Adaptable Resource Kit (ARK)
to assist in the development, trialling and evaluation of inquiry-oriented experiments

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Overview

The development of inquiry-oriented experiments in science requires time to prepare and refine documentation for students and demonstrators, as well as investment in the professional development of demonstrators and teaching assistants. There is an onus on the developers to assure that such investments are likely to produce the desired learning outcomes.

Inquiry oriented experiments differ from conventional 'recipe based' experiments in that more responsibility is given to students to develop their own approaches to addressing questions – and in some cases those questions have been posed by the students themselves. More specifically, in an inquiry-oriented experiment or activity, students:

- engage with (scientific) questions that have no predetermined answer;
- develop and implement approaches to address those questions;
- work to refine their approaches in order to enhance their methods/the quality of the data;
- gather evidence, and;
- formulate and communicate explanations/conclusions based on that evidence

Prepared as part of an ALTC National Teaching Fellowship[1], this document assists academics as they move from the early stages of developing an inquiry-oriented experiment to the later stages where the experiment is ready to be rolled out to its intended audience. The document builds on an approach to the development of new inquiry-oriented experiment outlined in the paper 'Realizing a framework for enhancing the laboratory experiences of non-physics majors: from pilot to large-scale implementation'[2].

Intent

The purpose of this document is to provide resources to assist staff developing new, or revising existing, student experiments to incorporate a strong inquiry orientation. It is aimed at assisting academics to gather evidence to support the development of an experiment and to gather evidence of its effectiveness against some clear criteria.

Our intent has been to prepare flexible and adaptable resources that:

- allow the voices of several key stakeholders to be heard as the process of developing an experiment progresses;
- is of value to academics from any science discipline;
- can be moulded or adapted to local circumstances;
- places particular emphasis on assisting in the design of experiments for large enrolment classes.

[1] http://www.olt.gov.au/altc-national-teaching-fellow-les-kirkup

[2] Kirkup L, Pizzica J, Waite, K M and Srinivasan, L (2010).Eur. J. Phys, vol. 31, no. 5, pp. 1061-1070.

What is in this document?

The document provides a collection of forms and guidelines which may be adapted to your context, and will help you assess the effectiveness of the materials created for students, and whether the new experiment is likely to help students achieve the desired learning outcomes - before you include the new experiment as part of your curriculum. Some of the forms and guidelines may be used to evaluate and fine-tune the experiment once it has gone "live". The documents include:

- a framework for developing, trialling and evaluating inquiry oriented experiments (see figure 1);
- a feedback form for use by discipline based academics in assessing the feasibility of an experiment;
- a feedback form for use by academics to assess the experiment based on a review of student materials used to support the experiment;
- model survey questions to be provided to senior students/demonstrators who trial the prototype experiment;
- model survey questions to be provided to students when the experiment goes 'live' with its intended audience;
- focus group questions designed to reveal student and demonstrators view of the experiment;
- a classroom observations checklist for academics and educational developers.

The forms support the process outlined in figure 1. This framework has been successfully applied to the development of experiments for a first year physics service subject[3]. The process provides opportunities to obtain feedback on the new experiment from a number of stakeholders, at appropriate stages in its development. Feedback is elicited from:

1. Academics engaged in teaching the subject;
2. Independent academics from the discipline area who do not teach the subject;
3. Students who have already passed the subject in a previous year, and laboratory demonstrators who will be supporting the new experiment;
4: Students who are the first to experience the new experiment as it goes "live".

As the process of developing a particular experiment proceeds, the challenges faced and findings obtained from stakeholders through stages 1 to 4 in figure 1 may be used to amend, enhance or transform the experiment.

[3] Kirkup, L., Pizzica, J., Waite, K., Srinivasan, L (2010) *Realizing a framework for enhancing the laboratory experiences of non-physics majors: from pilot to large-scale implementation* European Journal of Physics, vol. 31, no. 5, pp. 1061-1070.

