An Inclusive, Dynamic and Collaborative Framework for Improving Curriculum Review in a Post-Secondary Program

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Abstract:

This article describes a novel curriculum review framework that has been effective in alleviating many of the challenges facing curriculum review processes. The dynamic and formative framework is based on three core ideas:
(1) including all the stakeholders,
(2) conducting the review in real-time, and
(3) building respect and trust within and throughout the process.

Reflecting on the outcomes of this curriculum review process, the authors provide key recommendations for effective future practices that could help other postsecondary programs implement this framework within their own contexts.

Key Words:

Curriculum review; higher education; curriculum mapping; wisdom of practice; continuous improvement; dynamic curriculum review; collaborative curriculum review.

Curriculum review in higher education

"Curriculum" or "curricula" can be described as the learning that is developed and implemented for a given program. This includes content (i.e. what is taught) and pedagogical approaches (i.e. how it is taught). It is the responsibility of higher educational institutions to design, continuously review and redevelop up-to-date curricula to ensure academic programs are relevant to a constantly changing world. The term "curriculum review", as used in this article, is an umbrella term that describes the combination of two distinct processes: (1) a curriculum analysis and evaluation of the courses and (2) a subsequent curriculum renewal. A curriculum analysis and evaluation process studies the past syllabi and pedagogy of existing courses and informs the curriculum renewal process. The curriculum renewal process involves the redevelopment of one or more existing courses or the design of new courses to serve the academic program.

Overall, examination of curriculum review in higher education is limited (Oliver, Ferns, Whelan, & Lilly, 2010). Yet, increased attention has been paid to curriculum review processes at several postsecondary institutions over the last decade – often for accountability and accreditation purposes, e.g.; (Oliver et al., 2010; Perlin, 2011; Veltri, Webb, Matveev, & Zapatero, 2011; Willett, 2008). These studies have drawn attention to the complexity of issues associated with curriculum review (Arafeh, 2016; Sumsion & Goodfellow, 2004; Wang, 2015; Wolf, 2007). The complexity of the curriculum review process can result in challenges such as reluctance of faculty to conduct the evaluation, resistance to change, and lack of familiarity with the process (Davenport, Spath, & Blauvelt, 2009; Desha & Hargroves, 2014).

In attempting to address these challenges, a variety of curriculum review models have emerged since 2001, each with laudatory features. An early framework (Hull, St Romain, Alexander, Schaff, & Jones, 2001) focused on lessening faculty anxiety. Sperhac and Goodwin (2003) and Jacobs and Koehn (2004) advocated for gathering data from multiple data sources and stakeholders to allow for a deeper understanding of the curriculum. For instance, the framework that Jacobs and Koehn (2004) implemented in a community-based nursing baccalaureate curriculum acknowledged data collected from multiple stakeholders involved in student learning and resulted in further curriculum revision, increased community partnerships, and more positive feedback from students. Even later, Davenport and colleagues (2009) designed a structured curriculum review process with a well-defined timeline that facilitated the engagement of all involved faculty in the review process. More recently, Desha and Hargroves (2014) have advocated for a dynamic curriculum review strategy that raises awareness of the whole process, builds a capacity for participation, encourages collaboration both internally (from the department or the program) and externally (e.g., curriculum developers), and supports on-going monitoring and evaluation to inform continual improvement of the undertaken procedures and program offering. Finally, Dyjur and Lock (2016a) have reported on a curriculum review process structured to enhance the instructors' continuing growth and their ability to carry out a curriculum review. In that paper they identified four key recommendations for curriculum review practices to promote a professional learning environment: (1) mentoring and distributed leadership, (2) standardizing flexible structures and processes, (3) customizing the process for deep inquiry, and (4) developing collaboration.

We draw upon these frameworks by pulling out several ideas into a coherent curriculum review process. Specifically, this article provides a novel framework for dynamic continuous curriculum review of postsecondary programs that involves gathering formative feedback on student learning throughout the program and on the effectiveness of the curriculum review process itself, collecting data from all stakeholders, encouraging collaboration, and considering participants as partners. The curriculum review process is inclusive and contemplates the wisdom of practice by bringing in the disciplinary knowledge and practice of all involved in the review. The phrase “wisdom of practice”, as we use it in this context, refers to disciplinary experience that mainly derives how teachers and learners function in classrooms (Weimer, 2001).

Context and phases of the curriculum review

The Nanoscience program is an undergraduate minor program at the Faculty of Science of a research-intensive university in an urban western North American city. The learning model adopted in the program is an authentic science self-guided inquiry model referred to as “learning-science-by-doing-science” (LSDS) (Labouta et al., 2018).The minor consists of five courses, however the learning philosophy of the program (LSDS) is reflected in three core courses: NANS 301 (acquiring fundamental understanding of key concepts in nanoscience), NANS 401 (building testable hypotheses) and NANS 502 (executing self-directed nanoscience research projects). These core-courses became the main focus of this curriculum review process.

