



In-vitro Fertilization (IVF) as a Sociotechnical System: Using Actor-network Theory (ANT) for Teaching Undergraduate Engineers About the Ethics of Assisted Reproductive Technology (ART)

Prof. Rosalyn W. Berne, University of Virginia

Rosalyn W. Berne, PhD is Associate Professor in the School of Engineering and Applied Sciences at the University of Virginia in the program of Science, Technology and Society (STS) within the department of Engineering and Society. She received advanced degrees from the University of Virginia, in Communication Studies, and in Religious Studies with a focus on Bioethics. Rosalyn explores the intersecting realms of emerging technologies, science, fiction and myth, and the links between the human and non-human worlds. Her academic research and writing span considerations of ethics in biotechnology, nanotechnology, and reproductive technology, with two academic books, numerous conference papers and journal articles published under her name. She has also written in the genre of science fiction, and published award-winning books in the body-mind-spirit genre about her encounters with horses. She has taught courses in Nanotechnology Ethics and Policy; Gender Issues and Ethics in the New Reproductive Technologies; Religion and Technology; STS & Engineering Practice; The Engineer, Ethics, and Professional Responsibility; STS and the Frankenstein Myth. Rosalyn regularly incorporates mindfulness practices into her engineering school courses.

In-vitro fertilization (IVF) as a socio-technical system: Using Actor-Network Theory (ANT) for teaching undergraduate engineers about the ethics of Assisted Reproductive Technology (ART)

Abstract

While reproductive technologies have enabled many otherwise infertile couples to conceive, and contributed to the untold joy and satisfaction that comes with creating a family, the use of these technologies has also introduced into the process of being conceived and born, multiple and complex nodes of ethical concern. This paper describes an engineering school elective course on the ethics of reproductive technologies. And how, as a result of guest lectures by one of the leading embryologists in the United States, and class visits to his IVF lab, the students came to appreciate the moral agency of both human and non-human technological "actants" involved in the socio-technical network that surrounds assisted reproductive technology (ART). Thusly, the author advocates for inclusion of the Actor Network Theory (ANT) in engineering ethics pedagogy.

I. Introduction

If one is fortunate, a wanted pregnancy happens as a result of sexual intercourse; conception doesn't cost a dime. For 85 percent of the population, all one has to do is to relax, make love, and hope: no devices, pharmaceuticals, instruments, or intervening procedures are required. For others, however, the quest to birth a child can be emotionally arduous and financially taxing. According to the Centers for Disease Control and Prevention, up to 15 percent of couples are 'unable to conceive a child with frequent, unprotected sexual intercourse over the course of a year,' which categorizes them as being infertile [1]. Approximately 35% of infertility is due to male factors; 35% is due to female factors; 20% of cases have a combination of both male and female factors; and the last 10% are unexplained causes [2] Many such individuals, and same-sex couples, have been successfully aided by laboratory-based, technological intervention. According to the American Society for Reproductive Medicine, "With the preliminary 2015 data in, we can definitively say that more than one million babies have been born from assisted reproductive technology procedures done in the United States since SART and ASRM started to collect ART data with cycle year 1985" [2]. Reproductive technologies have become essential in enabling many such couples to conceive, and contributed to the untold joy and satisfaction that comes with creating a family. However, the use of these technologies has also introduced into the process of being conceived and born, multiple, complex nodes of ethical concern.

The present paper considers how by incorporating Actor-Network Theory into a reproductive technology course, students were able to appreciate the salience of the devices involved, giving rise to nodes of ethical concern, with the use of assisted reproductive technology. Of particular interest here is Dr. Thomas, board certified as a High Complexity Laboratory Director, co-founder of the IVF (In-Vitro Fertilization)

Program at the University of Virginia, and retired founding Director for the Reproductive Medicine and Surgery Center of Virginia. Dr. Thomas' involvement with the course is highlighted for the ways in which his role as a key actor in IVF, led to the students' increased understanding about ethics, and perhaps even to their empathy, regarding the use of technology to make impregnation possible where it may otherwise, never occur.

