up with 12 Eppendorf tubes). The solutions should appear clear after several hours.

To quantify the amount of ethanol in the solution, we are going to employ an optimized version of the cerium ammonium nitrate (CAN) methodology described by Reid & Truelove (1952) which can be used using CAN-alcohol to quantify alcohols in the range of 0.1 to approx. 5% w/v. Lau & Luk (1994) applied the use of an ethanol-CAN complex to the rapid quantification of ethanol in alcoholic beverages using the procedure below. More recently, the use of the cerium(IV)-ethanol complex has been adapted to colorimetric flow injection analysis (Pinyou et al., 2011).

Important note!

The CAN reagent contains dilute nitric acid and is a strong oxidizing agent. Were gloves and eye protection when handling it to prevent accidents. Clean up any spills immediately with water and a paper towel.

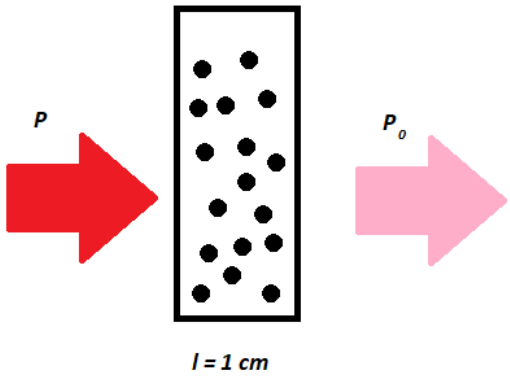
If you get it on your skin (please make sure that this does not happen) rinse the affected area with tap water immediately. If you get it in your eyes, rinse with water thoroughly.

Using the photometric procedure below, generate a standard curve using the ethanol standards provided (labeled “A” through “I”. Note that some of the provided standards may be out of the useful range. To complete these calculations, you will need to convert the “blue” value read by the app on your phone to percent transmittance (% T) which we can then convert to absorbance which will then be used to prepare a concentration versus absorbance plot from which we can get an equation to calculate the ethanol concentration of your actual samples.

$$\%\,Transmittance = \frac{P}{P_0} \cdot 100\%$$

Where *P* is the amount of light allowed to be transmitted (i.e. not absorbed) through the culture at each given time and P_0 is the amount of light let through a "blank" (in this case the tube before inoculation).

If we think about a solution in a cuvette, such as the one at the right, we are measuring the amount of light absorbed by the solution and how much light actually makes it through said solution (that is to say how much light is transmitted through the solution).



Absorbance can be calculated using Beer-Lambert's Law as follows

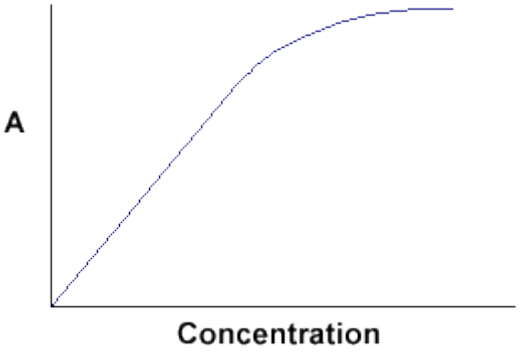
$$Absorbance(A) = 2 - \log(\%T)$$

Use the table below to calculate the absorbance data for the standard curve.

	Ethanol Standard (% v/v)	**Blue intensity (P)**		Transmittance (%)	Absorbance (~485 nm)
Blank	0% (tap water) **(P_0)**				
A	0.1%				
B	0.25%				
C	0.5%				
D	0.75%				
E	1%				
F	2.5%				
G	5%				
H	7.5%				
I	10%				

Prepare a standard curve (similar to the one at the right) for ethanol (x-axis, independent variable) and absorbance (dependent variable) and generate a linear equation which can be rearranged for x.

Note that Beer's Law is not obeyed at high concentrations so your standard curve may require "clipping" for ethanol concentrations that fall outside of the linear region.