In 2015, the director of the Nanoscience program launched a curriculum review and renewal initiative for the program that was developed 2 years earlier. The goals of the review were to articulate and evaluate the LDSD learning model of the program, to define the attributes of the program’s alumni, and to compare the leadership’s vision for the program to what was enacted by the instructors and teaching assistants, as well as to what was perceived by students. The ultimate objective of this process was to better understand student learning in the program, enhance its strengths and address any challenges, in order to improve the overall student learning experience.

At the beginning of the curriculum review the program director hired an independent researcher who collaborated with a curriculum development specialist and educational developers. They met regularly to design the review process, to develop questionnaires and protocols for interviews and focus groups, and to discuss the results and action plans.

The curriculum review process was divided into four main phases summarized in Table 1. Phase 1 involved articulating the vision for the program and its intended outcomes. In this phase information was obtained from the program director, instructors and teaching assistants through unstructured interviews and focus groups. In phase 2 students and participating alumni, instructors and teaching assistants, and the program director completed questionnaires about the program. Then curriculum mapping was used as a tool to align the perceptions of learning gains across the different stakeholders in this program. Curriculum mapping involves associating course outcomes with program-level learning outcomes and aligning elements of courses (e.g. teaching and learning activities, assessment strategies) within a program, to ensure that the program is structured in a strategic, thoughtful way that enhances student learning (Dyjur & Kalu, 2016; Harden, 2001). Phase 3 also engaged students and representative alumni, instructors and teaching assistants, and the program director in focus groups and interviews, to make sense of the information from phase 2. Phase 4 of the curriculum review is sometimes described as 'closing the loop'. The purpose of this phase is to define and implement action plans for continuous improvement (Banta & Blaich, 2010; Kalu & Dyjur, 2018; Kaupp & Frank, 2015; Veltri et al., 2011). An action plan that clearly articulates what faculty and staff should do in the next period in terms of curriculum renewal and improvement also helps the team take greater responsibility toward improving student learning (Kalu & Dyjur, 2018). One technique we adopted for closing the loop was to hold meetings with the program director and the teaching staff to further discuss issues regarding the curriculum structure of core courses. The implementations of the recommendations made by the Nanoscience program staff to address the students' needs are being tracked to measure improvement.

Table 1: Summary of the four phases of the curriculum review of the Nanoscience program.

<table>
<tr><th>Phase</th><th>Goals</th><th>Data collection methods</th><th>Participants</th></tr>
<tr><td rowspan="2">Program visioning and defining the program outcomes</td><td>• Defining the main attributes of the LSDS model (Program outcomes).</td><td>Unstructured interviews and focus group</td><td>Program director, instructors, and teaching assistants</td></tr>
<tr><td colspan="3">Collected data were used to create the program-level learning outcomes which went through a process of refinement based on further feedback from the whole staff until approved by everyone.</td></tr>
<tr><td>Curriculum mapping and program evaluation</td><td>• Determining the degree of alignment between intended, enacted and perceived learning outcomes</td><td>Questionnaires</td><td rowspan="2">Program director, instructors, teaching assistants, students and alumni</td></tr>
<tr><td>Collaborative analysis and sense making</td><td>• Triangulation to seek complementary information and explanations of the data from the questionnaires (Bergman, 2008; Erzberger & Kelle, 2003).
• Identifying action-oriented and research-based future plans for further improvement of student learning.</td><td>Focus groups and interviews</td></tr>
<tr><td>Closing the loop: continuous improvement</td><td>• Continuous improvement based on clearly defined action plans</td><td>Regular meetings</td><td>Program director, instructors, and teaching assistants</td></tr>
</table>

Figure 1 below captures the reiterated nature of the curriculum review process that leads to continuous improvement.

