Re-envisioning Neonatal Intensive Care through an Interdisciplinary Pedagogical Studio

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ABSTRACT

At Rensselaer, an interdisciplinary research team and collaborative studio course with architects and biomedical engineers have coalesced to re-envision the Neonatal Intensive Care Unit (NICU) in order to improve health outcomes of infants. Rensselaer's development of cross disciplinary programs such as its NSF funded: Product Design and Innovation (PDI) – linking Architecture, Engineering and Social Sciences; and Design as a Creative Model for Technical Inquiry – national interdisciplinary workshop dissemination, responds to the mounting concern for the future of professional education. Traditional practices have intensified disciplinary insularity through barriers of language, values, prestige, and proprietary interest. As an alternative to normative practice, we look at the potential for complex problem solving through team based interdisciplinary design, specifically in reconceptualizing neonatal intensive care.

1. BACKGROUND

At a seminar on interdisciplinary design at University of North Carolina (UNC) – Greensboro in 2002, Anna Marshal Baker talked about her research on incubator performance challenging its current boxy tray-like enclosure. As she notes: "existing incubators evolved as medical equipment with a singular purpose of providing a controlled, secure environment for preterm infants; yet infant incubators are living spaces that must accommodate and adapt to the ever-changing needs of the infant occupants and their caregivers. A well designed incubator will address adequately concerns related to infant development as well as basic functional issues related to caregiving, access, and physical dis-/comfort of attending family and staff.[14]"

At Rensselaer we began discussing the issue with biomedical and mechanical engineers, anthropologists, artists, and architects, analyzing the current and historical state of the incubator and its environment as a benchmark for start-of-life care and brainstorming the issue of experientially based care. Our project's objective, to utilize interdisciplinary methodology to solve complex problems was exemplified through the design of better products/environments for the NICU. The process intent was addressing the role of an interdisciplinary pedagogy, how teams form and thrive, how a specific research problem can deeply inform learning models, and what social structures are necessary for cross disciplinary initiatives. The product intent was to help neonates grow into healthy babies, ameliorate stress for parents, and enable the work of medical staff. This paper marks the initial stages of our cross-disciplinary investigations and our ultimate goals of using this experiment as a model for interdisciplinary pedagogy, research, design and assessment.

2. THE NICU

The NICU has evolved from being relatively low-tech and low-impact into a highly charged, sensory-overloaded condition. Undersized infants lay intubated in incubators surrounded by bulky equipment. Nurses and doctors observe, monitor and care for the infants, while parents stand by. Light and noise are

[14] Baker, Anna Marshall (2001) "DESIGN OF AN INFANT BED FOR HOSPITALIZED PRETERM INFANTS"

incessant. The environment is at-once life sustaining, yet antagonistic to the normal physiological of the infant and psychological development of both the infant and family. Such negative impacts are documented[15] and normative design works reactively to mitigate them. Unfortunately the design of NICUs does not yet positively focus on issues that benefit neonatal outcomes and promote infant development.

The challenges of NICU design go beyond biological to issues of functionality and logistics, requiring a complex set of interdisciplinary inputs. Aside from the matter of infant development amidst critical care, NICU design poses challenges to staff in that care delivery, and to parents who wish to understand the medical predicament, bond with their infant, and aid in the infant's development. The NICU, an appendage of complex medical facilities, has been at the mercy of half century old institutionalized design practices.

Even with the research that has been done on the developmental effects of the NICU environment, NICU design has been slow to change. The older NICU guidelines were developed by engineers working for large corporations, and were based on adult ICU guidelines[16]. The 80s focused on advanced equipment leading to insufficient attention to the environmental needs of all involved; the 90s switched to developmentally appropriate care, leading to dimly lit NICUs possibly compromising benefits of having the latest technology; now hospitals combine both, making varying commitments to the assembly[17].

More importantly, the trend seems to represent the compromise of research done about NICUs, both from social science and medical perspectives. The NICU is more than a sterile environment designed to keep a neonate alive; everything about it will eventually affect the babies' development. For example, prior to 32 weeks of gestation, neonates require perpetual dim lights. Later, they need a lighting cycle to feed their diurnal rhythm[18]. Few units address this. Even with guidelines rapidly being updated[19], many NICUs follow older codes, as there is a lack of funding, organizational restructuring, and staff training to restructure.