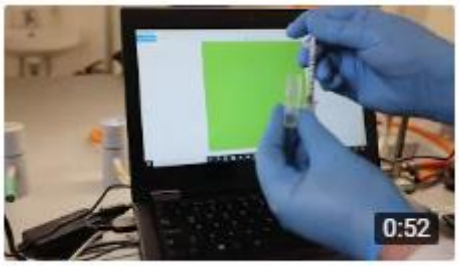


Ethanol determination procedure

Add 0.2 mL of CAN-reagent to a clean cuvette. Add 0.5 mL of sample (or standard) using a syringe and immediately measure the blue light intensity through the cuvette using the Colormeter Free App against the **blue background (~485 nm)** on the next page.

Note: iPhone users should try the Colorimeter RGB App.

To be clear, view the cuvette with it against the blue background on your computer screen and examine the intensity of the blue light *through* the cuvette (through its "clear" side).



A brief demonstration of the procedure (link)[2]

Note: yes, I know. I messed up. The video shows a green background…

[2] https://youtu.be/4cDNojdciEU

For experimental samples, calculate the absorbance value in the same manner as the ethanol standards and use this value to determine the ethanol concentration using the linear equation generated above (you are solving for concentration, x). Note that the P_0 value is from the tap water (0% ethanol) above.

Condition	Sample	Blue intensity (P)		T%	Absorbance (485 nm)		Ethanol (%v/v)	% ethanol yield
Blank (water instead of sample from above)	P_0							
0 g/L sucrose	1							
	2							
	3							
16 g/L sucrose	4							
	5							
	6							
48 g/L sucrose	7							
	8							
	9							
96 g/L sucrose	10							
	11							
	12							

Note that you will have to calculate the theoretical yield of ethanol for each initial sucrose concentration as well as averages and standard deviation where appropriate.

Quarantine Edition

VI

Experiment VI Antibiotic Sensitivity of Bacteria

Number of class periods: 1

Weight: (Part of Report #2 which is 40%)

Keywords:

Reading: Staley Chapter 6 and 7

Experiment VI- Antibiotic Sensitivity of Bacteria

Groups of 1-2
1 Lab period
Concepts and Techniques: antibiotics, minimum inhibitory concentration, paper disc diffusion assays

Hand-in: Full Report

Introduction

Antibiotics: A historical perspective

The use of molds to treat disease is found throughout recorded history although it is Alexander Flemming's accidental (re)discovery of penicillin (a β-lactam) that is frequently credited with starting the antibiotic revolution. Initially, penicillin was so highly valued that the urine of patients taking the drug was collected to recover the majority of the drug (80%!) which was not taken up by the body.

Figure 26 - 1940s advertisements and public service announcements raising awareness of Gram-positive bacterial infections

Due to the outbreak of war in Europe and the Pacific, large quantities of penicillin were required for the war effort to fight the inevitable bacterial infections that accompany battlefield injuries. Initially, no chemists were willing to take on the problem of isolating and mass producing the drug although penicillin was eventually successfully synthesized in the 1950s although this means of production was found to be highly inefficient and cost prohibitive. Thus, large scale microbial production was needed.

By modifying the structure of penicillin, other useful antibiotics with improved properties (better uptake by the body, different selectivity against other microorganisms, etc). As with all things, nature has readily adapted to the use of antibiotics and resistant strains have emerged such as methicillin resistant *Staphlyococcus aureus* necessitating the discovery of new ways to combat infection.

A list of some commonly used clinical antibiotics is provided in **Table 2**. A more comprehensive database can be found online at the following link[3].

[3] http://antibiotics.toku-e.com/

Table 2 - Inhibition Zones of Selected Antibiotics (modified from Cappuccino & Sherman, 2001; pg 191)

