7-8-2018

Developing a conversation: A strategy to engage faculty in pedagogical change

Allison M. Mercer

Jennifer E. Lewis

Susan Sutheimer

Adele J. Wolfson
Wellesley College, Awolfson@wellesley.edu

Title: Developing a conversation: A strategy to engage faculty in pedagogical change

Authors: Allison M. Mercer[a], Jennifer E. Lewis[a], Susan Sutheimer[b], Adele J. Wolfson[c]

[a]Department of Chemistry
Center for Improvement of Teaching and Research on Undergraduate STEM
University of South Florida
Tampa, FL 33620
jennifer@usf.edu
allisonm@mail.usf.edu

[b]Department of Chemistry
Green Mountain College
Poultney, Vermont 05764
sutheimers@greenmtn.edu

[c]Department of Chemistry
Wellesley College
Wellesley, MA 02481
awolfson@wellesley.edu

Abstract: Personal interviews were conducted with biochemistry faculty during which they were presented with student performances on a content survey. From these interviews, four themes that reflect faculty responses to the surveys emerged: awareness of student understanding, self-reflection on teaching practice, planned collaboration with colleagues, and emotional reactions. Here, we discuss these themes and their implications for creating conversation designed to promote reflection on biochemistry teaching.

Key Words: faculty interviews, self-reflection, emotions

Introduction

Biochemistry educators face numerous challenges that come with teaching a high-level interdisciplinary college course. These challenges include the diversity of student preparation and career paths, specialized language applied differently in prerequisite disciplines, and the need for faculty to collaborate across departments in support of student learning. These obstacles are not necessarily unique to the discipline of biochemistry, and neither are the solutions. One potential path for overcoming some of the difficulties of teaching is outlined here, within the context of biochemistry but applicable to any field: reflective conversations among faculty.

To deepen faculty awareness of students' knowledge, we administered a pilot survey to students on three topics of central importance in biochemistry and relayed the resulting information to faculty during personal interviews. The project was designed to be an iterative process, which over time will aid faculty in gaining a more holistic understanding of how their viewpoint of curriculum and instruction coincides with the student cognitive experience. Ideally the faculty, upon being presented with the results of student assessments, will become more keenly aware of something they had not known or not fully recognized regarding their students. Faculty can then use this information to change how they teach and, through collaboration with their colleagues, change the system in which they teach. Here, we report a widely applicable interviewing method for engaging faculty. Through this intervention, biochemistry faculty became aware of student understanding, reflected on their teaching practice, planned collaboration with their colleagues, and reacted emotionally to student responses.

Faculty Awareness

The connection between student learning and faculty effectiveness is an indirect one that does not consider all the factors that affect student performance [2]. When student learning outcomes are used to assess teacher quality at the pre-college level, there has been understandable faculty resistance [3, 4]. However, a clear understanding of students' progress toward mastery of core concepts is necessary for faculty to design their curriculum and pedagogy, and such understanding allows faculty to reflect on their own teaching practices [5, 6].

Core concepts in biochemistry have been defined by research groups and professional societies [7-9]. In whatever form these concepts are expressed, there is agreement that biochemistry is challenging for learners, requiring the integration of knowledge and skills from general chemistry, organic chemistry, and biology. It is well known that, despite instruction, students retain misconceptions and alternative conceptions about scientific principles, which have been uncovered using concept inventories in physics, chemistry, and biology [10-12]. The transfer of core concepts between courses and contexts is critical as students move through the curriculum. However, misconceptions are acquired very early in the study of chemistry, and current teaching practice does not necessarily allow students to transfer and deepen their understanding of chemistry into biochemistry [13]. Faculty may make unjustified assumptions about how well students are able to successfully recognize and apply a concept in a new context. As such, it is beneficial to assess students' understanding of core concepts in order to make targeted interventions to improve student learning.

Self-reflective practice

Self-reflection by faculty members may be the most important source of self-improvement, since only faculty "can provide descriptions of their work, the thinking behind it, and their own personal reporting, appraisals, interpretations, and goals" [14]. Berk indicates the importance of self-evaluations to both formative and summative evaluations [2]. When faculty are confronted with students' misconceptions or difficulties with material, they often attempt to remediate, whether by trying new frameworks or providing context [15, 16]. More recently, there has been a movement towards interdisciplinary and active-learning pedagogies in response to the limited success of earlier approaches [17, 18]. Self-reflection is an intermediate step between interpreting student responses and making pedagogical change, so it is both interesting and important to capture instances of its happening [19]. While on-the-spot self-reflection during an interview may not be the thoughtfully documented type of self-reflection encouraged by Brashkamp and Ory, it does provide spontaneous thoughts that would not appear in formal reports [14]. Faculty who recognize the role of their teaching in persistent student misunderstandings should be open to teaching approaches that stimulate conceptual change [19]. Indeed, by reflecting with colleagues on teaching, faculty may benefit by assimilating new practices and building a network of support to sustain a common goal of positive pedagogical change [20]. The methods presented here to spur these conversations are easily employed and can be engaging for all levels of teaching development.

