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A Developmental Model of Research Mentoring

Abstract

We studied mentoring relationships between undergraduate and graduate students in a summer undergraduate research program, over three years. Using a grounded theory approach, we created a model of research mentoring that describes how the roles of the mentor and the student can change. Whereas previous models of research mentoring ignored student roles and treated mentor roles as static, our model focuses on the development of the mentoring relationship over time. Our model explains how conflicts can occur if the mentor role does not match the maturity level of the student.

Keywords: model of mentoring, undergraduate research, mentoring, advising

A Developmental Model of Research Mentoring

Undergraduate students can establish academic relationships that enable them to succeed: positive academic relationships can help students persist in college (Pascarella and Terenzini 2005). Some of these relationships are mentoring relationships between students and faculty. Mentoring helps to reduce the barriers that students perceive in college (Hill, Corbett, and Rose 2010; National Academy of Science, National Academy of Engineering, & Institute of Health 2011; Ong, Wright, Espinosa, and Orfield 2011; Seymour and Hewitt 1997). We use Malachowski's (1996) definition of the mentoring relationship as one that is mutual, calls for academic and personal growth, and involves academic, research, and professional advice between the mentor and the student. Although the benefits of mentoring have been identified in many scholarly studies, there is little research that examines the way the mentoring relationship develops over time.

Our study contributes to the literature in three ways. First, rather than looking at the relationship at a single point in time, our study examines how the mentoring relationship can and should change over time. Second, unlike previous studies, we describe both student and mentor roles in the development of the mentoring relationship. Third, our model of mentoring explains some conflicts that can arise in the mentoring relationship.

In their review of studies on mentoring in the education, business, and psychological literature, Crisp and Cruz (2009) found a lack of an operational definition for mentoring and opportunities to improve methods when studying mentoring. Research on mentoring in contexts other than academia is abundant, and in some cases there are important parallels. For example, in research on the development of a mentoring relationship in business between a senior manager

and a junior manager, Kram (1983) conceptualized a developmental model to show how the mentoring relationship develops as the junior manager progresses in a career. Kram found that a relationship can move through the following four phases: initiation, cultivation, separation, and redefinition. Kram found some differences in mentoring relationships across genders. For instance, female junior managers seek female senior managers because of a "lack of an adequate male mentor" (p. 622).

We devote the remainder of this literature review to research on mentoring in academic settings, the context of our study. This research has focused primarily on understanding the personal and professional benefits for both mentors and students. In a study of seven graduate students and one postdoctoral student who mentored undergraduate researchers in molecular biology, Dolan and Johnson (2009) found that students sought mentoring relationships for professional growth, such as furthering their research. Aside from professional growth, however, mentors reported high personal growth, such as enjoying work life as a result of the mentoring experience. Similarly, Reddick et al. (2012) analyzed reflections from eighty-one graduate students from various disciplines, who reported gaining a deeper professional self-awareness as a result of mentoring undergraduate students. Additionally, graduate students reported gaining mentoring skills, and an ability to "help diversify their academic field by mentoring an emerging scholar from an underrepresented population" (Reddick et al. 2012, 41). The benefits of the mentoring relationship between faculty and graduate students have also been documented in the literature (Johnson 2007b; Johnson and Huwe 2003).

To understand how mentors and students gain personal and professional benefits, some researchers have developed models of the mentoring relationship. According to Lee (2010), all models of mentoring between faculty and graduate students categorize the types of academic

relationships faculty members have with their students. For example, the model presented by Gatfield (2005) defines four supervisory styles that differ in their levels of structure and support. The contractual style has high structure and high support, the directorial style has high structure and low support, the pastoral style has low structure and high support, and the laissez-faire style has low structure and low support. Out of twelve faculty members interviewed, Gatfield found that the majority employed a contractual style with their graduate students. Faculty supervisors are not limited to one style. Depending on the student, the supervisor may transition to different styles as needed.

To describe the mentoring relationship between Latina/o faculty members and graduate students, Lechuga (2011) classified mentors into three categories based on the context and expectations of their interactions with graduate students: allies, ambassadors, and master teachers. An ally invests time and energy into developing the student academically and personally. An ambassador develops the graduate student professionally through socialization into the field. Finally, a master teacher develops the graduate student's research skills via "structured learning environments" (Lechuga 2011, 767).

