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Docility is not Passiveness

Teaching Learners to *Learn* in Science Education

In this article we identify the need for active docility in teaching learners how to learn. Docility is understood not in the quotidian sense, but rather in a virtue ethics tradition where docility is a quality of character described as being both open to learning but also critical of the knowledge being assimilated. In considering the structures of science education, we present case studies from laboratory ethnography that help to illuminate the ways in which docility is crucial not only to learning how to learn, but also to the everyday requirements of the reproducibility of scientific data. In the analysis of the case studies, we highlight three key points: first, the challenges of exemplarity and maintaining pedagogical authority; second, the difficulty of striking the proper 'mean' of docility within different settings; and third, the need for cultivating docility that does not silo instances of learning.

Keywords: Docility, Virtue ethics, Science, Laboratory ethnography, Exemplarity, Education

1. Introduction

To be a scientist is to learn continually. One learns how to conduct an experiment from colleagues in the laboratory, one learns of new discoveries from the research of others, one learns applied skills from professional development courses, one goes to workshops, conferences, lectures, seminars … the list goes on and on. It would seem, therefore, that a key element of being a truly effective scientist is the ability to *learn* continuously.

In many branches of science, such as laboratory-based research, this continuous learning occurs in two different areas. In addition to the continuous scrutiny of research data and its contributions to the field of study, scientists also have to learn the tacit skills necessary to produce the data driving the research. They need to become proficient in the methods used to generate data in the laboratory and continually learn new methods to drive their research forward.

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Interestingly, the theoretical aspects of the discipline, together with critical data evaluation, are taught in very different ways to the tacit skills necessary to become a competent laboratory researcher. In particular, the latter is normally taught through a series of 'practicals' where students are instructed on how to successfully follow an experimental protocol (Lock 1988). These protocols have typically been subject to extensive trouble-shooting and their completion usually provides the students with a positive result, thus indicating the success of the undertaking (Abrahams and Millar 2008).

While this approach to fostering tacit laboratory skills has strengths – ensuring that students build up tacit skills in carefully controlled and supervised settings – the limitations of this approach must also be recognized. By continually expecting students to unquestioningly follow the steps outlined in the protocol, it is possible that they become habituated to affording protocols a level of authority and infallibility. Moreover, the selection of only protocols yielding positive results or definite products can lead students to make incorrect assumptions as to what constitutes the successful completion of a research protocol. Indeed, they may leave undergraduate training with little personal experience of failed experiments, negative results, or trouble-shooting (Firestein 2015).

In recognizing these structural limitations, we highlight a caveat in modern scientific training around the world. In many educational institutions, there is a compartmentalization of science training into 'theoretical' and 'practical' streams with different pedagogical traditions of learning. Without dedicated efforts to bridge this divide, students may emerge from undergraduate training as scientists who may be hypercritical in their assessment of data, but under-critical in the way they follow protocols and conduct laboratory experimentation. While it is likely that many scientists gradually overcome this compartmentalization in the course of their science careers, the process of developing a holistic approach to learning can be arduous for both student and supervisor. How, we ask, can we conceptualize an approach to education that equips students with a holistic attitude to critical thinking, an approach that maintains the rigor and criticality of the majority of scientific work? How can science students be *taught to learn*?

2. Docility as the Virtue of Learning

The idea of teaching science students to *learn* effectively is, of course, the subject of considerable pedagogical discussion. Nonetheless, many of these discussions continue to be focused on *classroom interactions*, and do not take into account the peer-learning and informal teaching that constitute the majority of teaching for tacit skills. Thus, it would appear that additional models of learning are helpful.

One focalizing concept that has not been examined in relation to science pedagogy has its origins in virtue ethics and relates to the virtue of *docility*[1]. The term originates from the Latin *docere* and signals an aptness and willingness to *learn* and not a passive orientation to *be taught.* In line with this etymology and specifically within the virtue ethics tradition, docility is defined as "a keenness to be instructed by others and a desire to obtain true knowledge" (Pieper 1985, 225)[2].

Individuals who have internalized the virtue of docility are thus not only humble and open to learning, but keenly critical of the knowledge they assimilate. Indeed, docility may be thought of as "the kind of open-mindedness which recognizes the true variety of things and situations to be experienced and does not cage itself in any presumption of deceptive knowledge" (Pieper 1956, 15).

The utility of docility as a virtue or character trait to discussions on developing well-rounded science students should be eminently apparent. It offers a means of cultivating an attitude to learning that transcends the potential siloing of education discussed above. Finding ways to cultivate docility as a core virtue for scientists will establish an embedded openness to learning and an inherent questioning attitude in all graduating students. The exercise of docility will necessarily provide them with the tools to bridge the different types of teaching and learning taught in the different realms of science education.

The development of docility in students, as a form of character development, is in itself not new. Indeed, in recent years developments in pedagogy and curricula have seen the rise of a number of character-focused initiatives. These include educating for "responsible scientists" (National Academy of Sciences 2009) and the rise in Active Learning pedagogy. This is a concept that has rapidly gained traction within educational sciences and is based on activities that enable students to take an active, engaged part in the learning process (Newton et al. 1999; Prince 2004). This contrasts with more traditional methods of teaching in which the student is relatively passive. Educational scenarios that employ active learning not only enhance

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1 It is important that the reader distinguish between the use of *docility* in virtue ethics (as is used in this article) and more colloquial usages. The latter tends to focus on 'teachable-ness' and to be more passive than virtue ethics interpretations that highlight the involvement of the student in the learning process.