Interacting with colleagues

Teaching has tended to be an individual pursuit, particularly in higher education. [21]. While we see faculty and institutions moving toward interdisciplinary projects and team teaching, the barriers to working across disciplines or even among different levels of undergraduate chemistry are entrained in the system [22, 23].

Working collaboratively is inherently less efficient; academics are not trained to work together; and existing administrative structures are not oriented toward promoting or supporting collaborative work, particularly work that crosses disciplinary, department, or school boundaries [21]. Similarly, several studies emphasize concerns by graduate students and early-to-mid-career faculty that academia lacks communities in which collaboration is respected, friendships develop, and faculty stimulate one another's intellectual interests [24]. The benefit of intentional cohorts ornetworks has been found to imbue faculty with confidence in teaching and provide the opportunity to exchange feedback on teaching practices [25]. Successful teaching teams engage in constructive conflicts, integrate their differences, and co-construct solutions [26]. When given institutional support, faculty are able to collaborate around the curriculum and conduct department- or course-specific teaching projects [20, 27]. In the best cases, collaboration allows resources to be used more effectively, faculty members to learn from one another, and each person to contribute from a position of strength [28].

Emotional Responses

The emotional responses of higher education faculty regarding their students, themselves, or their teaching are infrequently published in scientific journals, yet emotional experiences permeate all levels of teaching practice and can affect motivation and cognition [29]. A study of 40 post-tenure faculty indicated that scholarly work, including the development of teaching expertise, is intensely emotional, but these emotions are largely hidden because of social norms [30]. The affective dimensions of teaching include emotional factors [31]. Vloet and Van Swet consider emotions related to teaching as a component of professional identity [32]. Importantly, these emotions can be negatively affected by external imposition of change if not accompanied by coaching [33]. Accordingly, we were alert to the emotions biochemistry faculty exhibited in response to student survey results.

Methodology

This project was undertaken at two institutions: a predominately undergraduate institution (PUI) in the Northeast United States and a high activity research institution (R1) in the Southeast

United States. A 25-question survey was developed to assess the following biochemical topics: acid/base equilibria, energy diagrams and kinetics, and thermodynamics of ATP (adenosine triphosphate) hydrolysis. Three question sets were taken from the Molecular Life Science Concept Inventory (MLSCI) [34, 35] and modified to address these topics at multiple levels. Students were asked to report their confidence in their answer to each question on a 5-point Likert scale ranging from completely confident to completely unsure. A total of 25 true/false questions plus the corresponding 25 confidence questions comprised the final survey.

The survey was administered at the two institutions in the Fall 2016 semester. At the R1 institution, it was assigned to two large (over 200 students) one-semester introductory biochemistry classes as low-stakes quizzes on Canvas, a learning management system. The survey was administered twice during the semester: once in the first week of classes, and again after instruction but before finals. At the PUI, the survey was administered to several small courses at the end of the semester via Qualtrics, an online survey software. These courses included general chemistry, organic chemistry, and biochemistry. The survey was voluntary and participants were offered the incentive of being entered into a lottery for a gift card or were given extra-credit points. While the PUI data does not allow for a matched pre/posttest comparison, the observations of students' mastery at the end of several different courses allows for a broad view of what students understand at each point in the biochemistry sequence.

Interviews regarding student results of the surveys with four biochemistry faculty members were audio-recorded in Spring 2017. During the interviews, faculty members were provided with the student data from their biochemistry course in two formats. In the case of the R1, they were shown a simple bar chart with the pre- and post-instruction average percent scores for each of the 25 biochemistry content questions, with a line drawn at the 50% mark (as this is the chance of getting a true/false question correct by guessing), and a second bar chart that indicated the difference between pre/post scores by question (including directionality) with an indication of which differences were one standard deviation from the mean by calculation of a z-score. The PUI data were treated in the same way, but since there was no the pre/post collection, the different courses were used for comparison. With these data in hand, the faculty members were asked questions about their interpretation and use of the data. The interviews were semi-structured and included the following prompts:

- Looking at the actual questions that showed the biggest changes, positive or negative, could you comment on whether these would be expected?
- Given what you emphasize (or don't) in your course, do these particular topics as areas of gain or loss make sense to you?
- Might the results lead to any changes in your teaching or organization of the course? What if you saw the same patterns multiple times?
- Might these results influence how you interact with faculty who teach courses earlier in the curriculum?
- What might you want to see from students' [earlier] courses that would allow you to teach at a deeper level or without so much repetition?