Like Gatfield (2005), Murphy, Bain, and Conrad (2007) defined four supervising orientations that advisers have with doctoral candidates. Whereas a mentor may be personally invested in a mentee, an adviser may not be personally invested in an advisee. The orientations vary on how much control the adviser has over the relationship and whether the relationship focuses on the task or on the person. As an example, a task-focused adviser would prioritize the completion of a literature review without considering whether this task would promote the personal development of the student. An adviser who takes the primary responsibility over the research has a controlling orientation. On the other hand, an adviser who guides the research

process without taking primary responsibility has a guiding orientation. Thus an adviser can fall into one of four advising orientations: controlling and task-focused, controlling and person-focused, guiding and task-focused, or guiding and person-focused.

Whereas previous studies examined the relationship between faculty and graduate students, Tsai, Kotys-Schwartz, Louie, Ferguson, and Berg (2013) investigated the relationship between graduate students and undergraduate researchers. Tsai et al. collected data throughout the duration of a research program. They classified graduate student mentors by two mentoring styles: supervisory and coaching. A mentor acted as a supervisor when he or she prioritized the results of the research project over the relationship with the undergraduate researcher. On the other hand, a mentor acted as a coach when he or she prioritized collaboration and ability to work on the research project as a team. Tsai et al. arrived at these mentoring styles using two exemplary cases from their qualitative data.

Like Tsai et al. (2013), we investigated the mentoring relationship between graduate students and undergraduate researchers. We collected data from eighteen participants weekly during an eight-week summer undergraduate research program. Unlike Tsai et al., we specifically studied the development of the mentoring relationship over time. We created a developmental model, adapted from Grow's (1991) model of self-directed learning, that is grounded in the data. Unlike previous mentoring models, our model incorporates not only the mentor's roles but also the student's roles in a mentoring relationship, and our model addresses the development of the mentoring relationship over time.

Context of this Study

The context for our model is academic research, where the mentor and the student share a common research project. For this study, we examined mentoring relationships in the context of an eight-week summer Research Experiences for Undergraduates (REU) program supported by a grant from the National Science Foundation. The REU program was designed for undergraduate students interested in information security and reliable computing—designing computer systems to withstand failures of components. The undergraduates pursued many different research projects: for example, they designed algorithms to protect personal data, created mathematical models for the security of power grids, analyzed reports of attacks against a shared computing infrastructure, developed software tools to convert sequential code into thread-safe parallel code, and determined the efficiency of fault-tolerant agreement protocols. Some of the undergraduates were mentored by graduate students.

For the graduate student mentors, one of the authors led a mentor development program based on the program designed by Handelsman, Lauffer, Pribbenow, and Pfund (2005). This program of Handelsman et al. consisted of eight instructional sessions, which were designed to help the graduate students acquire and improve mentoring skills. At the beginning of each summer, the graduate student mentors[1] attended a half-day workshop. During the workshop, they drew on their prior experiences to identify effective mentoring practices, and they expressed their own hopes for the mentoring relationship. They wrote individual personal concerns about mentoring; their concerns were shared anonymously. The mentors began planning for the first week of the summer program: they decided how they would welcome their undergraduate researchers, what technical skills they would teach, and what expectations they would set for meetings and communication. After the workshop, throughout the summer, the mentors met

[1] The graduate student mentors will be called “mentors” for the remainder of the paper.

every two weeks to share experiences and to discuss mentoring case studies from the book by Handelsman et al. (2005). These cases presented common problems such as handling interpersonal conflicts, checking the undergraduate's work, and valuing racial diversity. Each mentor received a copy of a booklet on mentoring undergraduates (Merkel and Baker 2002; Temple, Sibley, and Orr 2010). Each mentor drafted an initial mentoring philosophy statement at the beginning of the summer and submitted a revised statement at the end of the summer.

In their mentoring philosophy statements, the mentors described their personal beliefs and values about mentoring, analogous to a teaching philosophy statement. When they drafted their statements, the mentors were guided by reflective questions. These reflective questions are presented by category in Table 1.