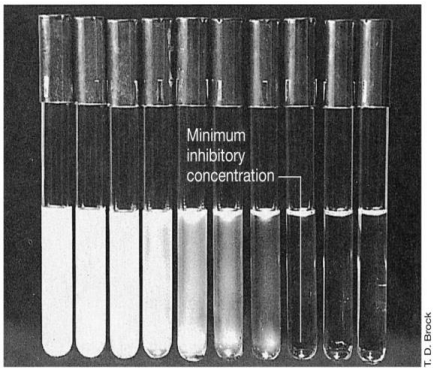
Disk Symbol	Antimicrobial Agent	Disk Content (µg)	Diameter of Zones of Inhibition (mm)			Mode of Action
			Resistant	Intermediate	Susceptible	
AMP	Amplicillin (against Gram-negative bacteria)	10	≤13	14-16	≥17	
	Amplicillin (against Gram-positive bacteria)	10	≤28	-	≥29	
C	Chloramphenicol	30	≤12	13-17	≥18	
CAZ	Ceftazidime	30	≤14	15-17	≥18	
CB	Carbenicillin	100	≤19	20-22	≥23	
	Carbenicillin (against *Pseudomonas*)	100	≤13	14-16	≥17	
CFS	Cefsnlodin					
CF	Cephalothin	30	≤14	16-17	≥18	
CIP	Ciprofloxacin	5	≤15	16-20	≥21	
E	Erythromycin	15	≤13	14-22	≥23	
FCA	Fluconazole					
FOX	Cefoxitin	30	≤14	15-17	≥18	
G	Sulfisoxazole (Gantrisin)	25	≤12	13-16	≥17	
GM	Gentamicin	10	≤12	13-14	≥15	
IPM	Imipenem	10	≤13	14-15	≥16	
L	Levofloxacin					
NV	Novobiocin					
P	Penicillin G (against *staphylococci*)	10 units	≤28	-	≥29	
	Penicillin G (against other bacteria)	10 units	≤14	-	≥15	
PB	Polymyxin	300 units	≤10	-	≥14	
R	Rifampin	5	≤16	17-19	≥20	
S	Streptomycin	10	≤11	12-14	≥15	
SF	Sulphafurazole					
SXT	Trimethoprim/Sulfamethoxazole	1.25/23.75	≤10	11-15	≥16	
Te	Tetracyclin	30	≤14	15-18	≥19	
Va	Vacomycin (against *Staphylococcus spp.*)	30	--	-	≥15	
	Vacomycin (against *enterococci*)	30	≤14	15-16	≥17	

The battle of the microbes: chemical warfare

As many different types of bacteria and fungi must compete in a habitat for limited resources, it should be surprising to imagine that they have evolved means of

Minimum Inhibitory Concentration

Drug interaction of microorganisms may be examined in several different ways. In order to determine the lowest concentration to inhibit microbial growth (MIC; minimum inhibitory concentration) are usually used two methods; dilution method (dilution) and disk method (agar diffusion method) (Figure 1).



Minimum inhibitory concentration (MIC) is the lowest concentration of an antimicrobial that will inhibit the **visible growth** of a microorganism after overnight incubation (Setzer & Vogler, 2006)

Paper disc diffusion assays

Paper disc diffusion assays are also commonly used to test the effective dosage of antibiotics against a cultivable bacterium. The ***zone of inhibition*** is measured after a period of growth (typically 24 or 48 hours).

Purpose

The purpose of this experiment is to find out which is the lowest concentrations to inhibit microbial growth of several different species of bacteria.

Materials and Methods

If you have an **allergy to antibiotics**, be sure to notify the INSTRUTOR prior to beginning this experiment!

Part A – *Preparing Media for Antibiotic Disk testing*

Preparation of Nutrient Agar Plates

Nutrient Agar (NA) can be prepared by placing a bottle of solid NA in boiling water in a sauce pan filled with water until the NA is fully melted. Hold the bottle of melted NA in a sauce pan at 50°C until ready to pour onto petri dishes.

When pouring petri dishes, be sure to observe good sterile technique! Wipe down your working area with 70% ethanol. Be sure to pour plates near a flame.

For each bacteria being examined you will need three NA plates so try to pour at least 6 petri dishes of NA.

YouTube link

Divide each petri dish into 4 sections by drawing on the backside (bottom) of the dish with a maker (the extra section should be kept as a control) as shown in Figure 27.

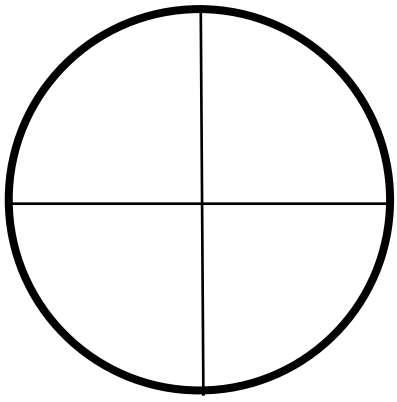


Figure 27 - A petri dish divided into six sections for antibiotic susceptibility testing

Part B – *Paper Diffusion Disks for Determining Antibiotic Susceptibility*

Preparing the bacterial lawn (Mueller-Hinton Agar Plates) and placing of Antibiotic Disks

Dip a sterile cotton swab into a culture tube containing the bacteria of interest (note: dilute the provided overnight culture 1:100 in Butterfield's Buffer). Swab the entire surface of the plate as shown in Figure 28; turn the plate 45° and swab the surface of the plate again. Turn the plate another 45° and swab. Allow the surface of the plate to dry.