II. STS 2500: "Ethics, Gender, and the New Reproductive Technologies"

At the University of Virginia, each January term (J-term) for the past 5 years, the author has taught a 10-day class that meets for 6 hours a day, on the subject of ethics in use of ART (assisted reproductive technology) for the treatment of infertility, and child-bearing for same-sex couples. The class is offered to undergraduate engineering students at UVA, who are required to take an elective during their second or third year of matriculation, chosen from an array of offerings in the STS program within the engineering school. The original course description read as follows:

"This course begins with depictions of childbirth, moves through the basic biology of human reproduction, and then considers the various ethical nodes of concern that arise with the use of technology to bring forth new life. Through film, literature, and case study, we consider the personal quandary of infertility, socialized expectations for bearing children, the desire for having children by single women and same-sex couples, and the technological solutions that by-pass the limits of otherwise unassisted conception and gestation. Of particular focus are the possible unintended consequences of using technology to manipulate the reproductive process."

The course covers IVF (in-vitro fertilization), GIFT (gamete intra-fallopian transfer), surrogate motherhood, sperm and egg donations. Ethical nodes of concern addressed (but not limited to) include conflicts of interest in commercial IVF; disparity of access to fertility treatments; a woman's compromised sense of connection to discarded embryos; and coercive donation practices for securing eggs. The courses' pedagogical approach has been to use fictional writings like *The Handmaid's Tale*; documentary films such as *Anonymous Father's Day*; comedic films such as *Baby Mama*, *Starbuck*, and *The Kids are Alright*, by way of introducing students to the variety of ways in which infertility and ART have been portrayed and explored in popular culture. Furthermore, these materials provide rich fodder for active discussion. Case studies introduce students to actual circumstances of using technological assistance in attempting to conceive a child. And guests to the class highlight the experiences of professional practitioners: a doula, a nurse midwife, and a high-risk obstetrician have been speakers. The analytical tools of ethical theory, such as the concept of "generalized procreative non-maleficence" [3] give students a language by which to discuss the various course materials. And because of J-term's extended daily meeting time, the opportunity exists for learning activities beyond the physical classroom.

After meeting Dr. Thomas at a social event, the author invited him to visit the class, believing that as an IVF laboratory director, his expertise would support the students'

learning about ART, and aid in their discernments over the ethics of thereof. On Dr. Thomas' initial visit to the class, he delivered a detailed lecture on the technology involved in IVF. Being engineers, the students especially appreciated the technical elements of his lecture, and they asked many questions about the workings of the devices and processes he described. But his presence was insignificant to the ethics focus of the course. Indeed; the subject of ethics never came up, not in his lecture or in the Q & A. This changed, however, in subsequent years, when students left the classroom to travel across town, to meet with Dr. Thomas inside of his IVF lab.

It was there that the students passed by the waiting room for patients seeking help with reproduction, and then saw with their own eyes, the array of technology involved in IVF. They put on scrubs and booties, and, once inside the lab, peered through the little window that connects the treatment room (where a woman receives one or more embryos into her uterus) to the laboratory space (where the embryos are formed and cared for). And it was there, in the IVF lab, that the students began to glean the centrality of technology in the life of the couples that become IVF patients. From an instructor's perspective, given what they were seeing and experiencing, the question became *what would be the best way to help the students to think about the engineering ethics of IVF?*

III. Bringing Actor Network Theory (ANT) into the STS 2500 course

The answer was for the students to consider the IVF clinic as a *sociotechnical* space, where couples arrive willing to make significant sacrifices of financial resources, to endure a roller coaster of emotions, and possibly to struggle over moral quandaries they may face in the process of achieving their aspiration to have a family. The conviction being, that the design and development of technological artifacts happens only within a larger social context. The students needed to understand that before they could appreciate the ethics involved. As explained by D. Johnson [4]:

“Once developed, artifacts do not function in isolation; they are always embedded in social activities, a social context. This is true whether we think about a simple artifact such as a baby bottle or a complex artifact such as a nuclear power plant. In both cases, complex social practices and relationships – social organization, cultural practices and meanings, systems of employment, complex manufacturing processes, assembly lines, distribution systems – are necessary both to produce and make use of the artifact.

The point is that we push all the social parts out of sight when we think about technology as material objects, and yet the artifacts are nothing without the rest. Only through combinations of people and artifacts do products get manufactured, services provided, people educated, security achieved, and so on. Thus, we should think about technology as *sociotechnical systems*, combinations of artifacts and social practices, social relationships, and social institutions.”