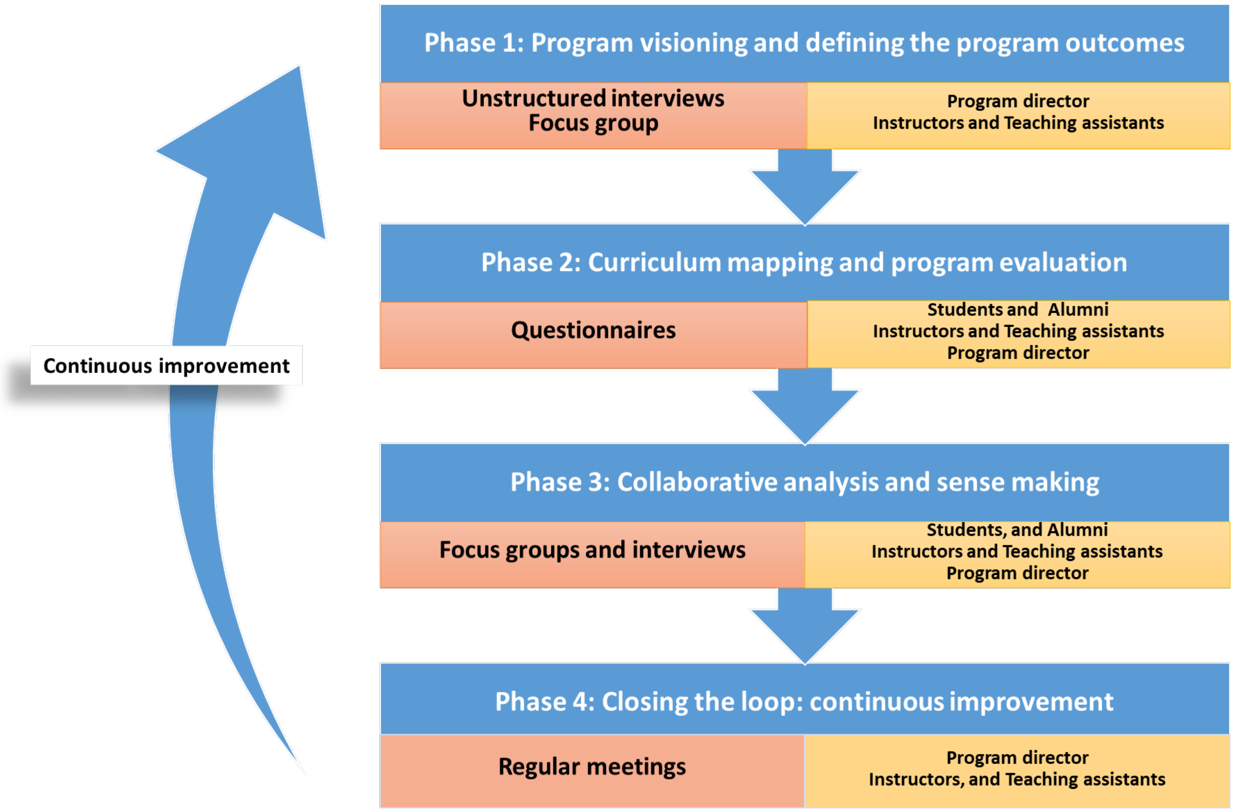

Figure 1: A visual emphasizing the process of the presented framework of the curriculum review.

Impact of the Curriculum Review

There are several ways in which the reflective approach we adopted will impact the design and redevelopment of our program. For example, using a heat map to capture the feedback provided by the director, the instructors, the teaching assistants, the students and the alumni offered a way to visually compare and contrast how closely the learning outcomes intended by the director were enacted by the teaching staff and perceived as achieved by the students. The heat map is presented in Table 2. Analysis of visual artifacts such as these revealed the current gaps in the program and has facilitated discussion with and feedback from the faculty, teaching assistants, students and alumni of the program. A thorough analysis of the heat map and the degree of alignment of intended, enacted and perceived learning outcomes will be the focus of another manuscript in preparation.

Learning outcome	NANS 301				NANS 401				NANS 502				Program	
	S	TA	I	D	S	TA	I	D	S	TA	I	D	A	D
Interdisciplinary skills	2	3	2	2	3	3	3	3	3	3	3	3	3	3
Experiential skills	1	2	1	1	3	2	3	2	2	3	3	3	3	3
Research skills	2	1	3	2	2	1	2	2	2	3	3	3	3	3
Problem-solving skills	2	3	3	3	3	3	3	3	3	3	3	3	3	3
Collaboration skills	2	3	3	2	2	3	3	2	3	3	3	3	3	3
Communication skills - written format	2	3	3	1	3	2	3	2	2	2	3	3	2	3
Communication skills - oral format	1	NA	1	1	3	1	2	2	3	3	3	3	3	3
Communication skills (average)	1.5	3	2	1	3	1.5	2.5	2	2.5	2.5	3	3	2.5	3
Creativity (average)	2.3	2.3	2.0	1.8	2.3	1.3	2.3	1.8	1.5	2.5	3.0	2.5	2.8	2.5
Curiosity	3	3	3	2	3	2	2	2	2	3	3	3	3	3
Deep thinking (average)	2.2	2.6	2.8	1.2	2.2	2	2.6	2	2	3	3	3	3	3
The phenomenon of self assembly	3	3	3	2	3	3	2	2	3	2	NA	2	3	2
Quantum confinement theory	3	3	3	2	3	1	0	2	3	2	NA	2	3	2
Knowledge (average)	3	3	3	2	3	2	1	2	3	2	NA	2	3	2
Electron microscopy	3	3	1	1	3	3	3	3	2	3	3	3	3	3
Atomic force microscopy	2	3	0	0	3	2	3	2	3	2	3	3	3	3
Thin film characterization	2	NA	2	0	2	NA	2	2	2	2	NA	2	3	2
Nanoparticle sizing and charge density measurements	1	3	0	1	2	2	3	2	3	3	3	3	3	3
Optical techniques	2	3	2	1	2	2	3	2	3	3	3	3	3	3
Technical skills (averaged parameters)	2.0	3.0	1.0	0.6	2.4	2.3	2.8	2.2	2.6	2.6	3.0	2.8	3.0	2.8