[Insert Table 1 here]

In addition to writing mentoring philosophy statements, the mentors responded weekly to questions that prompted them to reflect on their interactions with the undergraduate researchers. Every week, the mentors answered about six specific questions about the mentoring relationship. Examples of these questions are presented in Table 2. On average, mentors wrote a little over 300 words per weekly entry in an electronic journal. The journals provided a way to collect data across the entire summer, as the mentoring relationship developed and changed.

[Insert Table 2 here]

Research Methods

This study was approved by the local Institutional Review Board [Number blinded for review]. While we did not have a theory-driven hypothesis or research question, we followed a scholarship of teaching and learning process (McKinney 2007): we gathered data from the reflective journals and mentoring philosophy statements, and we systematically analyzed these data, to understand the learning experiences of the mentors.

Participants

All of the graduate student mentors participating in the REU program were invited by e-mail to participate in the mentor development program. All of the graduate student mentors who were interested in participating were accepted into the program. Four participated in the program in 2010, seven in 2011, and seven in 2012; no graduate student participated more than once. All but one graduate student participant mentored only one undergraduate. Each participant received a stipend for professional travel as compensation for participating in the mentor development program.

We are reporting on sixteen of the eighteen mentors for whom we have complete data. In total, there were fourteen male mentor and four female mentors. All mentors were graduate students in engineering, computer science, mathematics, or other sciences. Additionally, at the time of the study, all were seeking the doctorate degree. In 2011 and again in 2012, one mentor met with the undergraduate researcher regularly via Skype because the mentor had an industrial internship out of town. To preserve the mentors' anonymity, we identify the mentors by non-gender identifying pseudonyms.

Data Analysis

All identifying information, particularly the names of the mentors and undergraduate researchers, was removed from the initial and revised mentoring philosophy statements and from the weekly reflective journals prior to data analysis. Although we have data from only sixteen mentors, theoretical saturation or theoretical sufficiency was reached with this data (Charmaz 2014). We used grounded theory (Corbin and Strauss 2008) to analyze the reflective journals and mentoring philosophy statements because it allowed us to focus on the data. In other words, we analyzed the data inductively without an a priori framework and with the goal of developing a theory or model. Consistent with grounded theory, we developed a working model of mentoring that is grounded on the data and is adapted from Grow's model of self-directed learning.

During the analysis phase, we (the two authors) performed open-coding independently. Each of us analyzed at each of the documents from the mentors by looking for similarities and differences across these data (Corbin & Strauss 2008). We then compared our analyses and negotiated on codes. We agreed on the majority of the codes created independently during the first iteration, and we defined a list of consensus codes. During subsequent iterations of coding and code negotiation, we used the consensus codes to identify themes. From these themes, we created a model that describes the development of the mentoring relationship over the course of a research project. To assess the model, in the last week of the 2012 summer research program, we sought feedback from six graduate students who had participated in the mentor development program in 2012. Generally, the graduate students felt the model described the development of their mentor-student relationships accurately. Since we did not learn anything new from the assessment with the six graduate students, we concluded that we had attained theoretical sufficiency. Finally to increase the duration of contact with the participants, we collected data

over three summers. We reached saturation: the analysis of the 2012 data did not yield any new themes beyond the themes that we had already found in the 2010 and 2011 data.

Limitations

This study is limited in three ways. First, we did not collect data from the undergraduate researchers. Data from the undergraduates could have been used for triangulation, to confirm the mentoring roles in the model. Although we did not collect data from the undergraduates, we included the student role in our model because the student role is essential in Grow's (1991) model of self-directed learning. We identified the student role in the mentors' reflective journals and mentoring statements. Future research could include observations of the student's perspective to further assess our model. Second, we were limited by the length of the summer research program, a short term of eight weeks. This second limitation was a constraint of our design; in the discussion section, we outline how future research could strengthen the model by observing the mentoring relationship over a longer period of time. Third, like most qualitative research, the results from this study might not be generalizable to other contexts. However, grounded theory has allowed us to generate a model and use the model to make connections beyond the boundaries of our study.

Results

Our Developmental Model of Research Mentoring (DMRM) is a four-stage, descriptive model of the relationship between a mentor and a student who collaborate on a common research project, which frames the mentoring relationship. Our DMRM model is shown in Table 3.