Babies need to be touched; this is no different in a NICU[20]. However, normative NICU environments do not actively support this. Parents must come to terms with the fact that what they anticipated is not the outcome, and must also realize that they still have a child requiring love and attention[21]. Alienation between the parents and the babies unintentionally furthered by interactions with staff (i.e., comments like "It looks rough, there's no way of knowing if your baby will make it") make it less likely for the parents to come to the NICU to touch their babies. This presents a problem in the home environment, too, when the baby is finally discharged. The parents are unable/unwilling to take care of their children, in part because they still see conflicting images of what they assumed their baby was going to be and what their baby looks like in the incubator. So, the children never get the opportunity to enjoy "normalcy", even if it is medically possible[22].

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[15] There is much documentation on this matter. One example : Hancock, E. (Summer 1976). "Crisis Intervention in a Newborn Nursery Intensive Care Unit." Social Work in Healthcare 1(4).
[16] Interview between Shefali H. Sanghvi and Dr. Tani Sanghvi – November 28, 2004
[17] Gilbert I. Martin, R. D. W. (2002). "NICU Design -- Planning." http://www.pediatrix.com/documents/planning.pdf
[18] White, R. (2002). Lighting - Circadian Rhythms. http://www.pediatrix.com/documents/lighting_circ.pdf
[19] White, R. (2002). NICU Design Center. http://www.pediatrix.com/body_university.cfm?id=449&oTopID=92 These guidelines are mainly kept up to date through discussion forums through which people can ask questions, and the writers of various guidelines answer them.
White, R. (2002). Recommended Standards for Newborn ICU Design. http://www.nd.edu/~kkolberg/DesignStandards.htm These guidelines were created in 1992, based on previously existing guidelines, are updated periodically after major conferences (1993, 1996, 1999 and January 2002)
[20] Baker, Anna Marshall (2001) "DESIGN OF AN INFANT BED FOR HOSPITALIZED PRETERM INFANTS"
[21] Hancock, E. (Summer 1976). "Crisis Intervention in a Newborn Nursery Intensive Care Unit." Social Work in Healthcare 1(4).
[22] Ronald I. Clyman, S. H. S., Roberta H. Ballard, Robert S. Roth (1979). "What Pediatricians Say to Mothers of Sick Newborns: An Indirect Evaluation of the Counseling Process." Pediatrics 63(5).

3. THE DESIGN PROBLEM

Neonatal intensive care provides an excellent context to study the effective development of an interdisciplinary team approach to problem-centered research. At Rensselaer's School of Architecture we try to design with the following model: "The designer (most often, without the sponsor) identifies how to "devise courses of action aimed at changing existing situations…," in effect, deciding what concrete actions will produce the preferred situation… Methods are not neutral, and while one's values may bias one to employ certain methods and not others, conversely, the availability of a predetermined set of tools to work with, or the belief that there is only one tool that one needs to work with, leads to specific and differing 'courses of action aimed at changing existing conditions…' As the psychologist Abraham Maslow quipped: 'If the only tool you have is a hammer, you tend to see every problem, as a nail.'"[23] We, as in many schools of architecture, rarely interview the eventual inhabitants, nor do we engage the experts in the field. So we perpetuate the insularity of our design decisions – which ultimately have aesthetic pre-occupations.

For this project, it has been essential to introduce all participants to as many points of view about neonatal care as possible. The current NICU situation resulted from a segmented, rather than a systems, approach to design and begs for the collaboration of architects, engineers, physicians, social scientists, parents, community, and staff, with the goal of rethinking the overall environmental conditions that currently surround the infants, staff, and family. Beyond positioning us to contribute to the discourse, we hope to present a viable model for cross disciplinary work while also challenging normative architectural studies.

4. THE START OF THE PROJECT

Rensselaer School of Architecture convened students in Product Design and Innovation first semester, first year, Design 1 class, a cross-disciplinary course with Architecture, Science and Technology Studies, and Engineering to examine a problem that opens up multiple issues and perspectives of design.

To begin, we held a seminar with all faculty involved, students and most of our consultants, establishing what the various issues of design would be. The Chair of Biomedical Engineering, with expertise in design and cellular cleaving, questioned the differences between static and dynamic situations of NICU conditions including those changes the infant experiences moving from inside to outside the womb, all moments of transition such as the overall psychological developments of a neonatal child, the engagement of the parents in decision making and care giving, positive as well as negative stresses on the child, and the causes of prematurity. Then, architect Ted Krueger presented "Redefining Human" offering alternatives to what constitutes human and how technology extends the definition of what a human is.