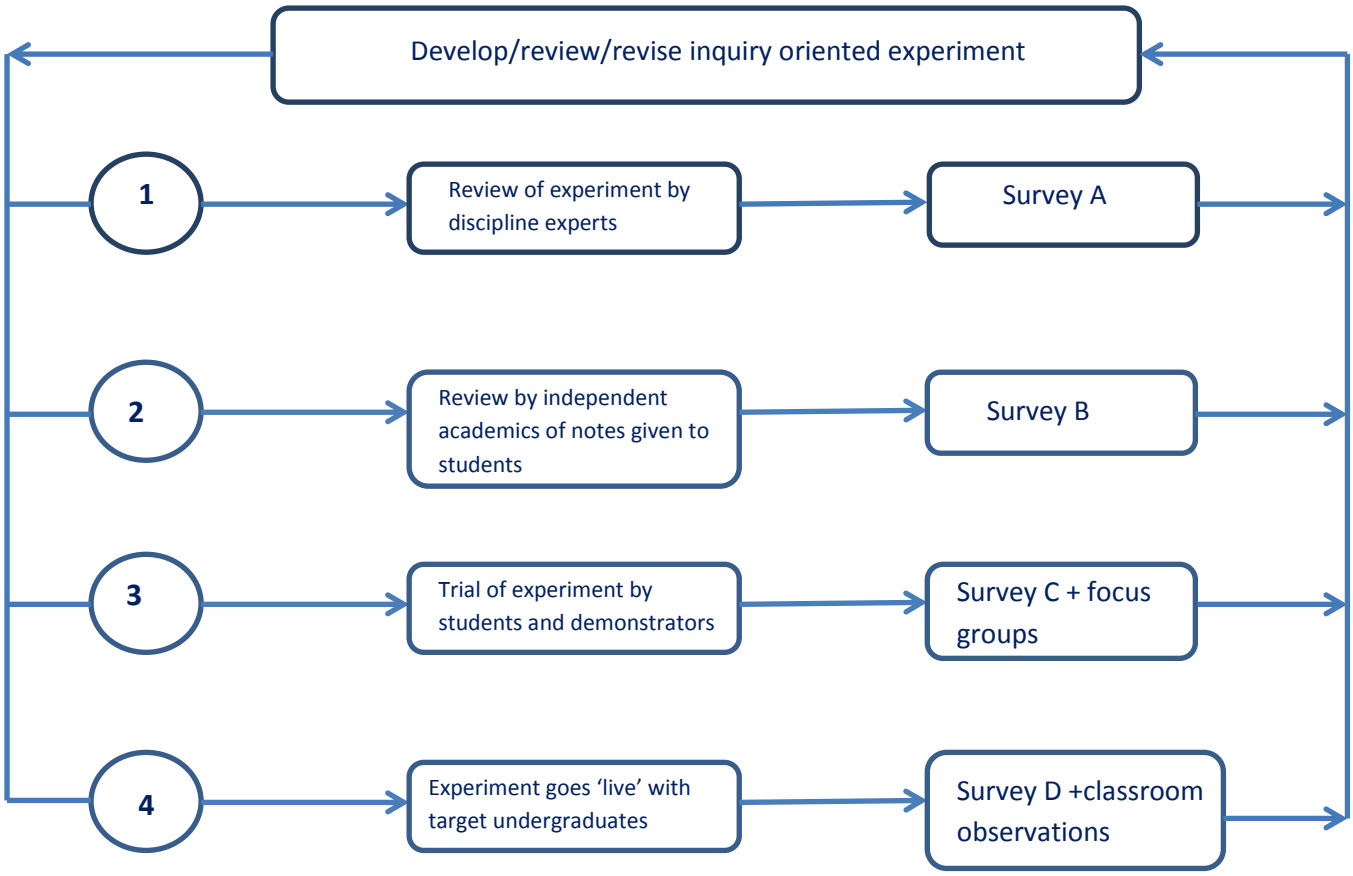

Figure 1: Flow diagram indicating the stages of trialling, evaluating and revising an experiment.

Flexibility

The resources contained in this document can be modified to suit various contexts. ***It is not intended that all the questions be included in surveys that you may run*,** but that appropriate questions are selected from the bank of questions offered.

For example, if the purpose of a particular initiative is to redevelop a recipe-type experiment to includes more inquiry, then several of the questions in survey A (for example 'Does the experiment connect well with the curriculum?', or 'Are there likely to be any Occupational Health and Safety (OH&S) issues with the experiment?') could be omitted.

Description of resources

Survey A - Feedback from academics in your discipline

A discipline-based academic, familiar with the topic of the experiment, can play an important role by trialling the experiment at a very early stage (even before student notes have been prepared). Such an academic is able to advise on feasibility and offer suggestions on the following issues:

- Is the experiment likely to assist in developing students' inquiry skills?
- What resources are required for the experiment and are there any budgetary implications?
- Is the experiment 'scalable'? Will it work with both small and large classes?

Such questions asked early in the development process can assist the developer to rethink an experiment at a stage where significant changes can made to the experiment, thereby avoiding wasting time and resources.

Survey B - Administered to independent academics who review notes for the experiment

Academics who have no stake in an experiment are often able to offer a detached and objective assessment of an experiment than those who have been intimately involved with its development. In contrast to survey A, this survey is designed to be administered after all the materials for student use have been developed. This survey is intended to assess, for example, whether the experiment is likely to foster within a student a deep approach to learning or whether the experiment has relevance to a student's professional development.