2 For more on Josef Pieper's philosophical influence on university education, see the discussion in Warne 2018.

content assimilation and retention amongst students but could also foster an approach to learning that extends beyond the boundaries of the course. The new perspectives and tools for facilitating learning that students (and educators) are exposed to could enhance learning in other scenarios. Thus, one could suggest that effective active learning can stimulate the acquisition of the habits of docility in both learner and educator.

Interestingly, however, there has been little discussion within these different character-focused initiatives about *teaching how to learn*. Indeed, the majority of current discussions focus on the effective assimilation of content – be it ethical or theoretical – and the development of rounded individuals. It is this caveat in particular that a focus on the virtue of docility can address.

If one re-evaluates the challenges of science education discussed above from a perspective that highlights our particular emphasis on docility, another key factor becomes evident. Docility as a virtue is interpreted and valued differently in the different contexts of instruction. Effective learning within theoretical instruction settings lies closer to defensive reasoning. For tacit knowledge settings, it would lie closer to passiveness. While these differing manifestations of docility are not irreconcilable, the markedly siloed structures of science education can cause difficulties for students. Indeed, without additional support students can find it difficult to transition from what is referred to in Character Education as "habituation virtue to full virtue" (Kristjánsson 2014, 152). This transition, from habits of docile activity within different settings to a truly internalized and 'pan-educational' docility, requires further exploration, as this process has implications beyond the individual, and can impact on the responsibility and integrity of science as a communal endeavor.

In this article, we use empirical research to unpack the difficulty of fostering docility within science pedagogy. Using a number of case studies, we highlight key challenges with fostering docility, namely:

1) It is difficult to 'teach how to learn' – this is understood as an issue of exemplarity that creates tension with maintaining pedagogical authority.
2) It is difficult to strike a balance between independence and group work and to apply the proper 'mean' of docility within different settings.
3) It is difficult to turn docile actions – or habituated behavior that unconsciously mimics docile actions – into an internalized virtue – suggesting a need for a pan-educational approach to cultivating docility that does not silo instances of learning.

While these case studies are exceptions in observations of the normal everyday activity of a laboratory, they do allow for the opportunity to see docility in action. Through the discussion of the case studies, we will highlight the educational and epistemic challenges relating to the absence of docility. We will identify ways in which these three obstacles can be, or were, overcome. We conclude by offering recommendations for the further study of docility in science, particularly relating to styles of pedagogy and curriculum design. Importantly, we acknowledge that taking a virtue ethics approach to learning poses certain limitations. Nonetheless, it has been argued that these limitations can be overcome with a modest approach to what we can or cannot observe and therefore analyze (Kristjánsson 2013, 285), as is discussed in greater detail below.

In the analysis of these case studies we made use of a virtue ethics framework. Virtue ethics is increasingly understood as a third approach to normative ethical theory; however, it is more than a character-based form of deontology and consequentialism (Oakley 1996, 151). The focus of virtue ethics takes into account such things as a concern with the agent, choice and action; motivations; and a holistic knowledge of the agent's moral life that encompasses choice, action and motivations (Nussbaum 1999, 170). Virtue ethics emphasizes excellence of character, is rooted in Aristotle's ethics, and has splintered into many branches of moral philosophy. In this article, modern interpretations of Thomas Aquinas' adaptation of Aristotelian ethics are applied, wherein Aristotle's *phronêsis* is considered by Aquinas to be the same virtue as *prudentia*, or prudence (Zagzebski 1996, 212). According to Aquinas, prudence is a principal virtue closely linked to a variety of other characters of excellences, such as docility (*docilitas*). Therefore, "[d]ocility is an integral part of prudence because one who is teachable is able to learn how to interpret how one should act" (Bezuidenhout et al. 2019, "*Docility as a Key Epistemic Virtue*," para. 2). As a character of excellence, docility intersects with a virtue ethics approach in order to understand the matter of teaching learners how to *learn* in science.

3. Methodology

In this article, we present a series of case studies that emerged during a year of laboratory ethnography within the university setting. Both authors participated in the daily activities of the two laboratories and observed these case studies *in situ*. Participation involved doing experimental bench work, attending weekly lab meetings in which we presented our own experimental findings, attending conferences with lab members, and participating in journal club. Each lab had distinct research interests; however, generally speaking they can be characterized as molecular biology labs within a teaching- and research-focused American university setting. Each lab had a small number of graduate students, lab technicians, lab managers and principle investigators. Lab members under 18 years of age were not included in this study. Both labs comprised an equitable mix of men and women. Each lab was the site of a rich embedded context of mentoring, teaching, learning and doing science.

In accordance with human participants research ethics, this study received approval from the University of Notre Dame Institutional Review Board. In following the principles of the *Belmont Report*, participants voluntarily entered into the research after being provided with adequate information about the details of the study (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research 1979). Each participating lab member signed a letter of consent before proceeding, and in the event that lab members did not sign consent, their participation was not documented in field notes and they were not interviewed.