Qualitative content analysis was employed in interpreting the interview data [36]. Three independent researchers listened to the interview recordings, selectively transcribed relevant excerpts, and developed a coding frame in an iterative fashion. Because selective transcription was employed rather than full transcription, care was taken to seek out excerpts discordant with the coding scheme. Discrepancies between coders were discussed until unanimous conclusions were reached. The final coding frame included the following themes that reflect faculty responses in the interviews: awareness of student understanding, self-reflective practice, interactions with colleagues, and emotional responses.

"Awareness of student understanding" captures instances where faculty learned something new about their students as a result of the interview; this includes discussions about student proficiencies, misconceptions, and whether the results coincide with faculty expectations of students. "Self-reflective practice" covers instances where faculty were self-critical about what or how they teach in the context of both biochemistry content and pedagogical form. "Interactions with colleagues" is defined as instances where faculty discussed working with other faculty to improve teaching at the institution, including past discussion and intentions for future interactions. "Emotional responses" refers to instances where faculty exhibited emotions and is further divided into two subcategories: positive emotions (with indicators such as "I like that" and "I'm pleased") and negative emotions (with indicators such as "I don't like that" and "I'm disappointed"). Excerpts from interviews provided in the results and discussion section are representative, not exhaustive, of the data collected and analyzed. Some of the excerpts were edited for clarity; edits are indicated by brackets and ellipses.

[INSERT FIGURE 1 HERE]

Figure 1. Methods outline of surveys, interviews, and results.

Results and Discussion

Table 1 provides examples of faculty responses in each of the categories identified

INSERT TABLE 1 HERE

Awareness of student understanding

While one might expect pre/post surveys to indicate that students have a limited amount of knowledge before the course and a large improvement of knowledge after the course, this is not often the case [37]. In our samples, the majority of the students' pretest scores were equal to or above 50% correct, with 50% representing "guessing" on a true/false test. On the R1 pretest, 76.6% (n = 458) of students had scores statistically above guessing. On the post-test, 82.3% (n = 419) performed statistically better than guessing. For the PUI, 116 out of 137 students scored greater than 50% correct after taking the prerequisite courses, and 22 out of 23 students did so after taking biochemistry. The faculty members addressed these data with diagnosing statements such as *"either they knew a lot [to begin with], or they didn't learn a lot"*. Early students' reasoning skills were noted: "*I'm impressed that the 100- level [general chemistry] students are able to make pretty well-educated guesses."*

Several questions on the survey, however, showed a decrease in percentage of correct answers from pre- to post-test, confronting faculty with persistent student misconceptions: *"They are holding onto some conceptions. I think…that makes me wonder if they are coming in with some conceptions that the course is just playing into as opposed to challenging them with new material."* Specifically, the misconception that breaking a bond does not require energy came up: *"Maybe they are not thinking about it in terms of breaking bonds but in terms of the step as a whole [which] is favorable. There is a problem. They are sophisticated in looking at the problem one way but they are missing some other fundamental things."* While this misconception is widely known [38], its prevalence was introduced to this particular faculty member through the pre/post-test and interview process.

In discussing questions that targeted prerequisite material, faculty expressed the challenge of teaching content they expected students to have mastered by the time they entered their classroom: *"When I first taught the course, I did not expect that I would spend so much time on pH... personally, I believe this is material students should have learned in high school...let's do it to refresh our memories and for the sake of the discussions we will have later on...but not spending so much time into this."* This disconnection between faculty expectations and students' abilities may arise when faculty make unsupported assumptions of students' prerequisite knowledge, or the students' ability to apply known concepts to new contexts. Employing a pre/post survey that measures current students' knowledge of core concepts may calibrate faculty expectations. The pre-survey can give faculty rich information on what students know in the learning trajectory and focus concepts for review accordingly.

Often, faculty members' comments came with reflection on the context of the biochemistry sequence: *"I'm captivated by the ones that go down…it makes you wonder how did they psyche themselves out? [They] did worse on this than [they] would have two years ago."* In this excerpt, the faculty member is referring to items where general chemistry students performed better than biochemistry students. Students may have talked themselves out of correct answers, and used previous knowledge to deduce answers – right or wrong. To work together, faculty need first to get a grasp of the students' knowledge and reasoning skills. The second step would be to reflect on this new information, to review their own pedagogy, and determine what is actionable for successful education.