To a great extent	3
To a moderate extent	2
To a small extent	1
Not at all	0

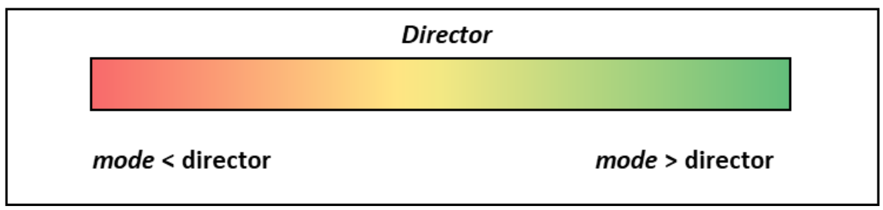

Table 2: An artifact of the curriculum review process

This table shows alignment of intended (by the director, denoted as “D”), enacted (by the instructors “I” and teaching assistants “TA”) and perceived learning outcomes (by the students “S” and program alumni “A”) for the Nanoscience courses (NAS 301, 401 and 502). Alignment is based on comparison of the modes developed from quantitative questionnaire data and is presented as a heat map relative to the perceptions of the director (yellow). “NA” indicates no mode due to different opinions by the respondents.

Insights from students and alumni in the curriculum review process have led to other discussions and improvements. Most of the students of the entry course of the program (NANS 301), for example, called for more prerequisites that are outside their disciplinary knowledge to better excel in the interdisciplinary science learning environment within the Nanoscience program. Following up on that, the Nanoscience program staff agreed to discuss this further in future staff meetings. The lead curriculum reviewer will be attending some of these meetings as well as meeting regularly with the program director to understand the selection of new pre-requisite courses for enrolment in the Nanoscience program. In another instance, students suggested offering more laboratory time in the courses (NANS 301 or NANS 401) preceding the capstone course (NANS 502) in which they are assigned a self-guided research project. In response to the students' needs, NANS 401 instructors, teaching assistants, and the lead curriculum reviewer worked to add a laboratory component to one of those courses. This included designing hands-on, inquiry-based activities in the context of the theoretical topics that are covered in the course.

These examples illustrate how the program was redeveloped as a result of analyzing the curriculum review data. The process helped instructors and administrators to leverage existing strengths and address gaps in the program, enhancing the overall student learning experience (University of Calgary, 2015). The curriculum maps not only pointed out trends and patterns in the curriculum, but offered an evidence-based way for instructors to reflect on and discuss issues such as redundancy and gaps in the program, with the overall goal of enhancing student learning (Dyjur & Lock, 2016b; Plaza, Draugalis, Slack, Skrepnek, & Sauer, 2007; Veltri et al., 2011).

Key Features of Our Approach and Their Benefits

In this section we discuss features in our curriculum review process and the benefits they provided.

1. Including multiple perspectives in multiple ways and bringing in wisdom of practice

As we noted earlier, our curriculum review process had broad involvement of various stakeholders and external partners. It also gives voice to the "wisdom of practice".

The phrase "wisdom of practice" refers to the knowledge and expertise practitioners in the field can bring to their work, thus providing nuanced understanding that can be missing from a purely theoretical approach (Weimer, 2001). First of all, integral to this project's success was to have the lead researcher, a nanoscientist, be well-immersed in the program under review, and thus have the same disciplinary knowledge and practice of the program. Sharing the same language helped in getting more accurate results, especially when the participants' responses included terms, topics and activities of significance in the nanoscience field. However, it could be argued that personal involvement in the research setting could be regarded as a loss of objectivity when sharing the study results (Yamagata-Lynch, 2003). Therefore, immersion in the educational setting under investigation was balanced by ensuring the lead researcher was not teaching in any of the courses from which the data were collected. Participation of the program director, instructors and teaching assistants in the curriculum review process ensured their wisdom of practice was actively incorporated throughout the process.

