Using teacher voices to develop the ASELL Schools professional development workshops

SCOTT CORNISH, ALEXANDRA YEUNG, SCOTT H KABLE, MARYKAY ORGILL AND MANJULA D SHARMA

This article describes how the Advancing Science and Engineering through Laboratory Learning (ASELL) Schools program was developed. ASELL School's directive is to facilitate the embedding of inquiry-based learning in secondary school classrooms through workshop-based teacher professional development (PD). The approach of ASELL Schools is to balance the lessons learned in education research with teacher voices and curriculum requirements in the design and implementation of teacher professional development. This has resulted in a unique workshop experience, where students and teachers work together on open-inquiry investigations. Afterward, teachers and students are separated for pedagogical sessions, and teachers are given time to discuss and share ideas. The discussion is focussed around the key ASELL Schools pedagogical tool, called the 'Inquiry Slider'. We outline an iterative process based on listening to teacher voices, which was used to develop the workshops. We also demonstrate that the Inquiry Slider is an effective pedagogical tool allowing teachers to focus and expand their efforts to bring more inquiry-based learning into their classrooms.

Introduction

While the notion of inquiry in research in the field of science education has been implicit for a millennium, or more, it was in the 1960s that inquiry took shape in a form suitable to be incorporated into curriculum documentation. In considering, "some of the materials and methods by which the curriculum can serve the needs of teaching science as inquiry", Schwab (1960), wrote:

> *The laboratory is easily converted to inquiry ... The laboratory ceases to be a place where statements already learned are merely illustrated and where perception of phenomena occurs within the restrictive structuring of terms and concepts already laid down. It ceases, too, to be preoccupied with standardized techniques. It becomes, instead, a place where nature is seen more nearly in the raw and where things seen are used as occasions for the invention and the conduct of programs of inquiry. The laboratory manual which tells the student what to do and what to expect is replaced by more permissive and open material. (Schwab, 1960, p. 187).*

However, simple as it may sound, the above shift in the laboratory required a novel perspective on how students made sense of science, and to be put into context in view of students' interpretation of the world in the everyday sense. Students' understanding of the world was valid and had to be acknowledged in the teaching of science (Driver & Easley, 1978). Instead of mistakes, misunderstandings, and misconceptions to be corrected, students' alternative frameworks and conceptual models were manoeuvred. Student understandings were to be guided to those more congruent with science understandings. The collection of papers by prominent scholars titled, "Children's ideas in Science" (Driver,

Guesne & Tiberghien, 1985), captures how this can be achieved in a laboratory or in an environment using hands-on activities or equipment.

Background

Research continues to show the benefits of inquiry. For example, in a meta-analysis Furtak, Seidal, Iverson and Briggs (2012) found that while the type of inquiry-based science teaching varied, there was a connection between inquiry-based science teaching and improved student learning. Other work by the National Research Council (NRC, 2000), has also identified the 'essential features' of inquiry as, engaging in scientifically oriented questions, giving priority to/analysing evidence, formulating explanations, connecting explanations to scientific knowledge, and communicating/justifying explanations.

Substantive resources and materials have been produced (see for example, BSCS Report, 2006; Millar, 2004; Watson, Nikolaou & Teamey, 2006) and inquiry is embedded in curricula in some form in most countries. On the other hand, in another meta-analysis, Asay and Orgill (2010) found that very few of the science classroom and laboratory activities published in a teacher practitioner journal from 1998 to 2007 included each of the five essential features of inquiry identified by the NRC in the United States (NRC, 2000). In fact, 63% of these activities included two or fewer of the essential features of inquiry. Thus, although research suggests the benefits of inquiry-based teaching, there exists a disturbing disparity amongst researchers, which does not bode well for implementation of inquiry in schools.

The work of Driver et al. (1978) and Schwab (1960) during the 60s and 70s emphasised in-service teacher education as appropriate for further building teacher capacity and skills in teaching through inquiry. This is because, with some classroom experience, teachers appreciate student thinking, alternative conceptions, have sorted out classroom issues and are ready to deeply engage in teaching through inquiry. In a review of papers on teacher professional learning through inquiry by Capps, Crawford and Constas (2012), some studies focus on how the conceptions of teachers have changed (e.g., Lotter, Harwood & Bonner, 2006; Wee, Shepardson, Fast & Harbor, 2007), while others correlate elements of PD and changes in teacher behaviour (e.g., Penuel, Fishman, Yamaguchi & Gallagher, 2007; Garet, Porter, Desimone, Birman & Yoon, 2001). What is not common is to include teacher voices in developing PD, listening to teachers' experiences and building on what teachers find valuable. This is despite the fact that research suggests that effective professional development should confront or address participants' current beliefs and assumptions about learning (Henderson & Dancy, 2007). How can we confront these assumptions without listening to teacher voices in the first place? Teachers, if involved, can make a significant contribution to their own PD (Hewson, 2007). It has been suggested that there has been a lack of listening to teachers' experiences when it comes to developing PD (Goodson, 1991). This article aims to address this issue by highlighting teacher voices, in both the genesis of a teacher PD program and also in their experiences of the program.