The structure of science education in both laboratories was similar to the structure of 'theoretical' and 'practical' streams outlined above. The graduate students had already completed their undergraduate studies, characterized by a heavy emphasis placed on lecture-based learning in the institutional setting. These formal lectures continued during their graduate studies. However, in addition to these lectures, students were developing practical, hands-on experience of laboratory work. Initially, postgraduate students were introduced to labs during a rotation, wherein they would work in one lab over the course of several consecutive weeks. During this time, they worked closely with either a senior lab member or lab manager, learning the necessary protocols both through observation and by doing them alongside their assigned trainer/peer. After a series of rotations, the postgraduate student formally joined one of the labs in which they had rotated, for the duration of their time in their program of study. Over the duration of a postgraduate student's education, the structure of the student's education was composed of both lecture-based learning and in-lab mentoring. Over time, it was expected that the new lab member would increase their capability to work independently and become a mentor themselves.

As will be elaborated below, how students transitioned from lecture-based learning to practical learning offered some interesting insights into the structures of scientific education. In particular, as the case studies highlight, this transition was often not smooth, and we gathered many examples of students struggling to engage with the practical lessons in hand. After reviewing these instances, it became apparent that many of these encounters were characterized by students (or teachers) either unquestioningly accepting the material in hand, or assuming that they 'knew better.' Both situations point to a lack of engaged learning, and thus to a lack of docile learning interactions. These observations thus led to a retrospective analysis of certain key interactions from a docility perspective, questioning *what went wrong* and then following up with how they were corrected.

In our analysis of these case studies we made use of a virtue ethics framework. Employing this framework, especially with respect to education, highlights a concern with becoming good in practical terms, rather than in theoretical terms alone, as well as the "nature and role of virtues" for both students and educators (Walker and Ivanhoe 2007, 5). From our observations within the laboratory we attempted to construct a narrative explaining *why* these incidents occurred, and how these could be related to the ways in which the students were instructed. In these analyses, it became apparent that many of these incidents were not arising because of deficits in the content being transmitted, but rather as a result of the learning structures that imposed an authoritative premise on interactions. It is important to note that these challenges arose on both sides of the interactions – the educator faced the challenge of transmitting the content effectively, but also *the student was not open to learning.* In recognizing this challenge, we focused our narrative on the virtue of docility and the ability to 'teach/learn how to learn.'

Nonetheless, we recognize that the use of virtue ethics as an analytic framework is unconventional and draw attention to the limitations of this approach. These necessarily relate to the difficulties of studying virtues empirically, namely:

- Identifying the presence of virtues, as personally held *character traits*, requires the individual subject to report their motivations for their behavior. Reports on virtuous motivations are thus subject to reporting bias.
- Evaluating the presence – or absence – of a virtue requires a subjective assessment by the researcher.
- Virtues, by definition, are contextual and interrelated – they do not occur in isolation, nor do they correlate on a one-to-one basis with actions. This complicates attempts to isolate a single virtue for study.
- Truly embedded virtues become second-nature for the practitioner and would therefore be less likely to be explicitly identified as a motivating factor.

In addition to these issues with empirical virtue studies, the virtue of docility comes with its unique set of challenges. Observing 'docility in action,' as the virtue that facilitates learning, requires looking beyond the content of the learning interaction to a nebulous set of soft-skills, including motivation, support, enthusiasm, responsiveness, and empathy. Identifying exemplars to guide students in the acquisition of docility is similarly complicated, as it would require identifying teachers who 'teach students how to learn.'

Nevertheless, these challenges are not necessarily insurmountable. The extended embedded fieldwork in the laboratories allowed us to generate thick narratives of the consequences of interactions and repeated observations of the same actions. This lessened the possibility of subjectively misinterpreting isolated situations or attributing the virtue/vice of docility to an interaction without understanding context. Extended discussions with lab members reflecting on their actions and experiences also lessened the subjectivity of our analyses. Furthermore, our understanding of the activities and the environment was strengthened by participating in lab activities over time and following the development of scientists from learner to role model. It is important to reiterate that our approach does not seek to measure the presence of virtues or virtue learning, but rather to understand the contexts and the tools that are necessary for the cultivation of, and the potentiality for, the internalization of virtue.

4. Teaching 'How to Learn'

As mentioned above, the virtue ethics tradition portrays docility as a "keenness to be instructed by others and a desire to obtain true knowledge" (Pieper 1985, 225). Docility thus shifts the educational focus from the teacher who *knows* something to the learner who *wants to know*. As a result of this shift, the student becomes an important partner within the educational interaction, bringing critical questioning and eagerness to the engagement. Importantly, however, a truly docile educational interaction requires the active participation of *every* individual in the learning scenario. Thus, both student and teacher need to exhibit docility, so as to be able to learn not only from each other, but also from the learning activity itself. Characterizing a learning interaction as docile "implies the aliveness, the eagerness of [all] knower[s]" (Schall 2016, 180).