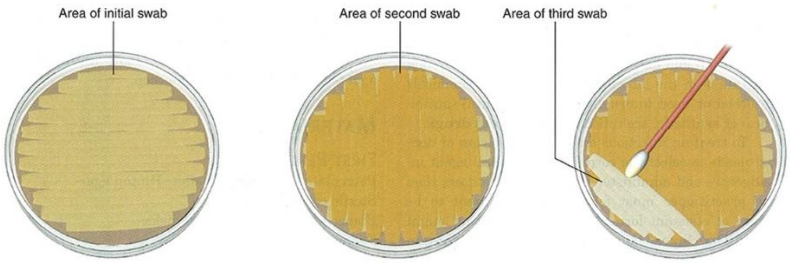


Figure 28 - Inoculation of a Mueller-Hinton agar plate (Cappuccino & Sherman, 2001; pg 192)

Alternately, inoculate the plate with 100 µL of an overnight culture of microorganisms and spread with a sterile "hockey stick". Allow the surface of the plate to dry for approximately 20 minutes.

YouTube link

Using flamed (and cooled) pair of forceps or a sterile needle, aseptically transfer the paper diffusion disks containing antibiotics to the surface of the agar plate. Note which antibiotic disk is being placed in which section! Seal the agar plate with parafilm.

YouTube link

Remember to NOT re-sheath the used needle. Dispose of any used needles into an extra petri dish and take it shut before discarding it into the garbage (alment rusl).

Incubate the plates for 24 - 48 hours at **37°C** (or other temperature as advised). **Make sure that the plates are incubated agar side up!**

After 48 hours, measure the zone of inhibition (the diameter of the area around the disk in which the bacteria did not grow).

Dispose of the agar plates by placing them in a small bag and tying it closed. Place in a normal waste basket (alment rusl).

Writing the Lab Report

Report the antibiotic sensitivity of the strains tested in Part A and the minimum inhibitory concentration (MIC) of microorganisms and antibiotics in Part B.

How do your results compare to your peers and the literature?

1) How are amplicillin, amoxicillin, and cephalosporin different from penicillin?
2) What effect does the lysozyme treatment have on Gram-positive organisms? Gram-negative? How might this alter the sensitivity of an organism to antibiotics?
3) Chemicals, difference between Gram positive bacteria, Gram negative bacteria, archaea, and eukaryotes?

4) Can the results of a MIC test be used to determine whether an antibiotic is bacteridiocidal or bacteriostatic? If not, design an experiment to determine whether or not an antibiotic is bacteriocidal or bacteriostatic.

X.G. Experience of leading, administering and developing courses and study programmes

Include a detailed account of each assignment, including extent, time, the nature of tasks, etc., as an appendix in Box G.

X.G.1 Development of Introduction to biotechnology course (2019)

Háskólinn á Akureyri
University of Akureyri

Innovation in Education

LFT1106– Introduction to Biotechnology

The course Introduction to Biotechnology (LFT1106; 6 ECTS units) was established about 5 years ago and developed as an introductory course for students within the biotechnology study line at the University of Akureyri within the Department of Natural Resource Sciences. The course was adapted from an earlier course, Marine Biotechnology, which had come to serve the same introductory function. Sean M. Scully took over responsibility for the course in the autumn of 2019.

Sean restructured 30% of the course using a **blended learning** approach to allow time for deeper discussion on specific topics of interest within biotechnology. Four lectures on the topics of proteins, biocatalysis, microbial biocatalysis, and bioethics were “flipped” in order to create time in class for discussion, using alternative media, and hands-on demonstrations of key concepts (such as column chromatography and stereochemistry). Additionally, a **focus on academic writing** was also woven into the course similar to the “writing across the curriculum” (WAC) model used at universities in the United States. Three biotechnology-centric writing assignments of increasing complexity were used to better develop student´s academic writing. Four mini-lectures on paragraph structure, writing flow, essay structure, and finding references were provided.