Context and purpose of this study/paper

In Australia, inquiry is explicitly embedded in curriculum documents. For example, the Preparatory to Year 10 Australian Curriculum: Science, includes a 'Science Inquiry Skills' aspect, and state authorities use various incarnations such as 'Scientific Inquiry Methods' in Victoria, and 'Working Scientifically' in New South Wales. This article is about an Australian project, called Advancing Science and Engineering through Laboratory Learning (ASELL), that aims to further teachers' capacity and skills with teaching through inquiry. ASELL Schools has a specific goal of accelerating the embedding of inquiry in Years 7 to 10 science across Australia through in-service teacher professional development workshops. Specifically, this article:

- describes how the ASELL Schools teacher professional development approach was developed in consultation with teachers;
- explains how the ASELL Schools teacher professional development approach is translated into practice;
- describes the model of inquiry, including how teacher needs have been incorporated, with regard to the curriculum requirements they face; and

• uses evidence to illustrate that teachers are finding the lessons learned at ASELL Schools workshops useful in their teaching practice.

1. Development of an approach cognisant of teacher voices

The ASELL Schools approach (Whannell, Quinn, Taylor, Harris, Cornish & Sharma, 2018) is based on the ASELL Universities program (Yeung, et al., 2011; Barrie et al., 2015), which runs professional development workshops for university academics to build their capacity to design and implement more educationally sound university laboratory programs. The first step in extending ASELL Universities into schools was to include teachers' voices, because teachers, as professional educators, would have the necessary expertise to analyse their needs, distil what would be valuable for their professional practice and contribute to the development of their own PD programs. A call was made by the ASELL Universities team at the University of Sydney inviting teachers to participate in a meeting to scope and brainstorm ideas to better understand the challenges teachers faced in implementing practicals/investigations in schools. A total of 13 teachers and 6 academics spent a day discussing and developing the key underlying features of a program to support teachers to deliver better practicals/investigations in their classroom. By the end of the day, the participants of the meeting agreed on the following four points.

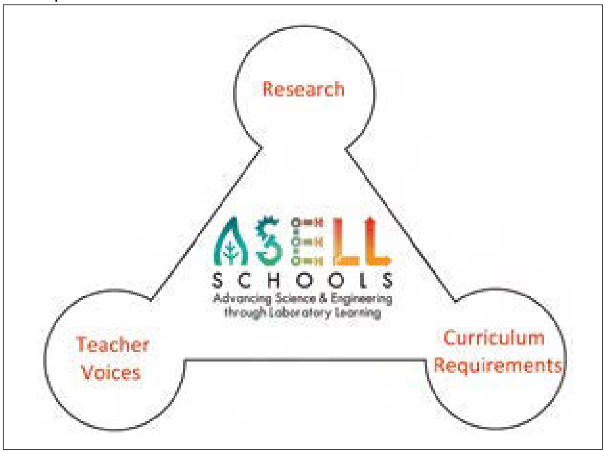

Figure 1: *The three pillars underpinning the development of the ASELL Schools professional development approach (Gordon, personal communication, 2016).*

1. **Run one-day workshops in schools,** within school hours, so that hesitant teachers could be enticed to participate.

2. **Implement investigations using readily available equipment and target curriculum requirements** to further build teacher confidence in carrying out more open-inquiry investigations. These types of investigations make science more interesting for students but are often time consuming to organise.

3. **Provide teachers with the opportunity to share understandings** of investigations, consider why and how to shift from recipe-based to open-inquiry approaches as articulated in curriculum documentation so as to suit teachers' skills and their students' capabilities.

4. **Include students and teachers, focusing on Years 7 to 10,** as this is when all students do science, there are fewer resources, and often teachers are not as well supported in comparison to those teaching Years 11 and 12.

The ASELL Universities academics sought to better understand the research underpinning the curriculum requirements so that the ASELL Schools workshops could assist teachers in delivering to the potential of the school curriculum. This approach led to the identification of the three pillars underpinning the ASELL Schools approach to professional development; research, teacher voices, and curriculum requirements, shown in Figure 1.

2. Translating the ASELL Schools approach into practice

Based on findings from the literature, the ASELL Schools team wanted to identify a simple tool to help teachers: (1) determine the current level of inquiry and student-directedness in an activity they might use in their laboratory classroom; and (2) identify ways in which they might make their activities more inquiry oriented. Thereby, increasing teachers' abilities to use inquiry-based teaching techniques by helping them develop the ability to modify existing activities, with which they are comfortable and for which they already have equipment, to make them more inquiry oriented. Not finding a tool to meet the needs of the teachers, the ASELL Schools team modified a table from an existing document to create a tool that might support teachers in their implementation of inquiry-based science teaching. This ultimately became the 'Inquiry Slider', the key pedagogical tool of the ASELL Schools program. The development of the Inquiry Slider is described in more detail in the next section.