True enactment of docility thus requires a two-way relationship between student and teacher. Indeed, docility in teachers enables them to continually learn from their interactions with students, and to continually question the what, how and why of their teaching. A classic example of this is Socrates. Socrates is often held up as an exemplar of docility, due to his pedagogical style in which he maintained that he did not know anything (Plato 1997, for example). Socrates not only fostered docility within himself, but also acted as an exemplar of docility for his students to emulate. Docile teachers recognize that while the willingness to know is the one thing that we cannot "give" to someone else, "we might be able to inspire him or even prod him to know himself" (Schall 2016, 178).

While the notion of docile educators and students sounds eminently feasible in principle, *in practice* this is necessarily complicated by a number of different issues that are closely related to the structure of modern scientific education which we described earlier. Specifically, in the first place, the university structures – particularly for science education – favor lecture-style teaching, which requires the instructor to impart a large quantity of knowledge to a relatively passive student audience. This style of lecturing offers little in the way of opportunities for educators to exemplify docility or for learners to emulate it.

Secondly, the traditional hierarchical structures of both in-class lectures and laboratory-based skill development establish an unequal power dynamic in which questioning instructors (or instructors admitting errors) and senior lab members who act as mentors is less likely. These traditional hierarchical structures can act as barriers to experiencing docility in the way we are proposing, where *every* individual is active in the learning scenario. These situations are further complicated by increasing class sizes. In large classes instructors are not only unable to offer the one-on-one engagement that fosters docility, but are also less likely to select lecture material that offers the controversy or learning challenges that necessarily stimulate docility.

Nevertheless, the opportunity to foster docility – while extremely difficult within certain areas of science pedagogy – is nonetheless present in other activities of teaching and learning that characterize science. A key aspect of scientific research is the ability to engage with, and react to, the work of others. As elaborated by Robert Merton, the fundamental norms of science include the *collegiality* which stimulates the sharing of research, and the *organized skepticism* with which these research offerings are interrogated and unpacked (Merton 1973). Such is the importance of these norms to science that their regular enactment has become a key aspect of science research in the 'journal club.' These are regular meetings held by research groups, teaching classes or departments at which new research publications are carefully discussed and critiqued. The case study below elaborates one such journal club meeting.

Case Study One: Field Notes Extract, 24 October 2016

Lab 2 is holding their weekly journal club. The paper under discussion is a recent study in their field of research. They will be going to a conference the following month at which the authors will be present. As a lab, they talk through the paper and evaluate their positions on the research presented and the data. They also speculate about the data missing from the report.

The PI says: "we'll add this to the stack of papers that we go to for comparisons. It's not a definitive paper, but it'll be something to check." Nonetheless, he follows up this comment by highlighting the value that this cumulative collection of papers has. He says: "these are really valuable resources, and we all need to know where to go to find them." The PhD student who is presenting the paper then goes on to talk the group through the paper. He starts off by saying: "the paper is quite boring. The supplementary is where it gets interesting." Once they have discussed the findings presented in the paper, one of the other lab members comments on the data, saying: "I don't think they're giving away all their data on Africa. I think they're hoarding it. They're tipping their hat to it, but they're not putting out all their data."

After the lab meeting the PI circulates an email further reiterating their discussions about the data they generate and that within their field. The PI highlights how a communal approach is valuable for the team and for advancing their research goals. He says:

"The list below is in preparations for orchestrating our conference posters. These are talking points about our general lab perspective. I want you talking about these. Pulling up papers if you don't know them. And speaking up and asking questions if you don't understand.

- What do you want to KNOW?
- Why do you need a complex sampling scheme to ANSWER it?
- What challenges does our 'big data' approach bring?
- How are we solving these challenges?
- Do we have a rigorous pipeline of data making and data processing?
- What are our analytical options when even a 'small' experiment consists of [a large amount of data]?"

Further on in the email he says: "… if you don't solve these challenges, there is not magic to making loads of data … just a bigger mess."

Within this journal club, the PI may be seen to stimulate docile reflexivity amongst his students by encouraging discussion about the data being presented – how it was created, where it should be included within their experiments, and how such data should be addressed in the future. In this way, the journal club fosters a critical engagedness in terms of *dealing with data*. In this way, we can see how docility can be fostered, as a "kind of open-mindedness which recognizes the true variety of things and situations to be experienced and does not cage itself in any presumption of deceptive knowledge" (Pieper 1956, 15).

5. Balancing Independence with Group Work Through Docility

A key element of laboratory-based science is the ability to work together. While popular literature presents pictures of 'lone scientists' and 'ivory towers,' the view on the ground could not be more different. Most scientific research today is collaborative, and it is unlikely that any one scientist would be solely responsible for all aspects of a research program. As is evident from the scarcity of sole-authored papers in scientific journals, scientific research involves many different people – PIs, researchers, technicians, students and so forth.

This highly communal aspect of scientific research is mirrored in the physical structures of laboratories and the working routines within them. In many laboratories, scientists have to work in confined conditions with colleagues from many different disciplinary and cultural backgrounds. They share equipment, reagents, communal spaces and expertise. Being able to 'get along' is a vital skill for harmonious working.