Parallel to bringing in the wisdom of practice and integral to his role in the curriculum review process itself, the lead researcher engaged in several pedagogical workshops on topics such as course design, curriculum review, and the development of a Scholarship of Teaching and Learning (SoTL) project. These professional learning sessions were essential to ensure the curriculum review research lead was prepared to conduct the review and to examine all of the qualitative and quantitative data generated throughout the process. Additionally, the educational development consultants added a depth of understanding of and great experience with curriculum review processes.

Having worked on curriculum review with most faculties across campus, they had many different strategies for engaging diverse groups in curriculum review.

The focus groups with the teaching staff were co-facilitated by the lead researcher and an educational development consultant who specializes in curriculum review and who consults with faculties and departments undergoing curriculum review. Such an approach was beneficial in that the facilitators both brought particular strengths to the session, allowing for more breadth and depth of responses. The lead researcher had the disciplinary knowledge to prompt participants to elaborate further in certain areas, whereas the educational development consultant had a breadth of understanding from working with diverse groups. This outside perspective also allowed the consultant to bring a more balanced approach to the session, compensating for a lack of objectivity that may occur within a highly focused discipline.

Integrating perspectives from the teaching staff alongside those of the program director in identifying and defining the main attributes of the model/program outcomes reinforced the sense of ownership that faculty members and teaching assistants felt in the Nanoscience program, and was critical to the review's success. The inclusion of teaching assistants (not a common practice in curriculum review processes) was essential to highlight interactions with students that are not normally captured by faculty in curriculum review processes, especially the challenges they encounter within laboratory settings. Below is one of the comments:

> There were two main challenges with teaching Nanoscience 502. First, the time commitment was high as students often expected much more face-to-face or laboratory time than allocated. Although there was less marking than in a traditional course, helping students design experiments and write readable research proposals was extremely time consuming. Similarly, experimental analysis and preparation of the research report were very time consuming as most students lacked the background and soft skills necessary to excel on their own. Second, the students themselves were challenging at times. Many students wanted an easy A without putting in effort. They were either unwilling or incapable of designing workable research projects and struggled immensely with every step of the course, leading them to be withdrawn and disinterested. Lastly, because of the logistics of ordering, there was sometimes significant downtime waiting for chemicals, meaning that lab time was concentrated in shorter time periods; however, there is no easy fix for this problem. (Teaching assistant, questionnaire data)

Among the stakeholders were current students and representative alumni of the program. Including alumni perspectives on the overall program and not on individual courses (students' perspective) is of utmost significance to get a better understanding of enduring perceptions on student learning gains throughout the whole program.

Our curriculum review process was strengthened first of all by informing the students about the purposes of the process and secondly by having them respond to a learning-focused instrument that was similar to instrument used for the instructors and teaching assistants. These features distinguish our process from others in which inclusion of students' perception of learning gains related to the program outcomes is less prominent (Arafeh, 2016; Lam & Tsui, 2016; Sumsion & Goodfellow, 2004; Veltri et al., 2011). Some curriculum review processes have relied on student course evaluations and other available sources of student satisfaction data in curriculum review (Oliver et al., 2010; Uchiyama & Radin, 2009). A few approaches, such as at University of Guelph (Wolf, 2007) and at University of Calgary (Kalu & Dyjur, 2018), collected data from the students via surveys and interviews/focus groups. However, in most cases the students were not aware of the curriculum review process, and not active participants. This represents a limitation to the current practice (Oliver et al., 2010). Using curriculum review to assess the learning outcomes and the embedded graduate attributes in programs was shown to be most effective when students were engaged as active partners in the review (Loacker, 2000).

Inviting student and alumni participation and adding their perceptions to the Nanoscience curriculum review was found especially valuable in the comparison of the perceptions of the students, instructors, teaching assistants and director with respect to the learning experiences and desired outcomes of the program. This comparison has allowed us to assess the points of connection and lack of alignment between what the students experienced, what the instructors and teaching assistants enacted and what the director envisioned. Finally, inclusion of the students' perspectives is a shift from teaching-focused to learning-focused approach in curriculum review. This was evident in our curriculum review process in which the academic staff of the Nanoscience program was consistent on inquiring on the students' perspective of the program curricula in order to take this in consideration in the curricular renewal. To give but one example of such concern:

> Was there a big hole that the students saw in the program? Is there a big letdown? Is there a big disappointment? Is there a big red flag about the program from everything (students' data) you (curriculum review lead) have seen? (Instructor, a focus group within the 'collaborative analysis and sense making' phase of the curriculum review)

Another feature of our approach was using different data collection instruments (Table 1). Data were collected via questionnaires since they are an objective method of collecting various information about people's knowledge and skills (Boynton & Greenhalgh, 2004; Kember, Leung, & Kwan, 2002). Three nearly similar instruments (questionnaires) were developed for students, alumni and the teaching staff. Questionnaires were a blend of Likert-type scale and open-ended questions. To opt for a deeper understanding of students' perceptions that were not obtained in a questionnaire, focus groups were conducted after analysing questionnaire data (Coe, Darisi, Satchell, Bateman, & Kenny, 2012). Focus group data helped us understand the "why" behind the trends captured in the questionnaires (Carey, 1994). As a practical application for this paper, we have included the script of the visioning focus group with the instructors and the teaching assistants of the program (Appendix I) and the student questionnaire (Appendix II).