A program for the workshops, was created, see Table 1. The workshop starts with an introductory session, setting the scene and highlighting the importance of focusing on inquiry when running investigations. The introduction also gives a very brief background on the research behind inquiry-based learning. The introduction session is followed by an exemplar investigation provided by the ASELL Schools team. This exemplar investigation is designed to give students and teachers direct experience with the open-inquiry level of student direction. During the exemplar investigation, teachers and students are intentionally paired together into lab teams/groups. Having the teachers working with the students in this investigation exposes teachers to students' capabilities of self-directed learning, and teachers are often pleasantly surprised.

Teachers then participate in a pedagogical session that introduces the main pedagogical tool promoted by ASELL Schools, the Inquiry Slider; to be discussed in the next section. For the subsequent investigations, teachers are encouraged to submit their own experiments, which they already use in their teaching. Following the investigation is a short, separate, debrief for teachers and students. In the teacher debrief, the Inquiry Slider is used to classify what level of inquiry the investigation is currently at and what essential elements of inquiry could be increased/decreased to improve the experiment. The students and teachers are reunited, so the teachers can hear the student feedback.

Time	Activity	
9:00–9:15	Welcome and Introduction	
9:15–10:15	Lab Session 1 — 'Open Inquiry' Exemplar Investigation	
10:15–10:45	Morning Tea	
10:45–11:45	Teachers only: Pedagogical Session – Inquiry Focus	Students only: Science Activity
11:45–12:45	Investigation 2 — Provided by ASELL or Teacher	
12:45–1:45	Lunch	
1:45–2:45	Investigation 3 — Provided by ASELL or Teacher	
2:45–3:15	Teachers only: Discussion and Wrap Up	Students only: Overall Debrief

Table 1: *A typical program for the workshops. The number and style of investigations change, as do the precise timings, so as to customise the workshop for the host school and participants.*

In the final pedagogical session, the teachers are presented with data gathered during the workshop. This live data is from a brief survey, conducted immediately after the introductory session, asking teachers and students: 'What are the most important elements of a good investigation?' Additional data from previous workshops is also presented to provide insights on using the Inquiry Slider and the utility of embedding inquiry through investigations. Throughout the workshop, teachers share experiences, discuss challenges and solutions, exchange experiences and learn from each other.

3. The model of inquiry used and its development based on teacher voices

Over the course of the project, three versions of the Inquiry Slider were used. The first two workshops used version 0 and will be collectively analysed and referred to as the 'first cohort'. The implementation of the workshop, along with the Inquiry Slider, was modified for the next three workshops. These used version 1, and will be collectively analysed and referred to as the 'second cohort'. The slider was ultimately modified again to make version 2, which was used for the majority of the developed program of the ASELL Schools workshops. In this article, we draw on data from 147 teachers who participated in 12 workshops from the developed program, occurring over a period of 20 months. The number of teacher and student participants in the different cohorts are summarised in Table 2.

Cohort	Students	Teachers
Pilot – First Cohort	34	37
Pilot – Second Cohort	45	29
Main Series – Developed Program	290	147
Total	369	213

Table 2: *Summary of participants and investigation of workshops included in this article.*

In the early stages of developing the ASELL Schools approach, the essential features of inquiry (National Research Council, 2000, p. 25) captured the imagination of the academics involved in the program. These features were used to develop version 0 of the Inquiry Slider, which was piloted in the first workshop, see Table 3 for details. While the teachers found version 0 useful for modifying their own investigations, they were concerned with the lack of alignment of the essential features with the various Australian curricula. In particular, they mentioned the difficulty of incorporating the Inquiry Slider into current teaching programs and assessment protocols. Specifically, they provided the following comments and recommendations.

1. The actions by the teacher and/or student had to be clear.

2. The need to emphasise that the students connect their results/observations with known science.

3. It should be made clear that as the level of open inquiry increases, the requirements from the students are also higher. For example, in an open-inquiry investigation, students are required to 'justify' their results while at the structured-inquiry level, the requirement is to 'conclude'. This has the potential to provide access for students of diverse abilities and facilitates differentiation in the classroom.

Consequently, the above process was used to construct the Inquiry Slider, which was first trialled with the second cohort of the pilot program. By listening to teacher voices from the first cohort, this version was further refined to strengthen point 2 above. Teachers expressed firm views about the importance of using investigations as an opportunity for shifting students' understandings to be more compatible with current science knowledge, which is in line with the sentiments expressed by Driver & Easley (1978).