[Insert Table 3 here]

To develop the DMRM, we adapted Grow's (1991) model of self-directed learning to mentoring. Grow defines self-directed learning as "the degree of choice that learners have within an instructional situation" (p. 128). Inspired by the situational leadership model (Hersey and Blanchard 1988), Grow's model focuses on the relationship between a teacher and a student. The model has four stages for the student and four for the teacher. The student should progress from a dependent learner (stage 1) to an interested learner (stage 2), to an involved learner (stage 3), and eventually to a self-directed learner (stage 4). According to Grow's model, the teacher's role should change to match the student's stage. The teacher should progress from an authority (stage 1) to a motivator (stage 2), to a facilitator (stage 3), and eventually to a delegator (stage 4). A principal goal of this relationship is to help the student reach an autonomous point of learning. A student can be a self-directed learner in one subject area and a dependent learner in another.

Like Grow's model of self-directed learning, the DMRM has four stages, and it emphasizes the importance of matching the mentor's role to the student's role in the mentoring relationship. In the DMRM, we also suggest that eventually the student can take the primary responsibility and become a colleague to the mentor. Next, we describe the four stages of the DMRM.

Stage 1: Novice and Director

In stage 1, the mentor holds the primary responsibility for the research project. During this stage, the student might feel new to the project, the people, the research environment, and

sometimes the campus. To complement a novice student, the mentor welcomes and introduces the student to the project. At this stage, the mentor is directive in setting expectations, goals, and objectives for the student. The mentor may assign specific tasks such as reading previous research articles and learning to operate laboratory equipment.

In our analysis, we found that in their initial mentoring philosophy statements, some mentors described their roles as directors. As a representative example, Addison felt responsible to direct and teach the student.

> Mentoring is like sailing a ship … In this metaphor, a mentor is a captain of the ship and mentees are crew members. As a mentor, I need to give specific direction to mentees to have their research proceed … to teach research to mentees is of course the biggest goal for mentoring. (Addison, Initial Statement, 2010)

In this metaphor, Addison was the captain, or the director, of the research project and the mentees (students) were the crew members, or novices who lacked the expertise of the director. When an undergraduate student is a novice to a research project, a mentor who acts as a director can help the student ease into the project.

Mentors acted as directors in the first weeks of the summer program by orienting the student to the research environment. For example, in the excerpt below Flannery describes the responsibility to take on the directive role and introduce the student to co-workers in the laboratory and the physical working space around campus,

> I introduced [the undergraduate researcher] to people in our lab and also showed her the facilities in our lab. We gave a brief overview of the project she will be involved in. We also made sure that basic formalities like access to the labs, cleanroom, library, etc. were completed in the least possible time. In order to make her feel comfortable, we gave her a

short tour of the campus. This helped her get used to the place faster. (Flannery, Reflective Journal, Week 1, 2011)

As a novice in stage 1, the student may be unable to advance the research project independently, but with the help of the mentor, the student should be able to follow instructions. Mentor Carson realized that the undergraduate student exhibited the stage 1 trait of imitating the mentor.

[Student's name] strongest skill is in imitation. He has been effective at using examples to duplicate results. (Carson, Reflective Journal, Week 3, 2010)

In summary, a stage 1 director initiates the student into the project by providing clear direction and by introducing the student to the project, the people, and the research environment. During stage 1, the student is unable to advance the research project without direction from the mentor. Stage 1 may be short in some mentoring relationships, especially in the case where a student is a fast learner or has previous research experience. However, stage 1 is a critical time to create a foundation for a developing mentoring relationship.

Stage 2: Apprentice and Master

As a student transitions from stage 1 to stage 2, the student understands the purpose and the context of the research project. Explaining the "big picture" to the student can socialize the student into a profession (Thiry and Laursen 2011) and can even promote the motivation of the student.

In stage 2, the relationship resembles the classic master-apprentice relationship. In the master role, the mentor still holds the primary responsibility for progress in the research project, but the student may start to make progress independently. At this point, the student should be

more knowledgeable about the research project than in stage 1. The stage 2 student understands his or her role in the project and is no longer a novice, but rather an apprentice. As an apprentice, the student should move beyond reproducing results to connecting results and knowledge to a bigger research picture. In stage 2, the student starts focusing on the "why" of the research project in addition to the "what." To assist with this shift of perspective, the mentor allows the student room for his or her own discoveries.

In our data analysis, we found that mentors expressed eagerness to ensure that the undergraduates understood the link between their research project and the "big picture."