These traditions of communality are further mirrored in the traditions of teaching *in situ*. An important element of science training is the 'hands on' experience received through under/graduate placements in laboratories. In these settings, students will be taught the tacit skills necessary for experimentation by other students or staff members. This 'learning through doing' is recognized as a key element in developing expertise and maintaining quality control through successive generations of scientists within the laboratory. In fact, the tradition of 'learning from others' is not limited to students, and it is common for staff members to train each other when necessary.

As a result of this 'hands on' training, every laboratory will have certain traditions and practices centered around common protocols, and routine laboratory 'chores' such as autoclaving, washing glassware and ordering consumables. These traditions develop over time in response to many different factors, such as prior training of staff, structure of the laboratory, services and bureaucracy within the community, and interactions with global collaborators and peers. Within such 'learning from others' situations, individuals are thus taught a *contextually-derived* practice which can differ from practices in other laboratories. Contextual awareness of these learning interactions offers an important means of observing docility (or the lack thereof) within these settings.

Case Study Two: Field Notes Extract, 01 February 2017

At a lab meeting one of the students is presenting her data – in the form of Western blots. This is not the first time that she has presented similar data and there has never been an explicit discussion about the protocol she is working from. In the course of this conversation, however, it emerges that she is using extremely high concentrations of antibodies and then freezing/thawing them before use. This is apparently to decrease the activity of the antibody – something she learnt from previous students. The student even says: "to be fair, it's not in the protocol. It's something I picked up."

The head of the laboratory is astonished. Why, she asks, do her students not just use a lower concentration of the antibody? She highlights both practical concerns – that it is extremely wasteful and expensive to unnecessarily use high concentrations of antibodies. There are also associated epistemic concerns – if these high concentrations of antibodies are reported in their papers (without the freeze/thaw stage which would not normally be reported) their Western blots will be irreproducible by others. Similarly, controlling for this freeze/thaw phase is imprecise, and even within the laboratory their results are less reproducible than they should be. Extensive discussions follow as to how to safeguard against similar 'protocol slippage' happening in the future, including a scrutiny of all protocols currently in use.

While such situations are not entirely uncommon within scientific research, they are also not the norm. In the learning environment, we often heard postgraduates suggest that "*if* a mistake was to be made, it should be made here." Laboratory heads are unable to personally oversee every experiment. Therefore, they rely on peer learning and support to ensure that practices are learnt and perpetuated. Thus, without a clear understanding of how to cultivate and strengthen docility in the laboratory there is a chance that poor quality data will continue to enter circulation due to the perpetuation of logical fallacies in the protocols being learnt and taught.

This case study clearly demonstrates the dangers of 'learning from others' without activating docility. In the case study, a spurious tradition (the concentration of antibodies used) was perpetuated through the training of numerous students because of a lack of critical questioning in these learning interactions. The student never stopped to question *why* the concentrations were being used, or why the accompanying steps (freeze/thawing) were necessary. Nor did she anticipate the trouble this step would pose for reproducibility. By prioritizing group-think over individual questioning, and subjugating concerns to the notion of "*… it's not in the protocol. It's something I picked up*," the laboratory members clearly exhibited the vice of passiveness over docility.

It is possible that this passiveness is a legacy of current trends in science education – particularly in how practical skills are taught within undergraduate courses. These sessions focus on the acquisition of basic laboratory experience by the repetition of experiments under direct supervision. Importantly, within these sessions, all protocols used have been carefully pre-tested and evaluated for clarity and reproducibility. Thus, the key object of these sessions is to become familiar with the laboratory equipment and the physical practices of science, rather than a focus on the experience that constitutes laboratory-based research. Indeed, as research benchwork involves the development and optimization of protocols, the adaption of working practices to suit the environment and resources available, and the co-production of knowledge with peers, undergraduate practicals offer little in the way of insight.

These undergraduate practical instances emphasize following instructions in the traditional hierarchy of authority, rather than critical engagement. Thus, the most effective students are the ones that follow instructions, rather than those who critically question why they are required to perform the steps detailed on the protocol. Such settings, it may therefore be argued, do not offer much scope for cultivating the docility we have discussed in this article. Indeed, in order to encourage students to cultivate a docility of experimentation in these settings would require that they be pushed to critically engage with what each step in the protocol means and to understand *why* they are doing what they are doing. Successfully and meticulously following a protocol without critically asking why steps are being taken, and specifically reflecting on the *science* behind it, is by no means a sufficient way to cultivate docility. In the case study of this lab meeting presented, the head of the laboratory is able to correct an action and the much-used protocol. Not only does this foster the critical awareness of each step of the protocol, but this corrective action also highlighted the need for reproducibility as a key aspect of scientific practice. Another example of group-think and docility in action, with a different corrective outcome, is provided next.

Case Study Three: Field Notes Extract, 23 May 2017

Three of the four graduate students are present when the head of the laboratory walks into the lab. There is marked concern and confusion amongst the students as the head of the laboratory asks how long they run the experimental material in accordance with the published protocol. Everyone answered 20 minutes, aside from one individual who stepped back to do to bench work. In reply to the unanimous response from the others, the head of the laboratory replied, "But the published protocol calls for two hours. Where did you learn this?" Those that responded began to answer, "We learned it during a lab meeting about six months ago." The head of the laboratory did not recall this and suggested that it must have been learned some-where else. In time, the grad student who went back to do bench work said, "You know, I remember that meeting, 20 minutes was suggested back then." There was further discussion amongst the group with the head of the laboratory starting to piece together the details of where this notion of 20 minutes came about.