The changes to the course were received positively by the students whom especially enjoyed the greater flexibility offered by taking this approach balanced against the direct contact with the instructor. This was reflected in the end of term evaluation of the course as well as from positive remarks from students made in passing. Future work to improve the flexibility of the course will include the addition of self-guided laboratory experiments that can be accomplished at home that will reinforce vital skills introduced in other courses.

Rannveig Björnsdóttir Dean Department of Natural Resource Sciences	Jóhann Örlygsson Department Chair Department of Natural Resource Sciences

X.H. Development and dissemination of knowledge

Peer-Reviewed Publications (Education)

Scully, S.M., Bjarnadóttir, B. (2021). Enhancing engagement in the learning cycle models for sciences. *In preparation*.

Scully, S.M. (2021). Making Biofuels from Complex Biomass. *Science in Schools*. Submitted.

Scully, S.M. (2021). Biofuels. *Science in Schools*. Submitted.

Scully, S.M. (2018). Some (microbes) like it hot. *Science in Schools*, *45*, 12-17.

Scully, S.M. (2016). Exploiting an interdisciplinary approach using undergraduate research. *Fine Focus*, *2*(2), 116-130.

Professional Presentations

Scully, S.M. Arctic universities: Centers for confronting 21st century challenges. The Role of Universities in Addressing Societal Challenges and Fostering Democracy: Inclusion, Migration, and Education for Citizenship. 26 March 2021. University of Akureyri.

Scully, S.M. Creating authentic laboratory experiences ... @home. Ráðstefna um náttúrufræðimenntun. 20 March 2021.

Scully, S.M., Bjarnadóttir, B. Expanding science instruction in Iceland through science outreach. Ráðstefna um náttúrufræðimenntun. 19 March 2021.

Scully, S.M. Designing for engagement: crafting a flexible learning approach with hands-on elements in the biological sciences. Hvað er góð háskólakennsla? - Kennsluráðstefna KHA (22. Apríl 2020)

Scully, S.M., Weaving Critical Thinking into the Biological Sciences. 4th Teaching Seminar. What is a good university education? Fjórða kennsluráðstefna Kennslumiðstöðvar HA. 23 May, 2019. University of Akureyri.

Scully, S.M., Teaching Hands-on Science on a Shoestring Budget. Vísindi í námi og leik (Science in learning and play). 30 March 2019. University of Akureyri.

Scully, S.M., Teaching Hands-on Science on a Shoestring Budget (Poster). Vísindi í námi og leik (Science in learning and play). 30 March 2019. University of Akureyri.

Scully, S.M., Science Literacy in Iceland: Current Status and Future Prospects. 23 January, 2019. University of Akuryeri. Social Science Forum (Félagsvísindatorg)

Scully, S.M., Ingvadottir, E.M. Research Integration into Microbiological Education. QEF Annual Conference**,** Integrating research into undergraduate learning: International and Icelandic examples. University of Reykjavik, 15 May 2018.

Scully, S.M., Unpacking scientific literacy and the state of science education in Iceland. Social Science Forum (Félagsvísindatorg), University of Akureyri, 7 February, 2018.

Scully, S.M., University of Toledo summer camp for the integrated activities grant. Oral paper. 225th Conference of the American Chemical Society Conference, New Orleans, 2003.

Scully, S.M., University of Toledo summer camp for the integrated activities grant. Poster presentation. 225th Conference of the American Chemical Society Conference, New Orleans, 2003.

X.I. Pedagogical activities outside the university

Please note that this list is not comprehensive

Breiðdals-og Stöðvarfjarðarskóli, Breiðdalsvík: ScienceDay	December 2020
Giljaskóli, Akureyri: Slime, hands-on science visit, 2nd grade	October 2019
University of Akureyri: Vísundur (Program supervisor, about)	2017 to present
University of Akureyri: 30th anniversary, ScienceShow	2017
Naustaskóli, Akureyri: Slime, hands-on science visit, 3rd-4th grade	2013
University of Akureyri: Vísindasetur, see here, here and here	2008 to present
Virtues Project: see here (Science Program Assistant)	2004 - 2006
American Chemical Society University of Toledo Student Affiliates (Secretary and outreach program assistant)	2002 – 2004
Sylvania Southview SciQuest	1999 – 2002