Self-reflective Practice

Self-reflection is a significant aspect to improving teaching. Faculty questioned their effectiveness in the classroom in response to items where students performed poorly: "*I believe* *we did a good job, or I don't know if I did a good job, but I spent quite some time on [intracellular conditions] we had many examples in the class".* Here, the faculty recognized that although a topic was covered in detail, students may still struggle to internalize and apply the concept. Faculty also questioned whether they challenged the assumptions students bring to the classroom: "*OK, I'll have to think about it, but again mostly what we are seeing are uptrends which is good. It makes me wonder if the class is operating on too much sort of standard information…".* Faculty also considered how their assessment choices emphasize skills and knowledge: "*It worries me that we are teaching an algebra problem [regarding acid/base], not a concept one… And like we're are not testing the right thing. ...I'd really like to rethink how we teach this because it's not sticking with them. They are not developing an intuition at all about what acids and bases are. They just figure out how to set up the set up the tables and a number pops out…".* Because students' experiences with assessment shape the way they approach learning [39], faculty reflecting on the role of assessment practices is crucial in deciding what to emphasize in their courses.

Particularly interesting are the impromptu and specific interventions faculty propose in response to the survey results: "*Maybe we need to tell students more about homoeothermic behavior... I point out that concentrations are realistic, but I don't say what realistic is. Maybe we should set aside time to discuss info on cell conditions at the outset of the course. I really hammer on pH, but it never occurred to me to say what "realistic" concentrations are [in the cell]."* Individual content knowledge of faculty can bring richness to the analysis of the curriculum. The interdisciplinary nature of biochemistry is often challenging; a potential solution is to draw from the expertise of faculty members who specialize in the various subdisciplines included in biochemistry.

Some of the interventions were beyond content and drew upon pedagogical strategy: *"I should do more having students explaining things in different ways like equations, words, pictures, stories... I do that in [general chemistry I] but should do more [in upper level]"* This type of reflection is particularly powerful because faculty are creating their own actionable curricular and pedagogical changes as a result of data on student thinking. Academic autonomy is often a strong value for those in higher education, so implementing changes from a top-down approach is likely to meet resistance [40]. Here, faculty make their own change for themselves and, through conversation, potential routes of change for their colleagues.

Interacting with colleagues

During interviews, we asked the biochemists if the results of the survey would influence how they interact with other faculty who teach biochemistry as well as those who teach earlier courses in the curriculum. Three of the four hesitated for a moment, possibly indicating that they were faced with a strategy that had not crossed their minds. Because of the tension between the solitary nature of higher education and the competing notion of working collaboratively, we were not surprised to observe this hesitation [41, 42]. Their replies, though, were in favor of opening the doors for collaboration. One faculty member suggested explicit content overlap in prerequisite courses for the sake of a solid foundation *"Well, I tend to get lecture-y [sic] with faculty that teach earlier courses like trying to keep them from promoting the idea that enzymes lower activation energy for example. I can really go off on that… I know the Bio I class has a large chemical component… I know those faculty members…I'm actually very good friends with them. It might be worthwhile talking to them and saying 'Look, if you want to bring up cell in biology because it is a cellular process, [you have] a large chemistry component, you might want to establish those differences.' … It might be worth talking to them, hearing them out."*

While this faculty member mentioned friendship with their colleagues, they discuss their conversations relating to teaching as “lecture-y”, which we interpret to be one-way rather than reciprocal. This is in line with prior literature that states these conversations are hard to develop, even amongst friends [24]. Another faculty member suggested partitioning material in upper level courses to achieve both depth and breadth of the current material *“I believe we should sit down with our colleagues [in Biology] and say ‘Look, we have a huge overlap in our courses, you take over the metabolism, you take over the molecular basis of cellular function, and then we can go in depth into that and you can go into depth into the metabolism.’ Right now, we have an overlap and we all struggle to finish the material.”* Both faculty members seem eager to work with other faculty and departments to determine a common goal to benefit student learning; however, their replies are merely of potential interactions that may or may not be realized. While intention is a good start, there is no indication from these interviews of a consistent collaborative effort or ongoing discussion regarding teaching practices and experiences.

Emotional Responses

Emotional responses permeated the interviews with faculty, just as emotions permeate the work of teaching. This is evident in several of the previous statements highlighted in the other sections, with statements such as: *“I’m impressed”, “I’m captivated”, and “It worries me”.* The following comments also overlap with the other themes of this paper, but emotion is at the forefront. Becoming aware of student decreased understanding, one faculty member had this emotional response: *“I wouldn’t be reacting to this so much if it was a flat line, like they didn’t get it, well…they didn’t get it, but the fact that it made it worse…”* Reviewing a set of scores that had very little change, another faculty member was similarly frustrated: *“Honestly, when I saw the data I was quite disappointed because I see literally no difference. To me it seemed that* *whether I [taught] the course or not, didn't make any impact on them."* These excerpts highlight the negative emotions faculty can feel when students perform worse than expected and when student performance does not improve with pre/post testing [37].