As a sociotechnical network, the IVF clinical process involves multiple human and non-human actors: There is the woman who intends to become pregnant; her partner and

intended co-parent; the gynecologist and obstetrical physicians; clinic administrators and staff; the laboratory technicians responsible for fertilizing the extracted eggs, selecting the most viable embryos for implantation, and preserving the remaining eggs for possible future use. The IVF clinic and staff are all part of that network. As are technological devices therein: artifacts such as a centrifuge, microscope, incubator, cryopreservation tanks, safe procedural hoods, laminar air-flow, air pressure differentials, micropipettes, booties and gowns.

In the field of “Science and Technology Studies” Actor-Network Theory is well established as a framework for looking at the infrastructure surrounding technological achievements. Its origins are found in the works of Michel Callon, Bruno Latour, and John Law. Scholars use ANT as a method to observe “science in the making,” in making detailed descriptions of the mechanisms at work in holding a network together. Instructors of STS use it to help their students to appreciate the dynamic and multiple elements of influence inside of a “sociotechnical network” of activity. Some have suggested that ANT is an amoral framework, being devoid of prescription and highly descriptive by nature, absurd in ascribing agency to non-human actors, and ineffectual in assuming all actors to be equal in a network of influence [5]. This would suggest that while it may be appropriate for teaching STS, ANT would not be an effective pedagogical tool for engineering ethics instruction. Yet, it could be argued that as the ANT framework is useful in identifying the ways in which the various actors may function as moral agents, it may indeed be effective in ethics considerations, such as with IVF. For example, ANT has been used as a tool for social, ethical and policy analysis of the issues arising from gene patenting and commercial genetic testing: William-Jones and Graham declared “the potential for transferring ANT's flexible nature to an applied heuristic methodology for gathering empirical information and for analysing the complex networks involved in the development of genetic technologies [6].

Crawford [7] identifies three principles governing ANT: *agnosticism* in abandoning any a-priori assumptions about the nature of the network, *generalized symmetry* in interpreting human and non-human actors, and *free association* in being without distinction between natural and social phenomenon, hence; “following the actor into translation” [7]. As such, when the reproductive technology ethics class visits him in the Reproductive Medicine and Surgery Center of Virginia, the students are able to ‘follow’ Dr. Thomas ‘into translation’ in the simplified network of in-vitro fertilization, his presence providing a direct engagement with, and observation of, ethical struggles that can ensue when technologies are employed to assist reproduction.

One key lesson that arises for the students is how biotechnological artifacts, such as the pharmaceuticals used to stimulate hyper ovulation, devices and machines for extracting and fertilizing eggs, tools employed for insemination, gasses, tubes, sensors, and canisters for preserving and storing embryos, are highly valued by Dr. Thomas and his fellows for their role in bringing forth life. In fact, preventing harm to the embryos in his care may be the highest ethical responsibility he expressed, among others that are assigned to his role as clinic director (a key actor in the socio-technical network that is the clinic itself).

Moral agency is ascribed as well to the technicians who fertilize the eggs, the men who (often anonymously) donate sperm, the women who donate (or sell) their eggs, physicians who implant the embryos, and the women who receive them into their uteruses as the intended or surrogate mothers, thus forming a network derived from their associations; processual, in being composed by, and built of, the activities performed by the actants.

Other actors are non-human. For example, the alarms set to be triggered in the IVF clinic to indicate a loss of power that would lead to an imminent drop in canister temperature, are actors designed to spur on immediate and urgent reactions from human agents; as “volitional actors” (actants) they are associated with other agents in the clinic.

An excellent teaching moment arose in March of 2018, when embryo storage tanks (key actants of the network), failed in two IVF clinics in the United States. The American Society for Reproductive Medicine (ASRM) immediately issued a statement [8]:

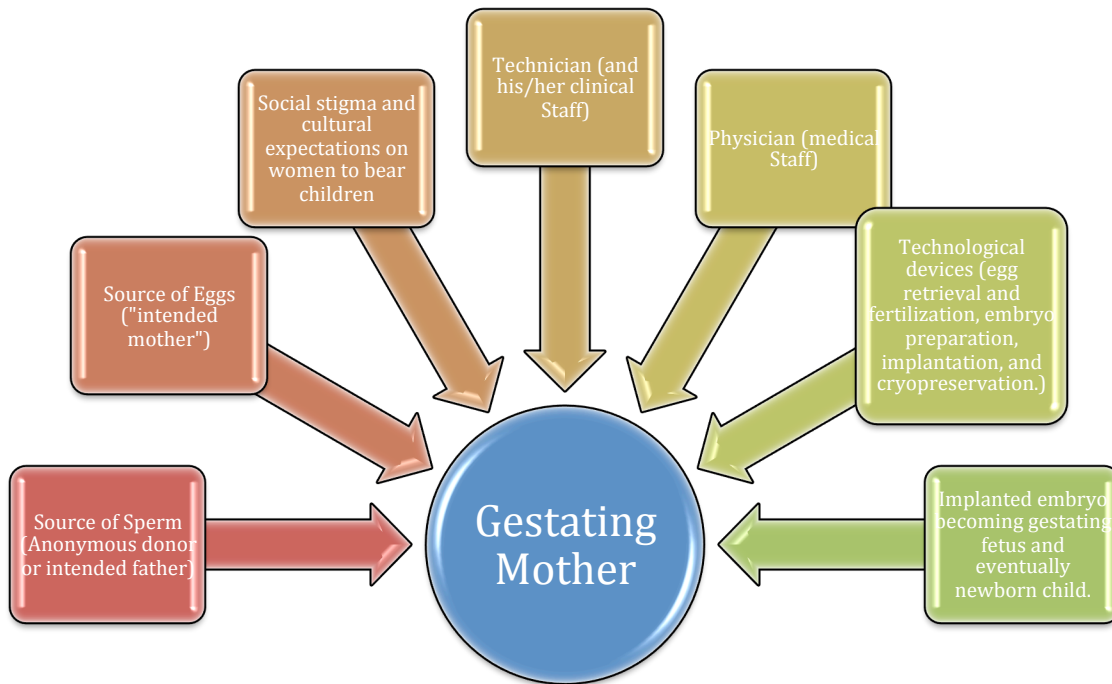
Washington D.C.- Cryopreservation of reproductive tissues is an essential part of modern infertility therapy. Up until last week, the history of cryopreservation had been a steady string of improved performance and reliability. We have now seen two major failures, apparently of equipment, redundancy and warnings, which have led to some tissue loss, though the extent of that loss is not yet fully determined.

We have not yet had the opportunity to fully review the incidents with the involved clinics and other relevant parties such as equipment suppliers. We expect to do that this week and then to gather leading experts and our own organizational leadership to review those facts and determine an appropriate set of recommendations for our members and their patients. In the meantime, infertility clinics around the country have been double and triple checking their own procedures and equipment to ensure everything is working properly.

Our hearts go out to the patients and staff at these involved clinics. We know these are very difficult times. Indeed, there is angst throughout the infertility community, patients and professionals alike. While no technology can be perfect, and we do not yet know exactly what happened here, we do know that the cryopreservation and subsequent use of reproductive tissue is a technology that has been used reliably for years around the world, and we can assure our current and future patients we will do everything we can to understand how these incidents occurred and how we can help our members work to prevent other such incidents from occurring.

The statement of the ASRM highlights the critical role of the multiple actants in the network that is IVF, including that of the technological devices. During the class' visit to the IVF clinic, Dr. Thomas repeatedly referenced the elaborate, technological systems in place, designed for the sole purpose of protecting the embryos and other reproductive

tissues. Indeed, his spoken words gave every indication that Dr. Thomas saw as his primary ethical responsibilities as an IVF professional, to select the best embryos for preservation, and then to protect them well. ANT would suggest that as non-human actants, the preservation tanks also have moral agency, co-responsible for the potential life represented in the reproductive material they preserve.



Graph depicts infertility treatment as a socio-technical network of actors having an impact on the gestating mother. A more accurate and complex interpretation would have the arrows pointing in both directions (suggesting that the mother also impacts the various actors), and arrows also going between some of the other various actors, such as between the physician and the technological devices he/she employs.

The moral significance of reproductive technologies is achieved through relational materiality. For example, with a gestating mother being the key actant and central in the network that is the treatment of infertility, an ethical query might seek to determine which technical processes and devices, also actants, have influence over the intended “good” outcome to achieve a successful and healthy pregnancy for her, culminating in delivery of a full-term newborn child, whether and how those actants may bring harm. ANT can also bring to bear the social construction of motherhood as an actant defining womanhood as the capacity to conceive and bear children, which then acts on the woman as a socially-constructed desire, wherein reproductive technology becomes essential to her sense of wholeness. Such could be the case with a woman (actant) who is without a partner or spouse, or one whose desperation to achieve pregnancy requires a substantial (perhaps even unaffordable) outlay of funds to pay for in vitro-fertilization, using eggs harvested from a donor, to be fertilization by an anonymous donor of sperm, and then implanted as an embryo into her own womb.