Our Lighting Research Center and Workplace Design faculty stressed that buildings are already implicated in health risks of many kinds. Preventive care, where the effects of the indoor environment on occupants is exacerbated, is even more obvious in the condition of the incubator and its extended housing – the NICU.[24]

For first hand experience, students toured the Albany Medical Center NICU, where the clear focus is the infant incubator - as Baker notes – "a piece of medical equipment that has remained relatively unchanged since the 1940s." The incubators have a large range of sophisticated diagnostic and monitoring equipment

[23] Warriner, Ken, Design 1 Syllabus at Rensselaer Polytechnic Institute, 2003 (quoting Herbert Simon)
[24] Wyon, David P., Solicited Review of PhD for Rensselaer Polytechnic Institute School of Architecture, ICIEE, Copenhagen, 2003

and the incubator is the infant's living space for an indeterminate amount of time. Based on observation, research and medical staff interviews, the class concurred with Baker, "that the incubator precludes efficient delivery of care and prevents forms of care-giving that best promote infants' behavioral development.[25]" The resident doctor shared what he saw as the strengths and weakness of the organization, namely issues of access, noise, light, and parental alienation. The head nurse's requests for the NICU concentrated on the quality of the working environment, including more desk space for report writing.

After this visit, Dr. Linda Layne, a cultural anthropologist, shared her own personal story of having a baby (ultimately diagnosed with Cerebral Palsy) in the NICU with the challenges and frustrations that she experienced. Layne spoke of her struggles to answer the question that was frequently asked by those around her, "How's the baby doing?" and challenged American narratives of linear progress which works with technology, but not necessarily with the development of sick neonatal infants[26]. Trying to force an actual situation which is very nonlinear into the assumed linear progression of things gave Layne a feeling of inadequacy, as though there were something wrong with her or with her child. During her experience she came across three different non-linear narrative models: the rollercoaster, the graduation and the course, which fit much better with her experience in the (NICU)[27]. The talk provided a context in which to understand some of the complexities from a parental viewpoint. Neonates can be improving in one area of development, and yet be struggling in others. Frequent backsliding and unforeseen obstacles are par for the course, and if seen as a conceptual programming framework, could improve organizational strategies.

After 2 weeks of research, including looking at normative development of infants and designing alternative models for enhancing current care, they were asked to investigate the incubator as an extension of the infant, of the parent, of the medical staff and of the space of the NICU with the goal of achieving a preferred condition through the means of technology, social interactions, and through a combination of both social interactions and technology. Embedded into these investigations were issues of medical access, parental involvement, sensory conditions and awareness, ease of continuing care, organizational models and the idea of extensions to the body or the space.

The assignment and research posited that the conditions of the NICU: are not optimal; compromise diagnostic and therapeutic capabilities; and frequently result in infant physiological and psychological developmental deficiencies. With the recent advent of the new HIPAA (Health Information Privacy Act) regulations, special attention was focused on exploring the concerns of privacy, security, and ethics, and the implications of each for design solutions and infant, medical staff, and family outcomes. Aside from the matter of infant development amidst critical care, it became evident that NICU design poses great challenges to nurses and doctors in delivery of that care, and to parents who wish to understand the medical predicament, bond with their infant, and aid in the infant's recuperation.

The aim became to design a flexible NICU environment that is simultaneously a family centered clinical care facility for the infant, a research and data based laboratory, and an agile educational facility. Moreover, it had to be able to accommodate the health, research, and learning needs off site and to have an integration of clear models of communication to staff, families, and researchers. The NICU environment itself needs to be self-learning, self-regenerating and have the ability to perform locally and globally, through the use of clear models of communications and seamless connections between the caregivers, infants, the space, and the technology used.

[25] Baker, Anna Marshall (2001) "DESIGN OF AN INFANT BED FOR HOSPITALIZED PRETERM INFANTS"
[26] Layne, Linda L. (1996) "'How's the Baby Doing?' Struggling with Narratives of Progress in a Neonatal Intensive Care Unit" Medical Antropology Quarterly 10(4): 629
[27] Layne, Linda L. (1996) "'How's the Baby Doing?' Struggling with Narratives of Progress in a Neonatal Intensive Care Unit" Medical Antropology Quarterly 10(4): 632-639

Here the NICU of the future is seen as an organization and a strategy for the evolutionary transformation of the resource, both physical and organizational. The need for a multi-disciplinary team becomes imperative to study ways to develop ongoing as opposed to discontinuous renewal of the unit.

5. RESULTS OF THE SUMMER STUDIO

Preliminary research led students to posit designs countering the hurdles presented by the current set-up of the NICU including: rethinking the overall layout of the space; developing hand-held intubation ports to allow for higher parental interaction; creating vital monitors in the form of wristbands worn by parents on and off-site; redistribution of space for extended families and consultation; and incubators modified to the body proportions and movement of infants. Later discussions with post-doctoral students and medical faculty at Harvard's School of Public Policy stimulated investigations into administrative culture, quality control and improvement, relationships, and interdependence of technical and organizational change.