The graduate students were concerned, convinced that they had followed the recommendations to the letter. As an additional member of the lab entered the room the question was posed to her as well, "20 minutes or 2 hours?" She responded like the others – 20 minutes. When asked where she learned this, she replied, "From one of our lab consultants, I didn't question it, I just did it."

As discussion continued, the head of the laboratory asked one of the grad students to run a quick 'mini experiment' to determine the best time point for the protocol. The 'mini experiment' would assess the concentration levels of the experimental at three different intervals: the 20-minute mark, the one-hour and the two-hour mark. Based on the outcome, the time point that resulted in the highest concentration yield would be the new lab specific protocol moving forward. Importantly, whatever the outcome, all in the lab would be informed about the details of the protocol in the future.

This third case study, contrastingly, offers insight into how the challenges of uncritical 'learning from others' can be transformed into a meaningful learning interaction for all involved, thereby fostering docility. In this case, all had been practicing what can be construed as a skill, the steps of a specific protocol that had been published and was therefore available to all. However, in this case, lab members had uncritically accepted a change in the protocol, requiring the suggested 'mini experiment.' This indicates two important points: one, the lab members were unable to question this change in a critical docile manner that we have been supporting, and two, the suggestion of the 'mini experiment' not only demonstrates a process centered on solutions, but also serves as an opportunity for critical, engaged learning. Both teacher and learner became active participants in the learning process, transcending the traditional hierarchies of authority discussed earlier.

This situation was transformational as the practical skill turned into the acquisition of a virtue as a result of wanting to improve that skill (Annas 2011, 21–23). In this case, the need for reproducible data, and the necessity of ensuring that the shared protocol was accurate, also potentially fostered the acquisition of docility amongst the lab members. In this case study the laboratory critically unpacked the manner in which the spurious protocol was perpetuated in the laboratory and demonstrated how the error could be corrected. Students exposed to this event were shown the right way of critically engaging with taught content. Together, these instances are *in situ* contexts that demonstrate how an active docility creates opportunities for the acquisition of a virtue through education. The next section below takes the discussion out of the laboratory and turns to the broader field of scientific practice. In doing so, it provides further evidence of the importance of active docility.

6. Turning Docile Habits into Internalized Virtues

So far, we have presented *in situ* case studies and their relation to our notion of an active docility. The cultivation of the virtue of docility, while of importance to science education and the internal consistency of laboratory practices, also maps on to a broader concern currently at the forefront of discussions on science. Since the turn of the century there have been increasing concerns about the reproducibility and replicability of scientific findings. This so-called 'replication crisis' is widely discussed in all fields of experimental research and is rooted in the emerging awareness that the laboratory data produced during the systematic application of the scientific method is not necessarily reproducible by others wishing to follow the described protocols (Ioannidis 2005; Bissell 2013; Open Science Collaboration 2015; Goodman et al. 2016). While some of this irreproducibility may be traced back to scientific misconduct (Check 2005) or "sloppy science" (Meyer 1999; Anderson 2007; Vaux 2012), much also relates to the minutiae of daily research.

In 2013, The Reproducibility Project for Cancer Biology[3] began an ambitious endeavor. In response to increasing concerns about the crisis of replication in research, this project set out to test high profile published cancer research experiments to determine their reproducibility. The findings of the project have clearly revealed that the smallest change in a protocol, either reagents or technique, may play a crucial role in determining the reproducibility of the same experiment by others.

A paper published in 2014 in *Cell Reports*, an open access journal, details the experience of two collaborating laboratories using "identical methods, reagents, and specimens" and yet found they were "unable to replicate each other's fluorescence-activated cell sorting (FACS) profiles of primary breast cells" (Hines et al. 2014, 779). Below is a section from the paper:

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3 The Reproducibility Project for Cancer Biology is a $1.3 million-dollar collaboration between Science Exchange and the Center for Open Science funded by the Laura and John Arnold Foundation. The main emphasis of their work is to independently replicate experimental results from a set of 50 research papers in the field of cancer biology published between 2010 and 2012.

We quickly discovered, however, that reproducing each other's FACS profiles would not be so straightforward. Despite the fact that both groups began with primary breast tissues from reduction mammoplasty and the set of FACS profiles obtained in each laboratory was consistently reproducible, the profiles obtained in Boston and Berkeley were not similar (Figure S1B). The question was why (Hines et al. 2014, 779).

This technology is increasingly used to identify diversity among populations of cells within biomedical research and underpins a considerable amount of research in the field of breast cancer research. Further on in the text, the authors elaborate on their experiences reproducing the data of other teams, highlighting the minute differences in their FACS protocols as a critical factor. In describing this they say the following:

… this time consuming and expensive exercise gave us the clue we had been waiting for: our methods for incubating the collagenase digests were distinctly different. In the Boston method, tissue was being stirred comparatively more vigorously in a flask with a stir bar at a speed that achieved constant agitation (300–500 revolutions per min [RPM]) until the digest was observed to be complete, which typically took 6–8 hr. In the Berkeley method, tissues were digested in 50 ml tubes using half the concentration of collagenase used in Boston (1 versus 2 mg/ml) while rocking relatively gently on a rotating platform (80 RPM) and for a much longer time (18–24 hr). We found that, in addition to the distinct FACS profiles obtained by each method of digestion, there was a dramatic difference in the efficiency of organoid recovery – roughly 53 more organoids were recovered from the slower and longer digest (Hines et al. 2014, 780).