As Crawford explains, ANT places those actants in relation to other actants of the network, as “combinations of symbolically invested “things,” “identities,” relations, and inscriptions” where struggles influence outcomes [7]. In other words, the engineering that has enabled the creation of reproductive technologies is a *relational materiality*, achieving its significance in the relationships of actants within a network.

Even for women (and men) who are not in need of clinically supported reproductive technology and procedures, the reproductive network involves multiple non-human technological actants, which carry the potential for moral claims being ascribed to its various actors. From over-the-counter ovulation indicators, to urine testing home pregnancy kits, to gestation of the embryo and fetus under close in utero-monitoring, the inducement of labor, reduction of labor pain, C-sections, and fetal-monitored delivery, multiple technological devices act on the women’s reproductive life, from before a pregnancy until after it’s completion. If she moves into the network of infertility, additional actants are engaged and involved. Among those being the scientists and the technicians at work in the laboratory, which, in the case of an IVF center, is located on the other side of the pass-through window of the clinic procedural room. Aside from the influence of the human actants in the network, there is a way in which the technology itself reshapes the sense of self in relation to the body, and the technology that supplants its role in reproduction. Underscoring the notion that the artifacts themselves are also acting as moral agents.

As Crawford [7] relays, “Simplified networks, when resulting in single-point actants, are those that are punctualized or are black-boxed. Punctualized networks are considered only in terms of their input and output, are “taken for granted,” or are counted as resource.” In the language of ANT, the IVF clinic “inputs” are sperms and eggs. Their “outputs” are viable embryos. As one student’s journal entry exclaimed in her reflections on what she experienced while visiting the IVF laboratory:

“Today’s visit to the IVF clinic gave me a real sense of how necessary technology is to produce a controlled environment. From the filtration of the air before you even step into the lab to the dark lighting environment where the egg is fertilized under a microscope, machines have been invented and refined precisely to control the lab environment. I thought some interesting examples of evolving technology were the modified transport incubator adopted from the NICU, and the change in the flexibility of the catheter throughout the history of IVF. Something striking I remember Dr. Thomas saying was that women who come in for their first ever IVF treatment are often extremely stressed about the procedure because of the unfamiliar environment. I think seeing all the machinery, sterility, and not knowing the science attributes to that . . . Dr. Thomas kept mentioning “the human aspect” of IVF. I thought this was illustrated well with the very literal separation between the treatment room and the lab. In the treatment room there was the patient and her body being modified/stimulated very much in vivo. The technology there involves the modification of the endocrine system as well as surgical tools and techniques. There is also a lot of patient care and nurses to aid in the process. Then the

transfer of the harvested egg must be placed in a dry heat bath for lab preparation. The lab is very much science-based in its upkeep and modification.”

When asked directly, to provide the students with examples of ethical challenges he had faced as an IVF clinical director, Thomas spoke of live birth risks to mothers of advanced maternal age; the high risks of multiple births for low weight, prematurity, poor development; and when couples had requested sex selection of the embryos. Over which he would assemble his staff to discuss their feelings and beliefs, and then they'd decide, together, whether or not to comply with such a request. In cases where there were already two or more of one sex children in the family (such as two girls), the staff would be inclined to go along with the selection request of a boy, for example. In other situations, such as simple personal preference for a boy or a girl, the answer would be “no.” When requests were made for the disposal of embryos, this posed a more difficult set of ethical challenges to individual staff members, and thus to the group. Indeed, being in the lab with Ted Thomas opened the students to being able to empathize with IVF technicians. A student's journal entry expressed that in this way:

“Being in the lab definitely felt as far removed from pregnancy and babies as possible. It was hard to remember that the samples and vials we were talking about contained the ingredients for potential life. However, it seems that the goal of these procedures (to make a baby possible for parents) is not far from the minds of the people working there.”