> I believe that a good research engineer must be able to keep returning to the big picture, both to revive motivation and to maintain focus in the right direction. One of my main goal[s] as a mentor is to help my student maintain an understanding of their work in the context of the larger motivations [sic] and ultimate socially desirable product. (Dana, Initial Statement, 2010)

In order for the student to see the bigger research picture, a stage 2 mentor helps the student work more independently. For example, the mentor might encourage the student to solve problems or consult with peers before asking the mentor questions. In the revised mentoring statement, Brady reflected on the importance of taking time to make sure that the student can become independent.

> A mentor is a leader of a project while a teacher teaches knowledge to students. Therefore, a mentor helps a mentee work for him/herself. In order to be more effective mentor, he/she should be friendly to make a mentee feel close each other so that they can ask questions without any hesitation. A mentor should spend more time in improving the interaction with a

> mentee since a work cannot be successful without smooth communication between a mentor and a mentee. (Brady, Revised Statement, 2010)

In summary, in stage 2, students start gaining independence and producing research results on their own. Students understand the bigger picture in their project and become motivated by the overall goals. As they become more independent, they begin to understand the "why" of the research project in addition to the "what."

Stage 3: Collaborator and Guide

As a student transitions from stage 2 to stage 3, the student contributes new ideas to the research project and gains an increasing sense of independence. During stage 3, the mentor and student share responsibility for advancing the research project; the student may take ownership of some aspects of the project. As a result, the mentor and student interact frequently.

In our data analysis, we found that students acted as collaborators by suggesting research ideas to further the research project. For example, in week 2, Noel wrote that the student spent less time than other students acquainting himself to the project because he had had previous research experience. Noel reported that the student took initiative by suggesting ideas for future research,

> Over the course of the week, I have been impressed with this progress and I hope it continues…The great thing is he has actually been suggesting some things that he would like to do beyond what we are asking him to do. (Noel, Reflective Journal, Week 2, 2012)

Additionally we found that many mentors reported their desire to see students take ownership of the research project and especially to be motivated and make progress on their

own. Mentors Brady, Carson, and Jesse summarized the type of mentoring that can be helpful in stage 3,

> I want to help my undergraduate [researcher] to not only do the work that he has been assigned, but also to begin to think beyond his assignments. I want to see him to take pride and ownership in his project, and to begin to create ideas and to be excited about the work that he is doing. (Carson, Initial Statement, 2010)
>
> I will encourage the undergrad to work independently but I will evaluate their decisions carefully to be sure that they are on the right track. (Jesse, Reflective Journal, Week 8, 2011)

Jesse also reflected on the importance of having an independent student and having an interactive mentor-student relationship with shared responsibility:

> As a mentor, I strongly believe that my role is to offer students several options to help them find out what works for them. Hence, it is crucial that students become independent in the choices they make, and it is the mentor's role to provide them feedback so that they can make the right choice. (Jesse, Initial Statement, 2011)

In stage 3, the mentor and student share responsibility for advancing the research project, with the mentor serving as a guide. The student is motivated to advance the project with the mentor's guidance.

Stage 4: Colleague and Consultant

As a student transitions from stage 3 to stage 4, the student takes ownership of the project. In stage 4, the student has the primary responsibility and the mentor serves as a consultant. The student is now a colleague to the mentor. The student may initiate new directions and develop his or her own ideas for further research. According to Lopatto (2003), some

faculty members believe that even undergraduate researchers should feel ownership of their projects and should gain independence from their mentors with time.

Fifteen of the sixteen mentors did not reach stage 4 of the mentoring relationship. Eight weeks was not enough time for a mentoring relationship to mature. During the last week of the program, Carson reflected about how a mentor might help a student achieve stage 4 by allowing the student to take on the primary responsibility.

> Place the responsibility for making progress on the undergraduate, [but] do not expect them to take that responsibility on their own. This can be done by asking them to set objectives and to read literature, but "telling" the undergraduate what to do creates a lot of work for you and does not make for an effective working relationship. (Carson, Reflective Journal, Week 8, 2010)

Brady worked with an undergraduate who was able to achieve all objectives of the research project and work independently. In this way, Brady acted as a consultant by finding a balance to encourage the undergraduate throughout the summer without taking the primary responsibility of the project,

> I have worked with a few undergraduate students before [this summer research] program. While I worked with them, I continuously tried to find out how to encourage them and improve their work performance. However, my undergraduate student this summer is good as it is. Since I personally do not like the situation under higher pressure, I hesitated to push him. (Brady, Reflective Journal, Week 7, 2010)

The end of the quotation shows the Brady's personal desire to avoid taking a directive role and instead embrace a consultant role.