Based on the consultation with the first cohort of teachers, version 1 of the Inquiry Slider was generated, which incorporated an analysis feature (see Table 3 for details). This version was used in the workshops run with the second cohort of the pilot program. As a more diverse cohort of teachers started participating in the workshops, a wide range of innovative ideas on how to further modify the essential features of inquiry to fit the requirements of Australian secondary school curricula emerged. The 'average' teacher, with their traditional 'tools of trade', critiqued and commented. The consistent messages were: (1) the need to include more specific reference to planning and conducting investigations; (2) explaining clearly how to create data tables, and collect and record data; (3) emphasising data processing and analysing; and (4) including scientific reasoning and problem-solving, and justifying conclusions based on evidence and scientific reasoning. The basic point teachers were making is that the resources they have, taken from textbooks and other sources, commonly do not clearly distinguish between the essential features of inquiry. For example, the 'planning' feature is often not present at all. Often the 'plan', 'conduct', and 'analyse' is rolled in together in the 'procedure', and students are asked to conduct the experiment, draw graphs, and make other analyses while following a set procedure. This feedback was

Version 0	Version 1	Version 2
1. Learners are engaged by scientifically oriented **questions**. 2. Learners give priority to **evidence**, which allows them to develop and evaluate explanations that address scientifically oriented questions. 3. Learners formulate **explanations** from evidence to address scientifically oriented questions. 4. Learners **evaluate** their explanations in light of alternative explanations, particularly those reflecting scientific understanding. 5. Learners **communicate and justify** their proposed explanations.	1. Learners engage in scientifically oriented **questions and predictions**. 2. Learners give priority to **evidence**, allowing them to develop explanations. 3. Learners engage in **analysis** to support their explanations. 4. Learners evaluate their **explanations**. 5. Learners **connect** their explanations with scientific understanding. 6. Learners **communicate and justify** their work.	1. Learner engages in scientifically oriented **questions** and **predictions**. 2. Learner **plans** how to carry out investigation and collect data. 3. Learner **conducts** investigation, recording data. 4. Learner **processes** and **analyses** data. 5. Learner uses scientific reasoning and **problem solving** to link evidence to science concepts. 6. Learners **communicate**, and justify findings based on evidence and scientific reasoning.

Table 3: *Essential features of inquiry and modifications driven by teacher voices. Version 0 is from (National Research Council, 2000, p. 25).*

incorporated into version 2 of the Inquiry Slider (see Table 3 for details), which has been widely used in the ASELL Schools developed program.

The NRC (NRC 2000, page 29) goes further and unpacks the essential features of inquiry and how they can be put into practice across many levels in the classroom. As an example, the first essential feature of inquiry is expanded in Table 4. The first level of how this is practised is when a teacher does a demonstration; the investigation is carried out by the teacher and the students observe. Demonstrations are a very common form of teaching in school science classes and beyond. Normally in demonstrations, a phenomenon is being observed, and there is no obvious questioning. The next level of inquiry for this feature would be where the teacher provides a question for the student who will then and carry out the investigation. This is followed by the 'structured' level of inquiry. For the 'questioning' feature, this would correspond to a teacher giving a broader question/statement that is then reflected on, and 'sharpened' by, the student. The next level of inquiry is the 'guided' level. At this level, the teacher supplies a series of questions/statements and the students selects from this list to create a question of their own. The last level would be the 'open' level of inquiry; in this case the student will create their own question, with no question provided by the teacher.

Figure 2 shows the final version of the Inquiry Slider, which has been implemented in the developed program of the ASELL Schools program. It is important to note that the Inquiry Slider is presented as tool that can be modified and adapted within schools to meet the needs of the students and teachers. This is a tool which summarises the different levels of inquiry for each of the essential features of inquiry.