2. Real-time curriculum review

Our framework supports a real-time process in which the instructors, teaching assistants and students map their curriculum as the course is running. "Real time" in this context means that the instructors, teaching assistants and students are mapping and reviewing the courses as they are being delivered, rather than as projected in a course syllabus prior to or after course completion (Uchiyama & Radin, 2009). This provides a robust dataset since perceived and delivered curricular counterparts for the same class participants are being compared. Accessibility of the curriculum mapping and review questionnaires to the academic staff in the Nanoscience program was ensured via emails which further facilitated and supported a dynamic and sustainable (ongoing) curriculum mapping process.

3. Trust-building and transparent attitudes and procedures

Curriculum review is an undertaking that can be intimidating to faculty members. Feelings of anxiety, indifference, and territoriality, especially when faculty are unfamiliar with the curriculum review process, can and do occur (Hull et al., 2001). Being aware of these possible difficulties, we communicated to those involved that the purpose of the review was to explore the pedagogical model (LSDS) and the entire learning environment inside the nanoscience program for potential improvements to student learning and to support scholarly conversations on authentic research in undergraduate experiences. Providing faculty and staff with a clear framework of the process while avoiding jargon related to curriculum review and clearly defining their roles in the process – responding to a questionnaire, attending semi-structured focus groups, approving/editing documents – mitigated a great deal of their anxiety of any administrative or analysis burden.

In addition, because this was a curriculum review research project, we reassured the participants that the intention of this process was not to evaluate their performance. One way we followed through on this assurance was to present data to the program director in aggregate form only and after approval from the participants.

Another practice that built trust and openness was to conduct the early focus group with teaching staff in absence of the program director. This was also essential to avoid possible bias in opinions and to obtain each individual's authentic visions on planned and enacted curricula.

Communicating clear deliverables facilitated discussions and communication of ideas among faculty and staff, e.g. meeting handouts and presentation slides, in the form of easily understandable schematics and figures. Thoughtful planning of various individual and group activities during focus groups further enhanced engagement and provided multiple sources of evidence for analysis. Ongoing contributions and commitment from the teaching team were fostered throughout the review by providing a balance between defined deadlines and accommodating their teaching, research, and other commitments. Further, participation of faculty and staff in assessment and interpretation of collected evidence allowed them to consider different ways to tie the evidence with future teaching plans (Banta & Blaich, 2010). Informed, respected, reassured, the teaching team engaged with the curriculum review and took ownership of the curriculum itself, as pointed out by one of the teaching assistants in a focus group: "I am proud that I'm one of the Nano [science program] team".

Recommendations for fostering effective and inclusive curriculum review

As a result of this process, three key recommendations emerged to help improve future curriculum review practices. First, adopting a real-time curriculum review process (Uchiyama & Radin, 2009) with a continuous improvement approach (Kalu & Dyjur, 2018; Wolf, 2007) creates a mindset of excellence, where internal stakeholders in the program are open to making changes based on data collected through the on-going curriculum review process. A real-time approach also encourages and supports curricular changes due to emerging issues in the field, new technologies, and different student demographics.

Second, using multiple perspectives is fundamental to adding richness and accuracy to the curriculum review data. Collaborative analysis that involves people in different roles in making sense of the data provides a deeper understanding of what is happening. The same data may be interpreted in different ways. This adds richness to decision-making processes, helps to identify a possible disconnects between the different curricular perspectives, and highlights potential gaps and areas for improvement in the learning environment.

Finally, creating an environment where the participants are informed and equally respected and a process that the participants can trust fosters active and authentic engagement and stronger collaboration.