In stage 4, the student is able to make progress on the research project independently. The student may initiate new directions for the research. The role of the mentor is to serve as a consultant to the student by providing advice when asked.

Mismatches

As in Grow's model of self-directed learning, some mentors took on a role or approach that did not match the stage of the undergraduate student. This mismatch of mentor and student roles can decrease the effectiveness of the mentoring relationship. More important, a mismatch can hinder progress in the mentoring relationship. Using Grow's terminology we identify two severe mismatches, outlined below, that occur when mentors and students take on roles that are complete opposites on the model.

Mismatch: Colleague and Director

A severe mismatch occurs when a mentor takes the role of a director with a student who is ready to be a colleague. In this situation, the student might have previous research experience and be well versed in doing research. The mentor may not recognize or may overlook the student's previous experience. The colleague-director mismatch could lead to an unsuccessful mentoring relationship because it is likely that the student may be unsatisfied with the approach of the mentor.

In our data, we did not encounter situations where a colleague student was mismatched with a director mentor. Because most students in the summer research program had little or no prior research experience, the students did not fully or independently take on the responsibility of the research project, and as a result, they did not reach stage 4. A severe colleague-director

mismatch could occur in the mentoring relationship between a directive advisor and an experienced graduate student or a post-doctoral researcher.

In our data we observed some examples of a less severe mismatch between an experienced or fast-learning student who took the role of a collaborator and a mentor who took the role of a director. Lane had low expectations for the undergraduate student because the undergraduate did not have previous research experience. Lane did not expect to gain much from working with the undergraduate. In the initial mentoring statement, Lane wrote that a good mentor "may be a confidant, a friend, or a peer, but the mentor/student relationship is not a partnership of equals." Lane used control theory as a metaphor for mentoring, explaining that "the mentee is a plant to be steered and directed by the efforts of the mentor." Lane's directive style was challenged by a student who exceeded Lane's initial low expectations. In week 4, Lane wrote, "[I am] struck by the fact that mentoring is a two way learning process. This is something to remind future mentors, who may feel that training will only cost them until the undergraduate can produce." Lane returned to this idea in the last week of the program:

> I was surprised by the dedication of my mentees. They threw themselves into what were often obscure areas, and have made some measureable, new results. I have nothing but praise for their character and abilities. I am currently placing their posters on our lab webpage, because I am proud of their accomplishments and believe that their work reflects well on our lab and lab members. They will be proudly listed as "lab alumni." (Lane, Reflective Journal, Week 8, 2012)

A mentor who takes a director role with a student who acts as a collaborator results in a mismatch and a missed opportunity. In this situation, the mentor does not help the student make progress to the next stage because the mentor is focused on directing and managing the student.

A student who does not feel appreciated for thinking independently might not make a meaningful contribution to the research project unless the mentor shifts to a more fitting role.

Mismatch: Novice and Consultant

A severe mismatch occurs when a novice student has a consultant mentor. In this situation, the mentor does not provide the initial direction and guidance that a student with no research experience needs. During the summer of 2012, we observed an instance of this severe mismatch in Kelly, who was clearly a hands-off mentor. In the initial mentoring statement, Kelly wrote,

> As a mentor, I only need to provide some suggestion and guidance on potential direction and related work. Students should decide what exactly they need to learn and how they learn.

During the first few weeks of the summer, Kelly learned that the undergraduate "feels that the project is interesting. However, [the student] still doesn't have enough background and skills…" In week 3, Kelly surmised that the undergraduate student should focus on improving "how to 'learn' new things"; however, Kelly did not take on a directive role to show the student how to learn those new things. In week 5, Kelly wrote, "I think I already tell him a lot, and he needs to think to learn. However, he doesn't think I gave him enough advice." During the following week, Kelly noted,

> My management is kind of free and based on trust. So I didn't give him a hard deadline, which I should. Since the [student] is different from me, he works better under pressure.