The students left the clinic with an understanding of the IFV technology as being non-human actants in the complex sociotechnical network of infertility treatment. The lesson there, as gleaned through ANT, was recognizing the potential life represented in the embryos, and the essential value of life's preservation, as being embedded in the technological design itself. Furthermore, that these devices take on moral character, even though morality is generally ascribed only to persons and not to technological devices. It might still be argued that the value of life, its potential and its preservation, are expressed in the design of these non-human actors. As another student wrote:

“Although mildly unsettled by the fact that hundreds of potential human beings were sitting frozen like glass in cylindrical tanks under the counter, Dr. Thomas' description of the security measures in place showed how seriously the lab handled the material. The extent to which all materials must be tested for toxicity was also surprising but reassured the safety of such precious matter. While the technology-filled lab can be seen almost as the antithesis of unassisted conception, much of the measures in place are to simulate conditions in the fallopian tubes such as lighting, temperature, and pH levels. Rather than trying to "better" the natural conditions by experimenting (with mice embryos) different culture systems, embryologists and technicians realize that the environment inside a woman's fallopian tube is really the best environment for fertilization and early growth.

“In addition to the technological feat that the clinic undertakes for successful pregnancies, the large amount of self-regulation of the field of assisted reproduction is astounding. While Dr. Thomas showed three regulatory bodies that release guidelines for good and ethical practices, he emphasized how important the clinic's own self-regulation is. Especially with no competitors in the area, the clinic seemed to stay up to date with latest technologies and practices to achieve higher birth rates than the national average. I will be curious to see the 2016 statistics, as Dr. Thomas expressed that by then the clinic was performing frozen embryo transfer, which was shown to be significantly better than fresh transfer in his other clinic. Although we have spoken about "horror stories" in assisted reproduction (Octomom, switching sperm samples and embryos), Dr. Thomas' honest experience saying how infrequent these cases are made me feel confident in the benevolence of the field. While there are flaws in some of the logistics of treatment (namely the financial limitations), there is evidence of good intentioned help to those who cannot conceive via other methods to bring children into the world.”

Thomas made apparent the ways in which IVF clinical directors function as “actants” in a network that, by its very nature, binds them together as moral agents carrying profound responsibilities in assisted reproduction: It has been important for the engineering students to understand the inter-relational aspects of ART. The sentiment expressed in the following communication from Ted Thomas, points to the need of an individual to identify himself not just as one person responsible for a new life, but functioning as part of something much greater:

Having developed my own set of close colleagues over thirty plus years, I would go so far as to say they have become an important community for my professional AND personal well-being. On the professional side, my contacts continue to help me navigate the science and ethics of embryology on a regular basis. That is also true for every other successful IVF lab director I know. BUT, some of my longest and best personal friendships have emerged from my profession. Perhaps that happens in many disciplines if you are in it long enough. I wonder if the people who witnessed the uncertain infancy of IVF and grew with it over 30+ years had an especially strong bonding experience.

As we have already discussed, I am extremely thankful for the privilege of witnessing the beauty and potential of an early human embryo in a microscope and for being the one who, on behalf of an infertile couple, provides the best possible platform for it to happen. That doesn't happen in a vacuum. To be deeply embedded in a professional community of men and women who have the same fire in their hearts for embryology and who love the challenge like I do has been one of the purest joys of my life. I don't see how I could be on this journey without them.

Beyond Dr. Thomas and his lab, students enrolled in the course sometimes came into personal conflict with the content of the larger narrative, which seems to be making value

judgments of what is “good” towards fulfilling the desires of intended mothers. They have noted, for example, the desire for a child of one’s own as achieved through IVF as being significantly more valued, and privileged, by virtue of its cost, over living babies available for adoption. Through a framework of ANT, students’ moral struggles over such matters come to light, as they realize that as individuals they too could find themselves within these networks, if one day informed by physicians that their ability to conceive will be unlikely through the heterosexual act of intercourse. (A reality already apparent for the lesbian women and gay men in the class, who may prefer to not try to procreate in that way.) The students become keenly aware of what it could mean to have to move out of a network of “natural” pregnancy, and into the network of IVF. The psychological, financial, material, and emotional preparations necessary become apparent, raising the students’ empathy for the subjects of our studies.