Conclusion

This article provided a novel real-time framework to collect, analyse, and present data on current teaching and learning practices in a postsecondary science program and on assessment of students' perceptions. This framework of curriculum review is distinctly formative rather than summative supporting constant monitoring and evaluation to inform continual improvement (Desha & Hargroves, 2014). Since the process we implemented collected data on the students' and staff's experiences and perceptions of their experiences within the program under study, it emphasizes a constructivist view of the curriculum review process which locates knowledge, attributes, and capabilities in students' minds. Finally, our transparent trust-building curriculum review process can meet the challenges indicated by Davenport et al. (2009) including reluctance in faculty to conduct the evaluation, resistance to change, and lack of familiarity with the process. It involves collaboration and collegiality (Uchiyama & Radin, 2009) between internal and external partners taking leadership roles in the curriculum review process (Desha & Hargroves, 2014) and gives voice to the wisdom of practice. By including the students' perspectives it shifts the program's approach to the curriculum from teaching-focused to learning-focused. Finally, it promotes continual improvement of the program and reinforces a sense of ownership of the curriculum itself by the program stakeholders. The key features and benefits of our presented curriculum review framework are depicted in Figure 2.

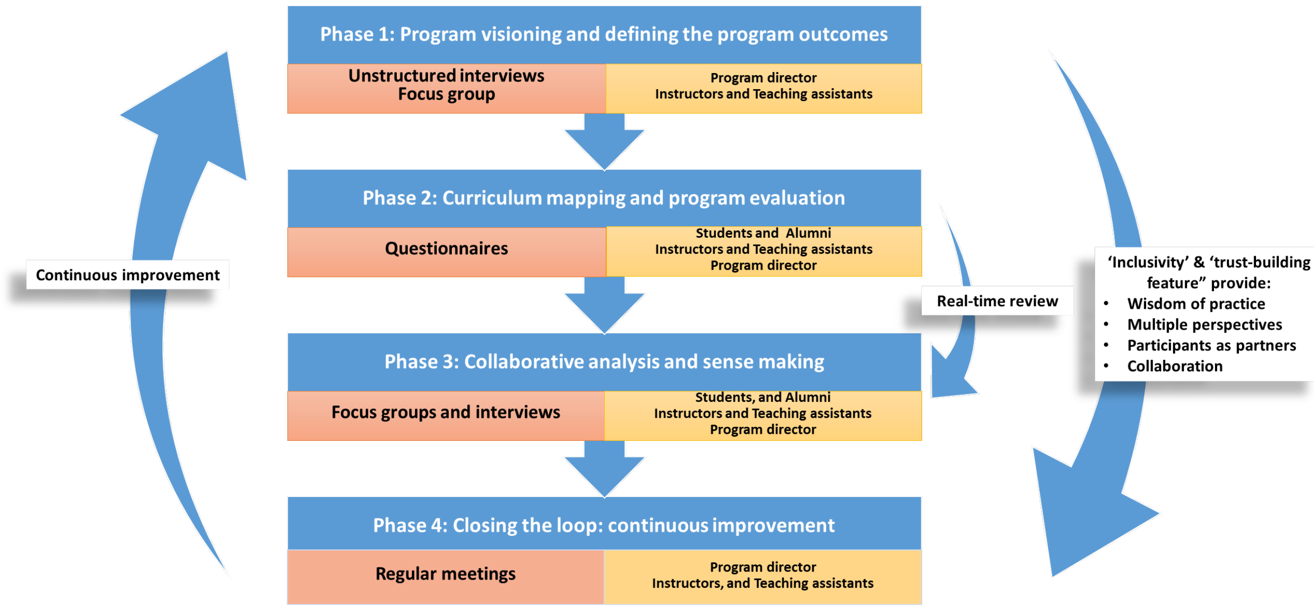

Figure 2: A visual emphasizing the benefits and key features and benefits of the presented framework of the curriculum review process.

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Appendix I: Nanoscience Program Visioning Session

Participants: Instructors and teaching assistants

Facilitators: The curriculum review lead and an educational development consultant

Intended Outcomes:

- To discuss the purpose of the Nanoscience Program
- To identify the key knowledge, skills and values that we hope the students gain through these courses in order to help inform development of program outcomes.

Questions in the handouts used to probe discussion:

Step 1: Program Visioning

- What is the purpose of the program?
- What unique areas of focus or strengths does the program offer?
- What learning experiences are core to the program? What key learning experiences will students engage in during the program? Describe this in your own words
- How would the teaching and learning experience in the Nanoscience program differ than other programs?
- Why should students choose this program? How will the program be of benefit to them?

Step 2: Essential Program Learning

- What STRENGTHS should students who complete this program possess?

- What is essential that students KNOW and be able to DO by the end of their learning experiences in this program? What key knowledge, skills and values/attitudes should student who complete this program possess?

Appendix II: Students Questionnaire

1. Please indicate your major or expected major: …………………………………………...
2. Please indicate if you are a full-time or part-time student.