The slower and longer digest of the collagenase was discovered to yield a better efficiency in the FACS method. They go on to add that "this sensitivity has obvious implications for those optimizing their own digestion protocols" (Hines et al. 2014, 780). While both protocols were, in effect, viable, they nonetheless resulted in disparate data sets.

Such observations are key to understanding the crisis of replication; however, the scientific community has yet to offer robust solutions to these issues. While the obvious solution would be to describe each protocol in minute detail, this is understandably unwieldy and would overwhelm the current academic publishing system. The extended protocols required in appendices for an increasing number of journals are a step towards such an ideal (Editorial 2013), but undoubtedly will run in to some of the problems identified by The Reproducibility Project for Cancer Biology: that some of the crucial steps are so small as to be overlooked and under-reported. Alternatives, such as video methods[4], have yet to make any inroads within the scientific community.

4 See for example www.jove.com. Accessed March 5, 2018.

By making the link between the training of scientists in the laboratory and the replicability crisis we do not intend to be harbingers of doom. Rather, to the contrary, we identify a space in which further studies of virtue development amongst scientists – particularly relating to bench work – can make a marked impact. The case studies highlight the benefits of cultivating the virtue of docility for the production of reproducible and replicable science within two laboratories. Such findings can feasibly be extrapolated to the scientific community more generally. If scientists are taught to be critically engaged in all aspects of protocol design, and questioning of all stages of protocol design and enactment, is it not possible that they will be more attuned to the minutiae of research that appear to underpin many problems with replicability?

7. Stimulating Docility Through Targeted Interventions

For Aristotle, the good student of ethics – or indeed, the ethical scientist – is not one who learns only by moral rules or precepts but one who learns 'the that' and 'the because' of moral action and lives well by observing the prudent and wise person and emulating him (Kristjánsson 2007, 99–113; Hursthouse 1999). Moral and social expertise, therefore, is understood as being "best gained through a novice-to-expert approach," an approach encouraged by modern psychology (Narvaez 2010, 171). This process of learning expertise can be developed through interventions from the following contexts and relationships:

- Personal exemplars – mentors need to be aware of the importance of *teaching how to learn*
- Support for supervisors in fostering docility – teaching supervisors how to teach – such as counseling courses, innovative pedagogy
- Attention in ethics curricula to making connections between learning and the justification of certain teaching styles, and more attention to informal teaching practices
- Institutional support
- Discussion on learning and action with students

So, how exactly does one teach the virtues? Character formation and the cultivation of virtues, particularly as it pertains to this discussion, "takes place in the context of social relations and institutions" (Laidlaw 2013, 50). Moreover, the nature of docility is to be in a relationship with a teacher who *knows* something and a learner who *wants to know*. Taking this one step further, virtues are dynamic in that the critical aspect of the student should include the effort to constantly improve not only what he/she has been taught, but also to correct the teacher and the context in which he/she has been taught (Annas 2011, 25).

a) Personal Exemplars – Teaching How to Learn

In the descriptions given above of how students are taught science – instruction in classrooms, practical sessions and the case studies presented – it would seem natural to emphasize the presence of a mentor as being a crucial part of learning how to be a scientist. Mentors play a vital part in providing educational opportunities for students within science, for example a PI of a laboratory is often chosen by postgraduates due to the admirable quality of their previous and future scientific accomplishments. In the language of Zagzebski's Exemplarist Virtue Theory and for our purposes here, mentors are equivalent to exemplars in that these are individuals who are admired for specific reasons. In this context, learning occurs through imitating exemplars (Zagzebski 2010, 51–52), which leads ultimately towards what Zagzebski qualifies as "moral training" (Zagzebski 2010, 54).

Nonetheless, modeling behavior on one you admire does not automatically lead to the cultivation of virtues. In many cases, such actions are limited to imitation, and lack the quality and essence of criticality necessary for true virtue cultivation. Imitation, it is important to recognize, does not lead us to understand how one can act in certain ways in *different* contexts.

In order to act in certain ways in different contexts, Annas proposes that understanding the three aspects of the drive to aspire is crucial for the learning of a virtue. These three aspects comprise, the understanding of the 'why,' 'how,' and 'what' of an act. These three levels of aspiration and discernment are the building blocks from which a virtue is learned (Annas 2011, 27). Furthermore, to have virtue is not just to act reliably in certain ways but to act reliably for certain reasons.