Survey C - Administered to senior students/demonstrators who trial the prototype experiment

Recruiting students who have already completed the subject in an earlier semester allows for an informed, student centred, and 'hands-on' review of an experiment and brings the issues of context and relevance to the fore. Recruiting demonstrators, who have had no input into the design of the experiment, brings another valuable perspective to the experiment and may also be a valuable professional development activity for demonstrators.

Survey D - Administered to 'real' students once the experiment has gone 'live'

This survey is intended to probe a student's experience of an experiment and contains similar questions to those appearing in survey C, allowing for a comparison between senior students' attitudes towards the experiment and those of novice students.

Focus Group questions

Short focus group sessions can bring to the surface issues that may not have been anticipated during the development of the experiment and can reveal matters such as the attitude of demonstrators towards a new experiment, or how they might run the experiment themselves when given the opportunity.

Classroom / Laboratory observations

The observation checklist is a guide to what kinds of activity and interaction you would usually expect to see as an inquiry-type experiment proceeds. Peer observers are able to provide a perspective on what actually happened during the class (as opposed to what was planned), and what issues should be focussed on that would be likely to improve the student experience. A peer observer should attend with the agreement of the demonstrator and be able to give the developer of the experiment confidential and helpful feedback for the purposes of improving the experiment while highlighting issues that might impact on student learning.

Survey A - Developing the Experiment

Feedback Form – To be completed by discipline based academics in assessing the feasibility of an experiment

	Question	Response
1	Would this experiment be a valuable learning experience for students?	
2	Does the experiment connect well with the curriculum content?	
3	Will the experiment give students an opportunity to be creative?	
4	Does the experiment require students to make judgements?	
5	Would students be able to complete the experiment in the allocated time?	
6	Are there any OH&S issues with the experiment?	
7	Can the experiment be scaled for large classes?	
8	Would students find this experiment interesting?	
9	Will students develop inquiry skills through this experiment?	
10	Does the experiment promote a deeper understanding of subject material?	
11	Could students confidently conduct this experiment?	
12	Would this experiment assist students integrate knowledge from different sources?	
13	Does the activity encourage students to seek a deeper understanding of the subject material?	
14	Does the experiment promote the development of problem solving skills?	
15	Is the experiment appropriate for students at this educational level?	
16	Would the experiment develop students' time management skills?	
17	Are students given control over the design of the experiment?	
18	What are the strengths of this experiment?	
19	What advice would you give the developer of the experiment before trialling it with students?	

Survey B – Developing the Experiment

Feedback form – To be completed by academics who peer-review the notes that accompany the experiment

	Based on the written details available on this experiment, there is evidence that the experiment:	**Extent of agreement (Please Tick)**				
Objectives:		**Yes**	**Probably**	**Possibly**	**No**	**Don't know/ unsure**
To foster deep approaches to learning	offers students a wider perspective on the role of science.					
	relates to a real world problem or issue.					
	integrates with the theory presented in lectures.					
	is sequenced with the lecture classes.					
	has open elements to it.					
	promotes an inquiry oriented approach to learning.					
	utilises students prior knowledge/experiences					
To have a relevance to students' professional development	promotes the development of experimental skills					
	requires the critical evaluation of data					
	encourages the development of experimental design and planning skills.					
	utilises data analysis techniques					
	requires conclusions be drawn from the data					
	involves the comparison of models with experimental data.					
	requires students to engage in effective teamwork.					

Objectives:		Yes	Probably	Possibly	No	Don't know/ unsure
To develop students' life long learning skills	provides opportunity for student autonomy.					
	requires information technology/literacy skills.					
	fosters time management/scheduling skills.					
	has assessment which consists of a variety of components.					
	requires student participation in discussion.					
To develop students' other generic skills	fosters teamwork skills in students.					
	encourages the development of written communication skills.					
	encourages the development of oral communication skills.					
	develops skill in leading discussion (presentation of results).					
	encourages lateral thinking &/or problem solving skills.					

In what ways can the materials prepared for student can be improved?

Survey C - Trialling the Experiment
To be completed by senior students/demonstrators who would answer the questions after they had trialled the experiment

		Extent of agreement (Please Tick)				
	Statement	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
1	The experiment worked					
2	There is sufficient time for students to complete the experiment					
3	The experiment encourages the development of students' conceptual understanding					
4	The pre-work assists in preparing students for the experiment					
5	The experiment assists students to develop their measurement skills					
6	The notes for students should be more detailed					
7	The experiment encourages the development of students' teamwork skills					
8	The experiment is interesting					
9	The demonstrator provided sufficient information					
10	Assessment requirements are clearly stated					
11	Students are able to develop their time management skills					
12	The experiment encourages the enhancement of students' oral communication skills					
13	The experiment encourages the students to think critically					
14	Students have an opportunity to be creative					
15	The student is given control over the design of the experiment					
16	The experiment is able to be delivered to large classes					
17	The experiment encourages the development of students' inquiry skills					
18	Class discussions were beneficial					
19	The experiment allows a deeper understanding of subject material					
20	The experiment encourages students' to integrate knowledge from different sources					
21	The design of the experiment allows for student autonomy					