Why were faculty so disappointed when they saw the results of the survey? After all, over 82% of the R1 and over 97% of the PUI students did better than chance would predict (greater than 50% correct) on the post surveys. What is a reasonable expectation? The well-known "overconfidence bias" leads most people, including both faculty and students, to overestimate their performance [43, 44]. In the case of faculty, overconfidence about their teaching leads in erroneous conclusions about student learning. Kearney and Sheffer further note that faculty members' false confidence about their own teaching may prevent any change in their practice [44].

While this may be true, the faculty members in the interviews did suggest practical changes: *"[The survey results] give me information that I didn't have. And I like that! It does give me some ideas about my earlier lectures…"* This excerpt encompasses much of what we intended to accomplish with this project: to further faculty understanding of student knowledge so they are empowered to take action.

From these interviews, it is apparent that faculty members in higher education can indeed be emotional when responding to the uncovering of student difficulties in their courses. Therefore, acknowledging and expecting emotions when undertaking these difficult conversations may help in producing the wanted productive discourse among faculty.

Summary/Conclusions

Our goal in presenting the results of student surveys on particular topics in biochemistry to faculty was to determine if this process would lead the faculty to a deeper understanding of the problems that the students encounter. A limitation in this study is the small number of biochemistry faculty interviewed, so the characterization of faculty thinking may not be exhaustive, but the conversations yielded by the methods were fruitful in what we set out to accomplish. By reflecting on the data, even experienced faculty members were able to recognize surprising gaps in student proficiency and to think about ways that these gaps could be addressed in their own courses. While literature is a powerful resource, utilizing student data from the courses faculty teach is personal and helpful in support of self-reflection.

We have previously reported that faculty recognition of student difficulties is directly related to the type of assessment they carry out. Faculty who test mainly quantitative material indicate that their students have difficulty mostly with quantitative material, whereas those who test mainly conceptual material indicate that students have problems mainly with concepts, not math [45]. This observation is further indication that appropriate assessment is needed in order to determine students' mastery and teaching effectiveness. However, none of these methods is likely to lead to improvement unless the knowledge gained by faculty about their students' grasp of material is accompanied by motivation to change [46]. Our direct conversations relating students' responses did lead to a more holistic understanding of the students' challenges, such that several faculty stated change was needed in biochemistry or the prerequisite courses. Some of the misunderstandings that students bring to biochemistry courses can be addressed by direct instruction in biochemistry and biology courses [13, 47]. Whereas others, which are more deeply-held, will likely require changes in pedagogy throughout the chemistry and biology curricula and collaboration among faculty as students transition from one level to another. We believe intentional teacher teams are a potential avenue for positive change [26]. One way to begin to form these teams is through direct conversations among faculty, supported by data from their own students.

During our direct conversations showing the student results of the survey, faculty were quick to acknowledge the flaws in student knowledge and surmise flaws in students' reasoning. They became aware of problems they might not have known about through other, more standard, assessment procedures. We see that this new awareness leads faculty to reflect on their own pedagogy. Quotations from faculty that begin *"I think…", "I can see why…", "Maybe we need to…", "This makes me think…"* indicate that the self-reflection process is initiated when becoming aware of student scores. Self-reflection in turn leads to emotional responses such as *"I like that", "That's more encouraging"*, and *"Yeah, that's strange."* Faculty, now curious about their students' difficulties, evolve new and deeper insights and begin to understand what is critical to creating successful progressions and eliminating misconceptions. However, the relationship between teaching strategies and student learning is tenuous, so that simple awareness of student difficulties is just a first step in addressing the misunderstandings revealed in pre/post testing [48].

The approach of interviewing faculty members about their students' performance is not a typical one in providing feedback to faculty. Berk includes student interviews, peer ratings, and self-evaluation as evidence of teaching effectiveness, but interestingly does not combine these to suggest pathways to change and improvement [2]. Pre- and post-testing is the most common quantitative means of assessing student understanding, particularly of core concepts, but is usually used by individual faculty members in their own classrooms rather than as a window into collaboration [49]. Other means of gaining insight into one's own teaching effectiveness exist including extended conversations with students, reciprocal peer learning, and informal discussion among faculty [14, 50-52]. Some of these are time-intensive and, hence, are unlikely to be employed by individual faculty members. Our method of pre- and post-testing followed up by direct conversations about the data with faculty members is more robust than informal discussions and relatively low-cost in terms of faculties' time and yielded valuable insights, even in this pilot study. Truly, any faculty member should be able to employ these simple methods to their teaching environment to help facilitate departmental and interdepartmental conversations around teaching.

Acknowledgements

The authors thank Charlotte Reed for her contributions to this project. We are grateful to the faculty members who allowed us to survey their students and who took time to be interviewed in depth and with great seriousness.