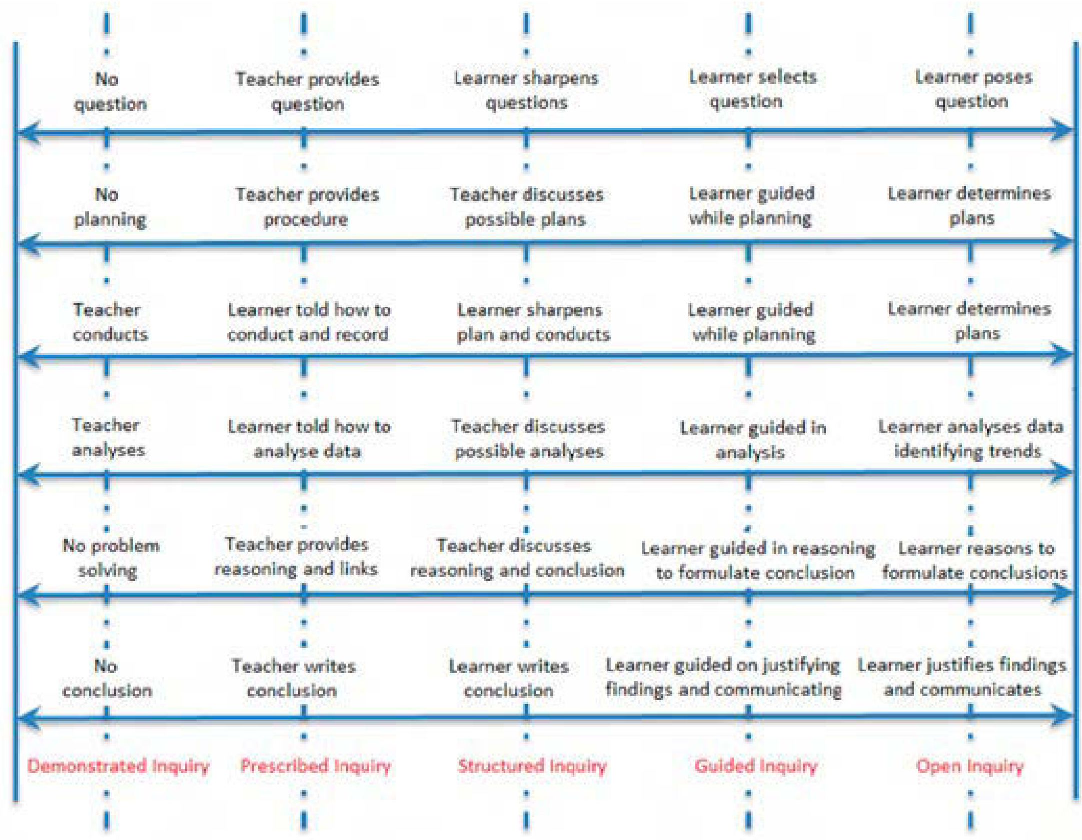

Figure 2: *The Inquiry Slider, as presented in the developed program of the ASELL Schools workshops.*

Feature	Demonstration	Prescribed	Structured	Guided	Open
Questions/Predicts	No Question	Structured	Teacher provides question	Learner selects question	Learner poses question

Table 4: *Unpacking the first essential feature of inquiry 'questions' into the spectrum inquiry level for classroom practice.*

During the workshops, teachers share experiences and strategies, learning from each other. One of the topics of conversation is that it is not always appropriate or advisable for all aspects of their investigations to be at the 'open' level of inquiry. The teachers converge on the notion that this is quite an unattainable and often undesirable goal. The process of using the Inquiry Slider empowers them to try small steps and not be overwhelmed by open inquiry. For example, a teacher might provide a question but leave the planning and conducting at an open level of inquiry, then again bring the level of inquiry back to help student in analysing and communicating their results. Teachers reflect that this is still a major improvement over the standard, and ever-present recipe format.

4. The evidence that teachers are finding the workshop useful

We draw on the sample from Table 2 to illustrate what the teachers were saying and how this information was used to refine the workshops. The data are from surveys completed by teachers at the end of a workshop. We draw on two sections of the survey, open-ended and Likert-scale questions. We report on six Likert-scale questions that were answered on a Likert scale of 'Strongly Agree', 'Agree', 'Neutral', 'Disagree', and 'Strongly Disagree'. The wording of some of the multiple-choice questions was modified for each cohort. Hence, for some questions, we don't report data from all cohorts. The four open-ended questions did not change between the different cohorts. The responses were grouped into categories for this analysis. Often, each response contained distinct comments that fell into different categories. Hence, the number of comments does not match the number of unique responses. For example, a comment like "I found the Inquiry Slider very helpful and loved the discussion with teachers", would count towards both the "Inquiry Slider" and "Discussions with teachers/ASELL Staff" categories.

One of the major components in determining which aspects of the workshops were effective in enhancing inquiry-based teaching was to find what teachers considered as the most valuable aspect of the workshop. Table 5 summaries the responses to the question: "What did you find to be the most valuable aspect of the ASELL workshop? Why?".

The top three comments on what are the most valuable are the same across both pilot cohorts, and the workshops of the developed program for the ASELL Schools workshops. For the pilot workshops, the top comment was "How valuable the discussions with teachers/staff" were. This was one of the objectives we had in designing the workshops and corresponds to the third point that we received from the focus group preceding the pilot workshops. Given the strong responses by teachers to this point, it appeared the pilot workshops have been successful in delivering on this objective. The choice of investigations was also highlighted by the focus group as an important factor for consideration when undertaking the workshops.

The 'investigations' were the second most mentioned aspect of the workshops which participants found valuable, shown in Table 5. This was fairly consistent, with 33% of respondents mentioning this aspect in the first cohort of pilot workshops, 46% of respondents from the second cohort of workshops, and 47% of respondents in the developed program. This was also the top response for the developed program workshops, with 'Discussions with teachers/ASELL staff' the second most common response.