   ☐Full-time student ☐Part-time student
3. What is your semester level? (Please select one)

   ☐Semester 1 or 2 (First year)

   ☐Semester 3 or 4 (Second year)

   ☐Semester 5 or 6 (Third year)

   ☐Semester 7 or 8 (Fourth Year)

   ☐Semester 9 or more
4. Please indicate the Nanoscience core courses you have taken or are currently taking: (Check all that apply)

   ☐Nanoscience 301 ☐Nanoscience 401 ☐Nanoscience 502
5. What are you considering doing after graduation? (Check all that apply)

   ☐Work in government or the public sector

   ☐Work for a non-profit or non-governmental organization

   ☐Work in private sector or business

   ☐Attend graduate school

   ☐Pursue another undergraduate degree (e.g. health, medicine, engineering)

   ☐Unsure at this time

   ☐Other (please specify):
6. In comparison to other courses you have taken at the University, to what degree have the Nanoscience courses actively engaged you?

   ☐To a great extent ☐To a moderate extent

   ☐To a small extent ☐ Not at all

   ☐I don’t know
7. Please rate the extent to which the Nanoscience core courses contributed to your development of the following skills and abilities (related to interdisciplinary, experiential, problem-solving and research skills):

	To a great extent	To a moderate extent	To a small extent	Not at all	I don't know
Ability to understand, analyze, and integrate knowledge across different disciplinary fields	☐	☐	☐	☐	☐
Ability to plan, design and execute experiments	☐	☐	☐	☐	☐
Ability to find information, collect data and assess its relevance and reliability	☐	☐	☐	☐	☐
Ability to use scientific knowledge to solve problems, and arrive at solution	☐	☐	☐	☐	☐

8. Please rate the extent to which the Nanoscience core courses contributed to your development of the following skills and abilities (related to communication and collaboration skills):

	To a great extent	To a moderate extent	To a small extent	Not at all	I don't know
Ability to work effectively as member of an interdisciplinary team	☐	☐	☐	☐	☐
Ability to explain scientific ideas effectively to people across different disciplinary fields <u>in written format</u>	☐	☐	☐	☐	☐
Ability to present scientific ideas effectively to people across different disciplinary fields <u>in oral format</u>	☐	☐	☐	☐	☐

9. Please rate the extent to which the Nanoscience core courses contributed to your development of the following skills and abilities (related to creativity and curiosity):

	To a great extent	To a moderate extent	To a small extent	Not at all	I don't know
Ability to adapt to new situations	☐	☐	☐	☐	☐
Ability to use or modify available resources to obtain results	☐	☐	☐	☐	☐
Ability to generate creative ideas by exploring many possible solutions	☐	☐	☐	☐	☐
Ability to pick out unusual associations of ideas	☐	☐	☐	☐	☐
Thirst for knowledge	☐	☐	☐	☐	☐

10. Please rate the extent to which the Nanoscience core courses contributed to your development of the following skills and abilities (related to deep thinking):

	To a great extent	To a moderate extent	To a small extent	Not at all	I don't know
Ability to formulate or articulate scientific problems	☐	☐	☐	☐	☐
Ability to partake in research projects to solve scientific problems	☐	☐	☐	☐	☐
Ability to assess scientifically-based arguments and/or information	☐	☐	☐	☐	☐
Ability to critically evaluate the basis of the included ideas	☐	☐	☐	☐	☐
Ability to extract significant points from assimilated information	☐	☐	☐	☐	☐

11. Please rate the extent to which the Nanoscience program contributed to your understanding of the following two scientific phenomena (related to knowledge specific to the Nanoscience field):

	To a great extent	**To a moderate extent**	**To a small extent**	**Not at all**	**I don't know**
The phenomenon of self-assembly	☐	☐	☐	☐	☐
Quantum confinement theory	☐	☐	☐	☐	☐

12. Please rate the extent to which the Nanoscience program contributed to your development of the following technical skills specific to the nanoscience field:

	To a great extent	**To a moderate extent**	**To a small extent**	**Not at all**	**I don't know**
Electron microscopy	☐	☐	☐	☐	☐
Atomic force microscopy	☐	☐	☐	☐	☐
Thin film characterization	☐	☐	☐	☐	☐
Nanoparticle sizing and charge density measurements	☐	☐	☐	☐	☐
Optical techniques	☐	☐	☐	☐	☐

13. In your opinion, what are the strengths of the Nanoscience program?
14. Please list up to three things you would KEEP in the current Nanoscience program:
15. Please list up to three things you would CHANGE in the current Nanoscience program:
16. In addition to first year general science or equivalent, would you recommend adding a specific pre-requisite course before studying in the Nanoscience program?

Yes	No	I don't know
☐	☐	☐

If you selected "Yes" as an answer, what topics would you recommend for better preparation of a student for the Nanoscience program?

☐First year biology

☐First year physics

☐First year inorganic chemistry

☐First year mathematics

☐Other, please specify:

17. Please add other comments you would like to share that would help inform the curriculum review process for the Nanoscience program.