This work was supported by an award from the National Science Foundation #1503980 to AJW and #1504055 to JEL. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

1. S. Singer, K.A. Smith (2013) Discipline-based education research: Understanding and improving learning in undergraduate science and engineering. Journal of Engineering Education. 102(4), 468-471.
2. R. A. Berk (2005) Survey of 12 strategies to measure teaching effectiveness. International journal of teaching and learning in higher education. 17(1), 48-62.
3. M. L. Smith, P. Fey (2000) Validity and accountability in high-stakes testing. Journal of Teacher Education. 51(5), 334-344.
4. P. H. Hinchey (2010) Getting teacher assessment right: What policymakers can learn from research. National Education Policy Center.
5. P. Hutchings (2010) Opening doors to faculty involvement in assessment. NILOA Occasional Paper. 4.
6. M. A. Miller (2012) From denial to acceptance: The stages of assessment. NILOA Occasional Paper. 13.

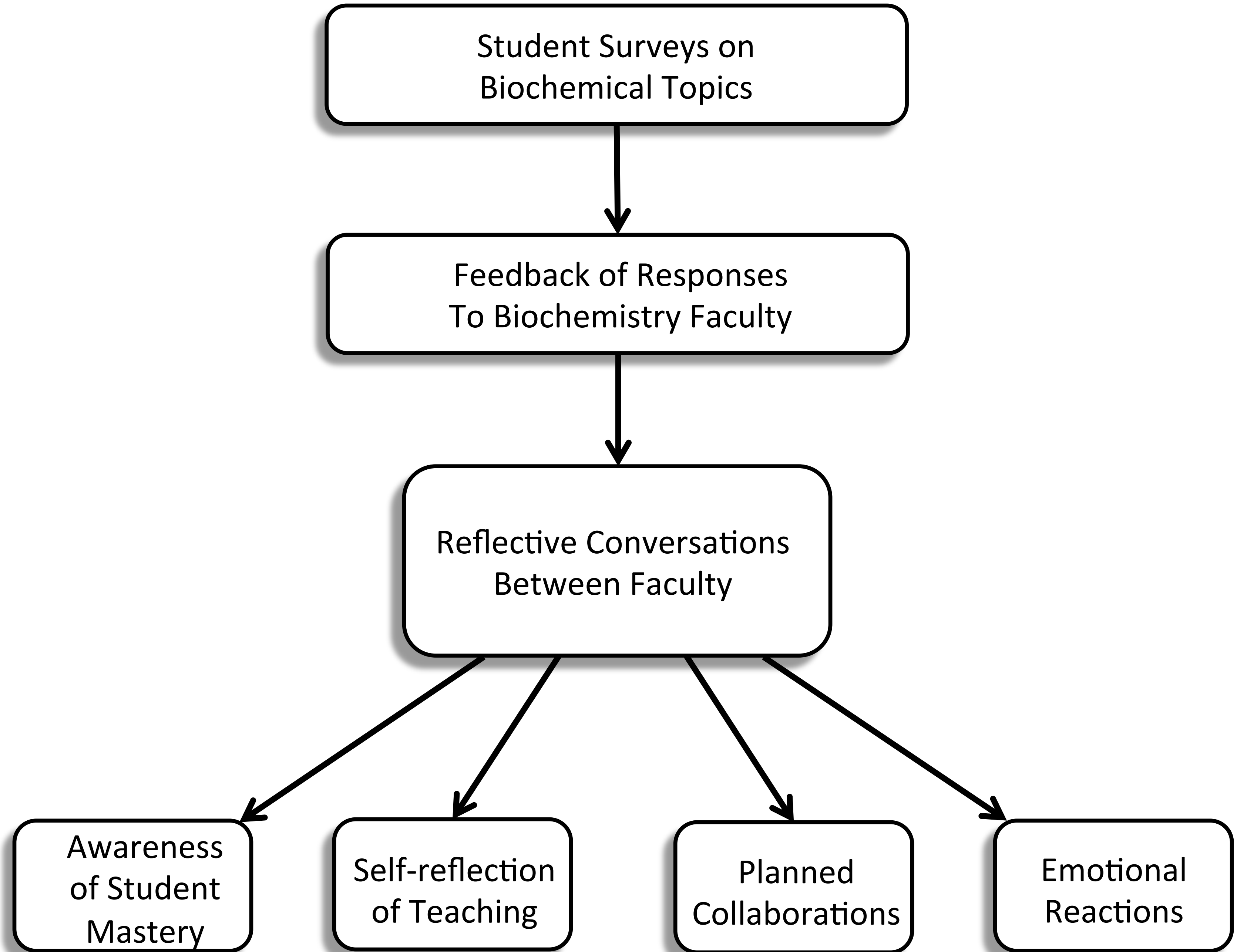
7. J. T. Tansey, T. Baird, M. M. Cox, K. M. Fox, J. Knight, D. Sears, E. Bell (2013) Foundational concepts and underlying theories for majors in “biochemistry and molecular biology”. Biochemistry and Molecular Biology Education. 41(5), 289-296.
8. J. Loertscher, D. Green, J. E. Lewis, S. Lin, V. Minderhout (2014) Identification of Threshold Concepts for Biochemistry. CBE-Life Sciences Education. 13(3), 516-528.
9. A. Wright, J. Provost, J. A. Roecklein-Canfield, E. Bell (2013) Essential concepts and underlying theories from physics, chemistry, and mathematics for “biochemistry and molecular biology” majors. Biochemistry and Molecular Biology Education. 41(5), 302-308.
10. D. Hestenes, M. Wells, G. Swackhamer (1992) Force concept inventory. The Physics Teacher.30(3),141-158.
11. D. R. Mulford, W.R. Robinson, (2002) An inventory for alternate conceptions among first-semester general chemistry students. J. Chem. Educ. 79(6), 739.
12. M. W. Klymkowsky, K. Garvin-Doxas, (2008) Recognizing student misconceptions through Ed's Tools and the Biology Concept Inventory. PLoS Biology. 6(1), e3.
13. A. J. Wolfson, S. L. Rowland, G. A. Lawrie, A. H. Wright (2014) Student conceptions about energy transformations: progression from general chemistry to biochemistry. Chemistry Education Research and Practice. 15(2), 168-183.
14. L. A. Braskamp, J.C. Ory (1994) Assessing Faculty Work: Enhancing Individual and Institutional Performance. Jossey-Bass Higher and Adult Education Series. ERIC.
15. A. C. Banerjee (1995) Teaching chemical equilibrium and thermodynamics in undergraduate general chemistry classes. J. Chem. Educ. 72(10), 879.
16. J. S. Piquette, H.W. Heikkinen (2005) Strategies reported used by instructors to address student alternate conceptions in chemical equilibrium. Journal of Research in Science Teaching. 42(10), 1112-1134.
17. M. M. Cooper, M.W. Klymkowsky (2013) The trouble with chemical energy: why understanding bond energies requires an interdisciplinary systems approach. CBE-Life Sciences Education. 12(2), 306-312.
18. T. Eberlein, J. Kampmeier, V. Minderhout, R. S. Moog, T. Platt, P. Varma-Nelson, H. B. White (2008) Pedagogies of engagement in science. Biochemistry and molecular biology education. 36(4), 262-273.
19. R. Duit, D.F. Treagust (2003) Conceptual change: A powerful framework for improving science teaching and learning. International journal of science education. 25(6), 671-688.
20. D. W. Sunal, J. Hodges, C. S. Sunal, K. W. Whitaker, L. M. Freeman, L. Edwards, R. A. Johnston, M. Odell (2001) Teaching science in higher education: Faculty personal development and barriers to change. School Science and Mathematics. 101(5), 246-257.
21. S. J. Bohen, J. Stiles (1998) Experimenting with models of faculty collaboration: Factors that promote their success. New Directions for Institutional Research. 1998(100), 39-55.
22. J. Lester (2009) Organizing higher education for collaboration: A guide for campus leaders. John Wiley & Sons.
23. National Acadamies (2005) Facilitating Interdisciplinary Research. National Acadamies Press.
24. M. D. Cox (2004) Introduction to faculty learning communities. New Directions for Teaching and Learning. 2004(97), 5-23.