What did you find to be the most valuable aspect of the ASELL workshop? Why?					
Pilot First Cohort N =18		Pilot Second Cohort N =24		Main Series Developed Program N = 107	
Discussions with teachers/ ASELL staff	14(88%)	Discussions with teachers/ASELL staff	11 (46%)	Investigations	50 (47%)
Investigations	6 (33%)	Investigations	11(46%)	Discussions with teachers/ASELL staff	34 (32%)
Inquiry Focus/Slider	4 (22%)	Inquiry Focus/Slider	11 (46%)	Inquiry Focus/Slider	30 (28%)
Teacher submitted experiments	2 (11%)	Working with Students	5 (21%)	Working with Students	28 (26%)
Inquiry Focus/Slider	6 (33%)	Inquiry Focus/Slider	6 (33%)	Inquiry Focus/Slider	6 (33%)
Background science to investigations/Lab Notes	2 (11%)	Interesting	1 (4%)	New techniques/tools from ASELL	12 (11%)
Working with students	1 (6%)	Educational/Lab Templates	1 (4%)	Fun/Interesting/Challenging	5 (5%)

Table 5: *Categories of teacher open-ended responses to the question, "What did you find to be the most valuable aspect of the ASELL workshop? Why?".*

What area of the workshop do you think most needs to be improved? What improvements would you suggest?					
Pilot First Cohort N = 12		Pilot Second Cohort N = 15		Main Series Developed Program N = 74	
More diversity of experiments	5 (42%)	Nothing	3 (20%)	Nothing/It was good	18 (24%)
More workshops	3 (25%)	Have less information, more open	3 (20%)	More time	8 (11%)
Receive material earlier	2 (17%)	More focus on currently used experiments/data collection methods	3 (20%)	More experiments/ discussion	5 (7%)
Finish earlier	2 (17%)	Tighter timelines	2 (13%)	Get manual before experiment	5 (7%)
More consistency in experiment write ups	1 (8%)	Diversity of experiments	2 (13%)	Link to syllabus/More Context	5 (7%)
More discussion on developing investigations	1 (8%)	Less emphasis on experiments, more on theory	1 (7%)	Access to more resources post workshop	4 (5%)
Feedback on survey within workshop	1 (8%)	Copies of presentations	1 (7%)	Wider variety of investigations	3 (4%)
Students and teachers together	1 (8%)	More Farlab	1 (7%)	Clearer plan for the workshop	3 (4%)

Table 6: *Summary of teacher extended responses about what needs to be improved in the workshop.*

In comparison to Table 5, notably fewer teachers responded to the question "What aspects of the workshop could be improved?", which is summarised in Table 6. It is pleasing to note that 18 teachers from the developed program said 'nothing'. However, there are still indications that there is room for improvement on the aspect of investigations. It can be seen in this question that 'Diversity in the investigations' was the most common response by workshop participants in the first cohort, mentioned by 42% of respondents. This feedback was taken into account in the second cohort of workshops, and as such, only 13% of respondents mentioned this as something to be improved upon. During the developed program, further consultation about what subjects schools wanted the workshop investigations to cover helped to ensure the diversity of investigations met the expectations of workshop attendees. This consultation with the schools resulted in a further reduction of teachers mentioning this as something to be improved upon with only 4% of respondents requesting more diversity of investigations in the developed program.

The involvement of students in workshops was also one of the objectives. However, this was mentioned as the most valuable aspect of the workshop by only one teacher in the first cohort of workshops. Additionally, when looking at the comments of what needed to be improved, it was suggested in the first cohort of workshops to get the teachers and students working together. Although the inclusion of students in the workshops was first suggested in the initial focus groups, the students and teachers were not explicitly made to work together. We found in the first cohort that students and teachers would generally form groups among themselves and not intermingle. So, although the teachers could observe students, they weren't working directly with them.

In the second cohort of workshops, students and teachers worked separately in the first practical but strategies were employed to entice them to work in combined groups for the subsequent investigations. After this change, there was a substantially increased number of comments, with 20% of the second cohort respondents mentioning 'working with students' as the most valuable aspect. This can be seen in Table 5, as the fourth most common response from the second cohort. In the developed program, students and teachers were encouraged to work together in all investigations. As a result, the 'Working with students' aspect continued to be a popular response as the most valuable aspect. Again, being the fourth most popular response in the developed program, with 26% of respondents mentioning it.

The importance of teachers working with students is further supported by a multiple-choice question that was used in the first and second cohorts of the program. The question was not retained for the developed program as this became an established feature based on teacher voices. It aimed to probe the effect of working with students in an indirect way, asking if the participation in the workshop reminded them of what is was like to be a student, rather than asking them directly if they thought the student involvement was useful.

The vast majority of responses were affirmative (strongly agree/agree), with very few in the responses dissenting (strongly disagree/disagree) as shown in Figure 3. There was also a sharp increase in the percentage of respondents that 'strongly agreed' with that statement in the second cohort of workshops. This also indicates that, by enticing students and teachers to work in the same groups, the teachers more effectively gain the perspectives of the students. The following quotes are from teacher responses to the question, 'What did you find to be the most surprising aspect of the ASELL workshop?':

> "That the student (me) can develop the question and figure out what to do, not heavily instructed."
>
> "How effective student centred/student inquiry is for classes of some ability."
>
> "The kids worked well in it."
>
> "What students felt was most relevant and important in labs."