Although the student was able to achieve some of the goals of the research project, in week 8, Kelly imagined how the relationship could have been adjusted:

> …I need to be more flexible and be ready to all different kind of situations from the mentee. Also, I've learned that sometimes micro-manage [sic] is not a bad thing, and may even be necessary.

Kelly realized that taking on a more directive role might have helped the student be more successful.

Kelly took on a consultant-like role even when the student needed clear directions. Kelly had high expectations for the student, but did not take on the directive role needed to meet those expectations. Similarly, mentors Parker and Sage from summer 2012 took an initial hands-off approach, and although their students were able to make progress on their projects, Parker and Sage thought they could have been more directive in the beginning of the mentoring relationship:

> The mentor needs to be precise and specific on setting goals for the [undergraduate] researcher. It is never the same how he and I look at the project. A mentor can't expect his mentee to know too many things or to have ideas on many things. It's a mentor's duty to give them the roadmap on how they can learn those things. (Sage, Reflective Journal, Week 7, 2012)

> I learned that while it is very important to not micromanage, the mentor should still have a clear-cut high-level plan for the student. (Parker, Reflective Journal, Week 7, 2012)

In the revised philosophy statement, Addison acknowledged that maintaining a directive role for the duration of the mentoring relationship may not be fitting for the student.

> It is also important for a mentor not to micromanage [students]. Thus, I as a mentor put out my best efforts to pursue the golden mean by specifically directing them to make regular outputs without micromanaging them. (Addison, Revised Mentoring Statement, 2010)

Addison attempted to be less directive with the student and tried to allow the student more independence.

Matching Mentoring Styles

Some of the mentors were keenly aware that they had to match their mentoring styles and strategies to their students. Noel wrote,

> Some believe the best way to mentor is more of a hands-off approach, while others a hands-on approach. The problem is every mentee is also going to have different personalities, aptitude, and work drive. To say one approach is the most effective is a little obtuse. It's more about knowing *when* to be more hands-on and then be hands-off. (Noel, Initial Statement, 2012)

Mason used the metaphor of riding a bicycle to describe how a mentoring style might depend on the progress that the student has made:

> When first starting, the mentor runs along with the mentee stabilizing him/her while he/she tries to pedal and gain his/her own balance. . . . After trying and perhaps falling, several times, the mentee is able to ride a short way by [himself or herself]. The mentor also knows each mentee is different, and takes a different amount of guidance to get to riding. A successful mentor is never negative and maintains patience….If successful, a mentor should have enabled the mentee to map out his/her own rides, enjoy his/her time along the way, get up when he/she falls, and someday, perhaps help mentor others. (Mason, Initial Statement, 2012)

Discussion

Our Developmental Model of Research Mentoring (DMRM) offers two advantages over previous models of research mentoring. First, the DMRM explains how the mentoring relationship can and should evolve over time. As the student gains experience, the student role progresses from novice to apprentice to collaborator to colleague. The DMRM suggests that the mentor role should progress along with the student, from director to master to guide to consultant, to avoid unproductive mismatches. Some stages may be shorter than others. For example, a student with prior research experience may not be a novice researcher for long. Previous models identified styles, perceived roles, and responsibilities (Lechuga 2011), which highlight various aspects of mentoring such as support and structure (Gatfield 2005). These styles can be person-oriented or task-oriented (Murphy et al. 2007). However, previous mentoring models did not indicate how roles may change over time. Our model addresses the changes that can occur as a mentoring relationship develops.

Second, the DMRM defines four roles for students in addition to four roles for mentors. Previous models (Lechuga 2011; Lee 2010; Tsai et al. 2013) defined roles only for mentors and ignored the roles of students. With roles for both students and mentors, the DMRM explains two types of mismatches that can produce ineffective mentoring relationships: the novice–consultant mismatch and the colleague–director mismatch.

Our mentor and student roles differ from Gatfield's (2005) supervisory styles in two ways. First, in DMRM, the mentor always supports to the student, but the amount of support may vary. For example, Gatfield (2005, 317) laissez-faire style refers to a "supervisor who may appear uncaring and uninvolved." In contrast, our consultant mentor does not provide support for the student continuously, but only when needed. Second, in DMRM, a mentor reduces the amount of structure in the relationship only when the student is ready to accept more

responsibility in the research project. In Gatfield's model, it is possible for a mentor to provide low support to a student who requires high support. Ideally, in the DMRM, the structure provided by the mentor decreases from high to low as the relationship develops from stage 1 to stage 4. Consequently, a mentor would provide high structure to a student who requires it, especially in the beginning of the relationship.