25. S. Van Waes, P. Van den Bossche, N. M. Moolenaar, A. Stes, P. Van Petegem (2015) Uncovering changes in university teachers' professional networks during an instructional development program. Studies in Educational Evaluation. 46, 11-28.
26. Koeslag-Kreunen, M.G., et al., Leadership for team learning: the case of university teacher teams. Higher Education, 2017: p. 1-17.
27. L. Hill, S. La Kim, R. Lagueux (2007) Faculty collaboration as faculty development. Peer Review. 9(4), 17.
28. D. Heiland (2014) Collaboration, in The LEAP Challange Blog. Association of American Colleges and Universities.
29. R. E. Sutton, K.F. Wheatley (2003) Teachers' emotions and teaching: A review of the literature and directions for future research. Educational Psychology Review. 15(4), 327-358.
30. A. Neumann (2006) Professing passion: Emotion in the scholarship of professors at research universities. American Educational Research Journal. 43(3), 381-424.
31. A. Badia Garganté, J. Meneses, C. Monereo (2014) Affective dimension of university professors about their teaching: an exploration through the semantic differential technique. Universitas Psychologica. 13(1), 161-173.
32. K. Vloet, J. Van Swet (2010) 'I can only learn in dialogue!'Exploring professional identities in teacher education. Professional Development in Education. 36(1-2), 149-168.
33. A. Darby (2008) Teachers' emotions in the reconstruction of professional self-understanding. Teaching and Teacher Education. 24(5), 1160-1172.
34. T. Wright, S. Hamilton (2008) Assessing student understanding in the molecular life sciences using a concept inventory. ATN Assessment. 1(1).
35. T. Wright, S. Hamilton, W. Laffan, M. Rafter, S. Clark, S. Howitt, T. Anderson, M. J. Costa (2011) Diagnostic assessment for the biological sciences: Development of a concept inventory: Final Report 2011. Australian Learning and Teaching Council.
36. M. Schreier (2014) The SAGE Handbook of Qualitatitve Data Analysis, SAGE Publications Ltd., London, pp. 170-183.
37. R. R. Hake (1998) Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American journal of Physics. 66(1), 64-74.
38. W. C. Galley (2004) Exothermic bond breaking: A persistent misconception. J. Chem. Ed. 81(4), 523.
39. K. Struyven, F. Dochy, S. Janssens (2003) Optimising New Modes of Assessment: In Search of Quality and Standards. Springer, Netherlands, pp. 171-223.
40. A. Kezar (2012) Bottom-up/top-down leadership: Contradiction or hidden phenomenon. The Journal of Higher Education. 83(5), 752-760.
41. V. L. H. Bevilacqua, J. L. Powers, D. L. Vogelien, R. J. Rascati, M. Hall, K. Diehl, C. Tran, S. S. Jain, R. Chabatya (2002) Collaboration between chemistry and biology to introduce spectroscopy, electrophoresis, and molecular biology as tools for biochemistry. J. Chem. Educ. 79(11), 1311.
42. J. Clevenger (1997) Collaboration: Why participate in an unnatural act? ACS Publications.
43. D. Dunning, C. Heath, J.M. Suls (2004) Flawed self-assessment implications for health, education, and the workplace. Psychological science in the public interest. 5(3), 69-106.