IV. Using ANT in teaching other engineering ethics classes

Augmenting the UVA STS 2500 class with Actor-Network Theory anchored the students’ understanding of the ethics of assisted reproduction, within a social-technical context of multiple human and non-human actors. ANT has also been a very helpful tool for teaching UVA’s STS 4600: “Engineering Ethics.” Through that course students are supported in writing their Undergraduate Thesis, from a design project based largely on the capstone project within their majors. The STS 4600 engineering ethics course guides students to identify a research question related to their capstone project, to incorporate social and ethical considerations. For example, as one student wrote, in synthesizing her capstone project and STS 4600 research [9]:

Many of the technologies schools are incorporating in the classroom are merely being used for the sake of incorporating more technology, rather than promoting deeper understanding or exposing students to tools that will help them beyond graduation. The STS component of this project focused on the cyber-security concerns that are brought about by an increased use in technology. By using the Actor Network Theory to understand the various human and non-human actors involved in this issue, the main risks to students’ privacy were identified to be increased data collection and monitoring by schools and other entities. The technical component of the project sought to address the other side of the problem by creating ways to use Mathematica, a high-level computational software, in classrooms with the intention of helping students use technology in a meaningful way.

The student ‘swriting above reflects an approach to teaching engineering undergraduate students, which integrates social and ethical considerations into their understanding of engineering. Applying the lenses and language of ANT to the teaching of engineering ethics, elucidates for students the complexity of inter-relationships inherent in all engineering practice.

V. Conclusion

In introducing and including ANT as a tool of analysis in the STS 2500 course, students came to appreciate the relational dynamics of ethics among and between human and non-human “actants” within the larger socio-technical network of assisted reproductive technology. Through the lens of ANT, Ted Thomas’ lectures, and the visit to his IVF clinic, students could understand how ART functions, in a dynamic way. As such, ethics emerged in the course, not solely as maximizing benefits, prescriptions for following rules, or adhering to codes and principles, but also as narrative negotiations between and among a variety of actors, some of who have conflicting interests. Similarly, the class visit to see a practicing nurse midwife in her office, and having a high-risk obstetrician join us for a conversation about her work, likewise helped the students to appreciate and understand how certain key actants engage in ethical negotiations with other actants in the network of assisted reproduction (i.e., an intended mother, an embryo, a clinician who rates the qualities of the embryos, those who deliver the full-term babies that result). In this way, engineering ethics emerge from the pages of the ethics cases and academic articles, to be enlivened inside a dynamic network of multiple people and technologies for the students to engage intellectually, and also with empathy.

References

- [1] Centers for Disease Control and Prevention (nd). *Infertility*. FastStats homepage. Retrieved from <https://www.cdc.gov/nchs/fastats/infertility.htm>
- [2] “SART,” American Society of Reproductive Medicine (ASRM), May 2018. Retrieved from research/press-releases-and-bulletins/SART_Data_Release_2015_Preliminary_and_2014_Final/
- [3] B. Saunders, “First, do no harm: Generalized procreative non-maleficence,” *Bioethics*, 2017. 31:552–558, John Wiley & Sons, Ltd.
- [4] D. Johnson, “Educating Sociotechnical Analysts for the Global Workforce: The UVA Approach” (unpublished)
- [5] L. David, "Actor-Network Theory (ANT)," *Learning Theories*, March 23, 2007. Retrieved from <https://www.learning-theories.com/actor-network-theory-ant.html>.
- [6] B. Williams-Jones & J. Graham, “Actor-Network Theory: a tool to support ethical analysis of commercial genetic testing,” *New Genetics and Society*, 22:3, 271-296, 2010. DOI: [10.1080/1463677032000147225](https://doi.org/10.1080/1463677032000147225).
- [7] C. Crawford, “Actor network theory” in Ritzer, G., Ed., *Encyclopedia of social theory*, vol. 1., Thousand Oaks, CA: Sage Reference, 2005. DOI: <http://dx.doi.org/10.4135/9781412952552.n1>
- [8] ASRM, “Statement on Second Report of Storage Tank Failure,” Mar 12, 2018, Washington D.C. Retrieved from: <http://www.asrm.org/news-and-publications/news-and-research/press-releases-and-bulletins/asrm-statement-on-second-report-of-storage-tank-failure/>.
- [9] N. Jantrania, Sociotechnical Synthesis, *Cybersecurity in Schools: Keeping Students Safe in the Digital Age: A Research Paper in STS 460*. Presented to The Faculty of the School of Engineering and Applied Science, University of Virginia, In Partial Fulfillment of the Requirements for the Degree Bachelor of Science in Engineering Science, March 14th, 2018 (Unpublished document)