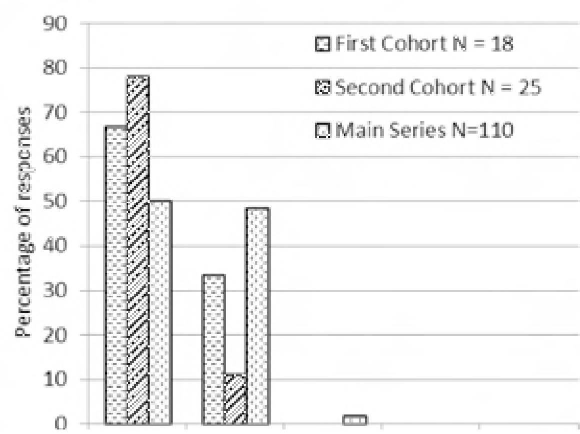

Figure 3: *Summary of responses to the multiple-choice question "Participation in the ASELL workshop has reminded me of what it is like to be a student".*

It is important to note that these types of responses are mentioned in what the teachers found surprising. This result suggests that many teachers are not likely to request student interaction in their professional development, even though this was reported consistently as one of the most valuable aspects of the workshops.

Another multiple-choice question using the Likert scale asked 'Overall I found this workshop valuable', consolidating Table 5 into a single question, which is summarised in Figure 4. Again, the result was overwhelmingly positive, with almost all the responses from the first and second cohort, and the developed program being either 'strongly agree' or 'agree'.

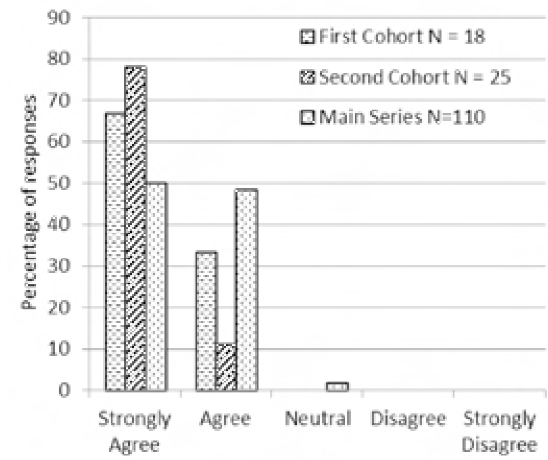

Figure 4: *Summary of responses to the multiple-choice question: "Participation in the ASELL workshop has been a valuable experienced for me/Overall valuable".*

When looking at the impact of the Inquiry Slider pedagogical tool, we can see from Table 5, in the answers to the extended response question about the 'most valuable aspect' question it was the third most popular response in the first cohort of workshops, being in 22% of the responses. There was also a request in the first cohort of workshops that there be time given for feedback at the end of the investigations. For these reasons, the pedagogical session in the middle of the workshop was improved to give more examples of how the Inquiry Slider can be used. Also, the 15-minute debrief sessions at the end of the 2nd and 3rd investigations were instated for the second cohort of workshops. As a result of these changes, the number of respondents who mentioned the inquiry slider/focus in the 'most valuable' question increased to 46%. However, this did decrease in the developed workshops to 28%.

There was no multiple-choice question on the Inquiry Slider in the two pilot cohorts. However, four questions were added to the end of workshop evaluation survey for the developed program workshops. The responses to the questions are summarised in Figure 5. Two questions focus on how the Inquiry Slider can improve the quality of teaching. The first question is direct: "The inquiry slider will help me improve how I teach science through inquiry", and 88% of the teacher responded in the affirmative to this question. A very similar 87% of teachers also responded in the affirmative to the other question about quality of teaching; "The inquiry slider will help me refine curriculum resources to better meet my student needs". There are also two multiple-choice questions about the use of the Inquiry Slider. The first is directly about the respondents use: "I will use the inquiry slider with at least one investigation", a large majority (90%) of teachers answered in the affirmative to this question. Similarly, 85% answered in the affirmative to the question: "I will share the inquiry slider with other teachers". This is a very encouraging result about the possible wider reach that the developed program of workshops has had on the teaching community. While further study is required to determine how many teachers are continuing to use the Inquiry Slider after the workshops, this immediate response suggests that it could potentially be a valuable tool for embedding inquiry in the classroom.