Fig. 1: Light Changer

Fig. 2: Port Connector

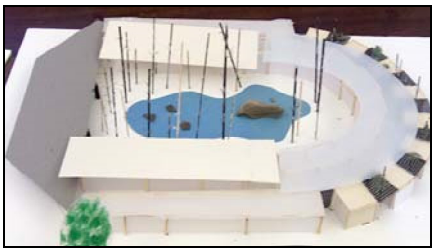

Fig. 3: NICU Redesign

These initial proposals proved that an intensive interdisciplinary research-centered investigation of design issues in the NICU could yield innovative products, approaches, and designs. A permanent team of two architects and a mechanical engineer with leadership experience in interdisciplinary projects, a biomedical engineer and entrepreneur, a medical anthropologist, and a pediatric neurologist has been formed - working together to codify the sensory integration and unitary processing of the NICU neonate in the areas of vision, tactile sensation, sound, and olfaction and create a working set of principles blueprint for the design of products (neonatal clothing, headgear, haptic interfaces, filters etc), as well as environments and organizational systems. This interdisciplinary approach will integrate a broad range of coexisting forces in the NICU: biological/medical; behavioral/sociological; technological/ethical; and political/economical.

6. FURTHER INVESTIGATIONS

Following on the success of the first year design course, we started a hybrid Biomedical Capstone design and Architecture design course with a three-pronged approach for research into current social, technical, and environmental conditions. Students collaborate to devise new design solutions while building interdisciplinary teams. These design solutions optimize existing neonatal intensive care technologies and environmental set-ups, while examining whether to re-purpose them from and for other contexts.

The focus of this class shifted from the NICU to neonatal intensive care in the context of technologically underdeveloped countries burdened by overcrowding, uncertain sources of electrical power, limited

availability of clean water, non-sterile conditions and lack of technically trained professionals. The class decided to focus its energy on the most acute problem[28] in order to have the greatest impact on the overall health of premature babies. Examining neonatal care, for 32+ week gestation, through the lens of a developing country, encouraged us to reevaluate the singular technologically centered approach of our health care system towards a more family centered one with a goal of increasing the overall level of care.

For these conditions, ventilation of the neonate is one of the main obstacles inhibiting both transportation of and parental interactions with the infant. The students concentrated on integrating a new method of ventilation with a carrying device using kangaroo care. Kangaroo care provides heat by placing the neonate in skin to skin contact with the caregiver's own body, instead of relying on expensive equipment to provide a stable heat source. The carrying device can act as a filter for unwanted light and sound, protect the neonate from temperature swings, adapt to the changing needs of the growing neonate and provide portable ventilation allowing the neonate to be brought home earlier. Other designs include an electricity producing stroller that can also power an integrated ventilation system; a self-sufficient low-cost low tech, family centered comprehensive system of care for neonates and prenatal care with capabilities to provide clean drinking water to reduce the number of premature births by maintaining the health of the mother.

The biomedical engineers have focused on integrated CPAP (Constant Positive Airway Pressure) designs that work in this context. Premature and underdeveloped lungs are in danger of collapse; CPAP augments a neonate's breathing by providing a pressurized source of enriched oxygen that increases the neonate's absorption of oxygen and keeps the alveoli in the lungs from deflating. One of the designs incorporates a humidifier, thermal regulator, and mixing chamber into a single unit, thereby simplifying use. As the air moves into the mixer it is heated and humidified, a heating element in the pipe itself keeps the air mixture at the correct temperature as is dispensed to the neonate. The heating elements of the unit serve the dual purpose of preheating the air to reduce stress on the neonate's lungs, as well as producing steam to sterilize the machine after each use allowing all of the pieces to be reused, which will save on operating costs. In one design, because the unit is connected to the mother's body, a venturi was used as the mixing chamber to reduce the number of moving parts, and decrease the size and weight of the unit[29].

7. INTERDISCIPLINARY ISSUES

The project is very exciting with huge potential, but highlights the difficulties having to do with negotiating differential curricular schedules, discipline values, etc. Geisler notes, "Communication between disciplines is kept to a minimum due to barriers of language, values, prestige, and proprietary interest (as each discipline seeks to protect its information in order to remain indispensable.)"[30] In group meetings it was quickly agreed that prenatal care in developing countries should be the focus. Subsequently there has been conflict as the engineers are being led by their professor to generalize, ignoring site specific cultural and environmental issues. The architects see specific context as key to understanding the design and the criteria upon which the project will ultimately succeed.