If docility is to be fostered amongst science students, it is therefore imperative that they have access to exemplars of docility. The ability to watch how these mentors approach learning interactions (as in Case Study One) or correct mistakes in the learning process (as in Case Study Three and the *Cell Report* discussion) is vital. By emulating these exemplars of docility students will be able to understand why, how and what they need to learn in order to become competent, reliable and resourceful scientists.

b) Support for Supervisors in Fostering Docility

Despite their importance, it is necessary to recognize that becoming an exemplar of a virtue is by no means an easy and straightforward process. Indeed, there is little literature that examines how individuals develop from learners to exemplars, or how they learn to transmit their understanding of virtues to others. Becoming an exemplar of docility adds extra complications – particularly within a hierarchical educational setting – as individuals need to be confident to admit their own faults, while still preserving the student's trust and respect. Striking such a balance is no small feat and requires considerably more scrutiny.

As it stands, current university structures lack mechanisms to support supervisors and lecturers in developing as exemplars of docility. While many universities offer courses on pedagogy and supervision, very few offer courses directly teaching tools that link the two. Moreover, few courses (if any) offer mentors the range of skills needed for the informal teaching interactions that characterize postgraduate science training. The development of virtues-based courses that span these different areas of instruction would appear of critical importance for the development of future generations of effective supervisors and docile students.

c) Attention in Ethics Curricula to Making Connections of Learning

A key observation made during the fieldwork, and highlighted in the case study, is that science students are taught – but are also taught to think – in markedly different ways depending on the activity at hand. Within lectures and tutorial groups students are taught to engage critically with published papers and work from other laboratories. In these interactions, one might say that the virtue of docility can easily flourish. Students are expected to be open to learning, but critically engaged with (and critical of) the content of their coursework.

In contrast, within the practical laboratory sessions students are encouraged to follow pre-tested experimental protocols with the understanding that the meticulous execution of the instructions will produce the desired results. While undoubtedly building tacit skills, such an approach does not necessarily offer many opportunities for the virtue of docility to be cultivated. Instead, students easily slip into the vice of docility by omission – becoming too accepting and uncritical of the content with which they are engaged.

Interestingly, the markedly different way in which the theoretical and practical aspects of science are taught at an undergraduate level is rarely remarked on. Nonetheless, this 'siloing' of learning traditions can lead to significant problems further on, as was demonstrated by case studies two and three. In both studies it is evident that the postgraduate students continue unquestioningly to accept instructions within the laboratory, and do not act on the virtue of docility to critically question the protocols from which they work. Such evidence highlights the importance of trying to bridge this pedagogical (and virtue) gap in undergraduate education.

d) Institutional Support and Discussions on Learning and Action with Students

In order to effect a change in learning patterns within science curricula, institutional support is needed. Indeed, resources need to be committed to developing resources for both supervisors and learners around *learning to learn*. Yet courses about docility are not enough. Many systemic issues need to be addressed to ensure that cultures of docility truly flourish within learning institutions. These include the difficulties resulting from universities being deeply hierarchical structures; curricula design is often very conservative; increasing student intakes decrease the contact time between lecturers and individual students; and crowded curricula and lack of available funds often de-prioritize the development of soft skills such as learning.

Indeed, how the transition from habituated virtue to full virtue is brought about in this siloed educational environment is difficult to envision. Full virtue involves not only performing the right actions but performing them "for the right reasons and the right motives: knowing them, taking intrinsic pleasure in them and deciding that they are worthwhile" (Kristjansson 2013, 278). This process takes considerable time and requires the student to gradually 'grow into' the virtue. In the realm of modern science, where education and research are increasingly speeding up in response to economic concerns, the notion of creating spaces to 'grow into docility' requires critical examination[5].

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5 This difficulty of envisioning the transition from "habituated virtue to full virtue" (Kristjansson 2014, 152) is one that many virtue scholars (Kristjansson 2014; Narvaez 2013) recognize. This gap has roots in Aristotle's original work in *Nicomachean Ethics* (Aristotle 1985), where he does not present the roadmap of action that bridges these two phases of virtue development. While we do not propose to suggest such a bridge, we do acknowledge the challenge this presents to a virtue ethics informed pedagogy.

8. Conclusion

The case studies presented in this article clearly draw attention to an often-overlooked issue: that we rarely consider *how to teach/learn how to learn* in science. Of course, within the extensive literature on science education and engaged learning there are a wide range of resources on pedagogy and student engagement. However, these are often dispersed and highly specific. Re-examining learning interactions through the lens of cultivating the virtue of docility thus offers an important means of focalizing attention and discussion.

Through our ethnographic study of laboratory research and education we contend that a coherent and detailed understanding of how to 'teach students how to learn' is absent or hidden from many discussions on science education. We further claim that the siloed manner in which science is taught at an undergraduate level can have negative implications for the student's development of critical and independent thought in future studies. We believe that a new focus on the virtue of docility, as a means of exemplifying this necessary skill, addresses a critical area for future research. In particular, it is of importance that elements within the learning environment that could hamper the cultivation of docility are identified and ameliorated.

Through our case studies we not only demonstrate that docility plays an important role in the development of robust, independent researchers. We also highlight how the absence of docility in scientific researchers can have significant epistemic consequences relating to data reproducibility and reliability. Indeed, the unquestioned perpetuation of a highly sensitive methodology has had significant implications for all fields of science currently wrestling with the ability crisis. Such observations strongly support the need for sustained attention to be paid to the development of virtues in science – particularly that of docility.

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