44. E. M. Kearney, S. M. Sheffer (2015) The overconfident professor: I know I taught you better than that, in Tomorrow's Professor Postings. Stanford.
45. A. M. Mercer, J.E. Lewis, A. J. Wolfson (2016) Learning progressions for biochemistry: Faculty perceptions. in Biennial Conference on Chemical Education. Greeley CO.
46. J. A. Centra (1993)Reflective Faculty Evaluation: Enhancing Teaching and Determining Faculty Effectiveness. The Jossey-Bass Higher and Adult Education Series. ERIC.
47. G. M. Nazario, P.A. Burrowes, J. Rodriguez (2002) Persisting misconceptions. Journal of College Science Teaching. 31(5), 292.
48. J. C. Libarkin, S. W. Anderson (2005) Assessment of learning in entry-level geoscience courses: Results from the Geoscience Concept Inventory. Journal of Geoscience Education. 53(4), 394-401.
49. M. D. Sundberg (2002) Assessing student learning. Cell Biology Education. 1(1), 11-15.
50. K. S. Taber, T.A. Student (2003) How was it for you?: The dialogue between researcher and colearner. Westminster Studies in Education. 26(1), 33-44.
51. D. Boud (1999) Situating academic development in professional work: Using peer learning. The International Journal for Academic Development. 4(1), 3-10.
52. K. E. Thomson, K.R. Trigwell (2016) The role of informal conversations in developing university teaching? Studies in Higher Education. 1-12.

Table 1
Faculty responses to student performance

Category	Representative responses
Awareness of student understanding	"*I'm impressed that the 100- level [general chemistry] students are able to make pretty well-educated guesses." "They are holding onto some conceptions. I think…that makes me wonder if they are coming in with some conceptions that the course is just playing into as opposed to challenging them with new material." "..personally, I believe this is material students should have learned in high school.."*
Self-reflective practice	"*It worries me that we are teaching an algebra problem [regarding acid/base], not a concept one…" "I should do more having students explaining things in different ways like equations, words, pictures, stories..."*
Interaction with colleagues	*"I believe we should sit down with our colleagues [in Biology] and say 'Look, we have a huge overlap in our courses, you take over the metabolism, you take over the molecular basis of cellular function, and then we can go in depth into that and you can go into depth into the metabolism.' Right now, we have an overlap and we all struggle to finish the material."*
Emotional responses	"*… Honestly, when I saw the data I was quite disappointed because I see literally no difference. To me it seemed that whether I [taught] the course or not, didn't make any impact on them." "[The survey results] give me information that I didn't have. And I like that! It does give me some ideas about my earlier lectures…"*


Student Surveys on Biochemical Topics
Feedback of Responses To Biochemistry Faculty
Reflective Conversations Between Faculty
Awareness of Student Mastery
Self-reflection of Teaching
Planned Collaborations
Emotional Reactions