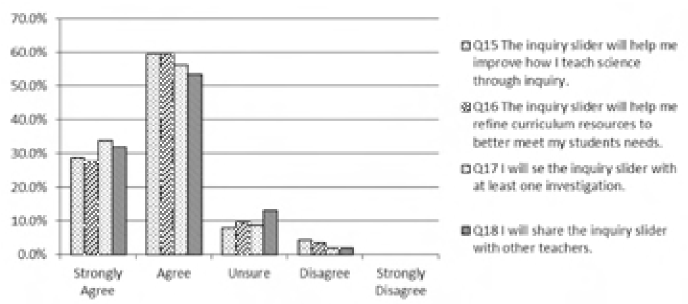

Figure 5: *Summary of multiple-choice questions on the Inquiry Slider from the developed program workshops*

Conclusions

We have outlined the genesis of the ASELL Schools project and the Inquiry Slider pedagogical tool, with care taken to highlight the teacher voices as part of the process of developing the PD model. We have also reported on teacher responses to which core features of the project are of value to them. This includes the involvement of students in the workshop, specifically having teachers and students working together in small groups. Also, the use of the Inquiry Slider pedagogical tool and the discussions and perspectives of other teachers and the ASELL staff were identified by the teachers as the most valuable aspects of the workshops. The investigations that the teachers and students take part in were also identified as one of the most valuable aspects of the workshop. In developing the PD, there was an iterative process of refining the workshops by listening to teacher voices on what areas of the workshops could be improved. This process is described in reference to improving some of the core features of the program. The vast majority (>80%) of teachers who attended a workshop found it to be overall a valuable experience, and said they would use the Inquiry Slider and share it with others. We recommend that further study be undertaken to include a larger number of ASELL Schools workshops, and to also follow up with teachers and students, to find out how many have actually changed their practice and what impact this has had on their students. For more information see the ASELL Schools website; http://www.physics.usyd.edu.au/asell.

References

Asay, L. D., & Orgill, M. (2010). Analysis of essential features of inquiry found in articles published in The Science Teacher, 1998-2007. *Journal of Science Teacher Education*, *21*(1), 57–79.

Barrie, S. C., Bucat, R. B., Buntine, M. A., Burke da Silva, K., Crisp, G. T., George, A. V., … & Yeung, A. (2015). *D*evelopment, evaluation and use of a student experience survey in undergraduate science laboratories: The advancing science by enhancing learning in the laboratory student laboratory learning experience survey. *International Journal of Science Education*, *37*(11), 1795–1814

BSCS (Biological Sciences Curriculum Study). (2006). *Why does inquiry matter? Because that's what science is all about!* Kendall/Hunt Publishing: Dubuque, Iowa, USA

Capps, D. K., Crawford, B.A, & Constas, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education*, *23*(3), 291–318.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, *5*(1), 61–84.

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's Ideas in Science.* McGraw-Hill Education (UK).

Furtak, E. M., Seidal, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82*(3), 300–329.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915–945.

Goodson, I. F. (1991). S*ponsoring the teacher's voice: Teachers' lives and teacher development. Cambridge Journal of Education, 21*(1), 35–46.

Gordon, T. (2016). *Personal communications.*

Henderson, C., & Dancy, M. H. (2007). Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics. *Physics Review Special Topics – Physics Education Research, 3*, 1–14.

Hewson, P. W. (2007). Teacher professional development in science. In S. K. Abell & N. G. Lederman (Eds.). *Handbook of research on science education.* Mahwah: Lawrence Earlbaum Associates.

Lotter, C., Harwood, W. S., & Bonner, J. (2006). Overcoming a learning bottleneck: Inquiry professional development for secondary science teachers. *Journal of Science Teacher Education, 17*(3), 185–216.

Millar, R. (2004) *The role of practical work in the teaching and learning of science.* Paper prepared for the Committee: High School Science Laboratories: Role and Vision, National Academy of Sciences, Washington, DC. The University of York.

NRC (National Research Council). (2000). *Inquiry and the national science education standards: A guide for teaching and learning.* Washington DC: National Academic Press.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*(4), 921–958.

Schwab, J. J. (1960). Inquiry, the science teacher, and the educator. *The School Review, 68*(2), 176–195.

Watson, R., Nikolaou, L. and Teamey, K. (2006). *Beyond Fair Testing: Teaching Different Types of Scientific Enquiry*, work done at King's College London, Published by Gatsby Science Enhancement Programme (SEP), London.

Whannell, R., Quinn, F., Taylor, S., Harris, K., Cornish, S., & Sharma, M. (2018). Open-ended science inquiry in lower secondary school — Are students' learning needs being met? *Teaching Science, 64*(1), 35–43.

Wee, B., Shepardson, D. P., Fast, J., & Harbor, J. (2007). Teaching and learning about inquiry: Insights and challenges in professional development. *Journal of Science Teacher Education, 18*(1), 63–89.

Yeung, A., Pyke, S. M., Sharma, M. D., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., … & Lim K. F. (2011). The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The first Australian multidisciplinary workshop. I*nternational. Journal of Innovation in Science and Mathematics Education, 19*(2), 51–72