Beyond the difficulties that Geisler identifies are the structural barriers to interdisciplinary design. Although this course was 8 months in planning, the difference in operation between the disciplines and the needs of interdisciplinarity were not clear to the chair of the Biomedical Engineering department. She didn't realize that the classes have to meet together to clarify disciplinary responsibility nor that the large differences in expectations between the two disciplines ultimately can cause the demise of the project. The engineers have a very structured course that is designed to move rapidly towards resolution and finished products. The architects have a very open-ended course that meets separately from the engineering course, and is

[28] Neonatal deaths in developing countries account for 99% of all neonatal deaths a year: http://www.commondreams.org/headlines05/0303-05.htm
[29] SLIC Solutions: Jenny B. Chang, Mariah Hughlock, Conchita Mirasol, Vianny Lembert Santana, Jamie Scurrah, Jenn Zuba (March 10, 2005) "Neonatal Ventilator for Developing Countries: Progress Report #2"
[30] Geisler, C. (2002) 'Multidisciplinary: The Renewal of the University and its Curriculum,' *NEH Seminar*, Boulder.

being assessed by different professors. These split administrative entities create barriers to collaboration between the engineers and architects who are responding to very different expectations, both cultural and specific to the course. The students have figured this out, and are meeting independently as a collective group, separate from scheduled times with faculty. There is a definite learning curve to interdisciplinary interactions. As the class proceeds, trust and mutual valuing is growing. We don't believe that the shift from our original conception of redesigning the NICU and its technological and social context to the rethinking an adjustable ventilation device with skin-to-skin care for developing or rural environments could have emerged in a single discipline's answer to the problem.

Despite the many challenges and obstacles it is clear that interdisciplinary design is necessary for real change to occur in the dynamic world we inhabit. The problems that we are facing in the twenty first century are too complicated for a single discipline to have all of the answers. For years we have had specialists working in isolation from each other on problems with very limited scopes. Neonatal intensive care is a perfect example of thinking in terms of systems and interactions on multiple levels with advanced technology that inhibits parent child interactions, and infant development. Having students face some of the obstacles while still in school allows for an opportunity to experiment in an environment where failure has less catastrophic consequences, enabling them to take risks and develop a new way of working.

Fig. 4: Kangaroo Care

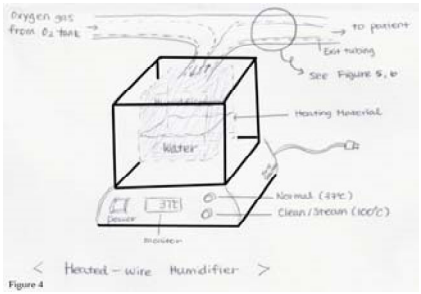

Fig. 5: Ventilation Integration with Kangaroo Care

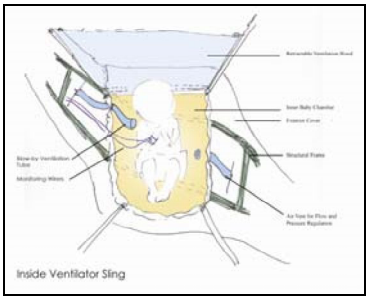

Fig. 6: Mixer Diagram 1

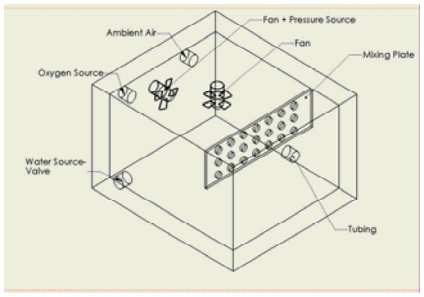

Fig. 7: Mixer Diagram 2

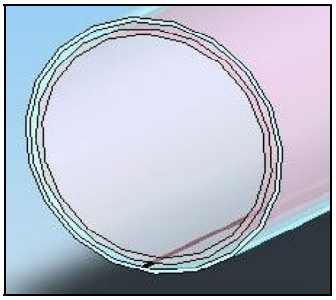

Fig. 8: Venturi Mixer

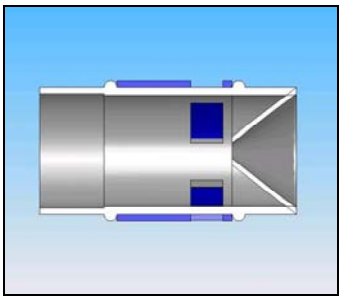

Fig. 9: Integrated Heating Wire