The DMRM does not require the student to progress linearly from stage 1 to stage 4. Though we did not observe the non-linearity in our data, the vast literature on development stage models (Evans, Forney, Guido, Patton, & Renn 2010) suggests that the DMRM has a similar quality. The mentoring relationship is non-linear in that it is not uni-directional: the student (and mentor) may move back and forth between stages.

Conclusions

In this study, we have adapted Grow's model of self-directed learning to mentoring and presented a four-stage developmental model of research mentoring (DMRM). Since context matters when thinking about the type of academic relationships that mentors have with students (Hoffman 2014), we expect that our model can apply to other mentoring situations where the mentor and student are collaborating on a research project. These mentoring relationships include mentoring between faculty and graduate students (Dodson, Fernyhough, & Holman 2006), mentoring between faculty and undergraduates (Adedokun, Bessenbacher, Parker, Kirkham, and Burgess 2013) and between graduate students and high school students (Bleicher 1996).

Our model can guide research mentors to become more proficient in their roles, by matching their level of support to the current needs of their students. As an example, Hammond

and Lalor (2009, 31) found that faculty mentors of undergraduate researchers were "high-quality researchers, very knowledgeable and respected by their peers, but not as proficient in an advisory role." Mentors who are proficient in their roles as advisors can help students succeed in their higher education journeys. On the other hand, mentors who are not proficient in their roles may discourage undergraduates from continuing in the field: one bad research experience with a faculty mentor can discourage an undergraduate from pursuing graduate study (Jiang and Loui 2012; Johnson 2007a). Part of being proficient in their roles and matching mentor support to students' needs is inviting and providing feedback on the mentoring relationship. Our model could have helped mentors like Kelly and Lane assess the mentoring situation, in their cases the severe mismatches, and adjust appropriately to facilitate progress in the mentoring relationship and the research project.

As highlighted in the literature (Gatfield 2005; Lechuga 2011; Murphy et al. 2007), a deeper understanding of mentoring styles can lead to a more fruitful mentor-student relationship. Our study highlights the importance of changing mentor roles as the research project progresses and the student matures as a researcher. Transitions in roles should occur when the student understands the purpose of the research project (stage 1 to stage 2), contributes new ideas to the project (stage 2 to stage 3), and achieves independence in advancing the project (stage 3 to stage 4). Future studies of mentoring could examine specifically the types of milestones that signal transitions between roles in the progression of the mentoring relationship.

Our study shows that mismatches can occur in mentoring relationships. Two mismatches are particularly severe: the pairing of a colleague student with a director mentor, and the pairing of a novice student with a consultant mentor. When a student who is ready to be a colleague is paired with a mentor who is directive, the student may feel "micromanaged" by the mentor

(Lechuga 2011). On the other hand, when a student who is a novice to research is paired with a mentor who acts as a consultant, the student may feel abandoned by the mentor. Both mismatches could lead to disengagement in the research project and an unsuccessful experience for both parties. Mentors can avoid mismatches by adjusting their roles appropriately. Mentors may also be able to foresee mismatches through an understanding of best practices that yield successful mentoring relationships (Ahn, Cox, Deifes-Dux, and Capobianco 2013).

Our model could serve as a reference point and be integrated in practice. The model could be incorporated into a mentor training programto address the mentors' development and roles in a mentoring relationship. For example, the mentors could review the model and discuss the transition between stages, the roles, the mismatches, and the overall progress of a mentoring relationship. The model presented in this paper could be combined with other resources that provide guidelines on mentoring (Handelsman, Lauffer, Pribbenow, and Pfund 2005; National Academy of Sciences, National Academy of Engineering, & Institute of Medicine 1997; University of Nebraska-Lincoln; University of Michigan 2014; University of Washington; Vesilind 2001)

A successful mentoring relationship may be a critical aspect of a student's college or graduate experience. Our Developmental Model of Research Mentoring can help guide mentors and students in understanding the ways a successful mentoring relationship can develop over time.

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