As a learning experience how would you rate this experiment? Please circle one of the following options:

Outstanding **Very valuable** **Worthwhile** **Of little value** **Of no value**

Opened ended questions:

1. What are the strengths of this experiment?

2. In what way(s) could this experiment be improved?

Survey D - Evaluating the Experiment -

To be completed by 'real' students once the experiment has gone 'live'

		Extent of agreement (Please Tick)				
	Statement	**Strongly agree**	**agree**	**Neutral**	**disagree**	**Strongly disagree**
1	The experiment worked					
2	I had sufficient time to complete the experiment					
3	I was able to complete the experiment easily					
4	The pre-work helped me prepare for the experiment					
5	I had an opportunity to be creative					
6	The laboratory manual should include more detail					
7	Class discussions were beneficial					
8	I found this experiment interesting					
9	The demonstrator provided sufficient background information to make sense of the experiment					
10	Assessment requirements are clearly stated					
11	I can see the relevance of this experiment to my degree					
12	I now feel more confident about completing future experiments					
13	I was encouraged to evaluate the quality of my data					
14	I learned a lot from this experiment					
15	I was given control over the design of the experiment					
16	The demonstrator was encouraging					
17	The aim was clearly stated					
18	My interest in this subject has increased					
19	The demonstrator gave me good feedback					
20	The experiment connected well with the lecture material					
21	The experiment built my teamwork skills					
22	I was required to manage my time effectively					
23	I developed my measurement skills					
24	The experiment was linked to real life					
25	There was a strong inquiry focus to the experiment					
26	I had an opportunity to think for myself					

As a learning experience how would you rate this experiment? Please circle one of the following options:

Outstanding very valuable worthwhile of little value of no value

Opened ended questions:

1. What are the strengths of this experiment?

2. In what way(s) could this experiment be improved?

Focus groups – Evaluating the Experiment

Guidelines for focus groups and model questions for demonstrator and student focus groups

Focus groups allow for in-depth information to be gathered and provide further insights into the students' experience, and their attitudes towards the innovation. Within focus groups, students often provide suggestions for improvement or further development which academics may not have considered. Here are some guidelines for developing a deeper and broader understanding of inquiry experiments through focus groups.

- **Clear Purpose** - Focus groups should be clear in their purpose. Your intent may be to investigate a pre-determined question or to gain better insights about survey data. It is important to be very focused about your purpose to limit the number of questions.
- **Appropriate group composition** - Recruit participants who will provide information to meet your purpose. Consider if demographics are important i.e. gender, age, year of study, and possibly cultural diversity.
- **An appropriate moderator/facilitator –** It may be beneficial to have someone other than the experiment designer run the focus group, as students may speak more freely. A project officer, or someone from a teaching and learning unit may act as a facilitator.
- **Recruit more participants than you need** - 8-12 participants is a good size. Aim to recruit more students than you need as there is often around a 20% no-show.
- **Participants come with their own agenda** - Moderators should remain neutral and refrain from guiding responses. Often unanticipated statements from students provide useful insights
- **Appropriate time and place** - Plan a one hour session as soon after the experiment as possible in a comfortable convenient room. Refreshments help to create a relaxed atmosphere and act as a recruitment incentive for students.
- **Offer an incentive for participation –** Movie tickets, iTunes vouchers, Coop Bookshop Vouchers are commonly offered.
- **Recording the focus group –** It is useful to use a video or audio recorder. It is difficult to ask questions, listen for answers, respond with appropriate "probe" questions - and take comprehensive notes at the same time. If you are using a recording device, you should ask the students for their permission to do so. Alternatively, you may ask a colleague to take notes while you facilitate the discussion.
- **Transcribing the discussion and analysis –** If you have the budget, specialist transcription services will provide you with verbatim documents within a very short timeframe. These documents then allow a number of people to analyse the focus group document and to compare their analyses.
- **Listen –** It is important to listen attentively during the focus group as you may find opportunities to probe further, and participants will not always follow your script. Listening closely is likely to allow you to create a natural conversational setting, and elicit useful responses.

Good Moderating

- Encourages discussion and full participation
- Pays attention to body language/and the use of language
- Outlines to participants the purpose of the focus group, the time allocated, confidentiality and that that there is no right or wrong answer

Guidelines for developing focus group questions - your focus group 'script".

Encourage diverse responses - Use open ended neutral questions. Often there are specific areas you might want participants to comment on. A well designed open-ended question is likely to elicit responses covering that area. However, it may not, so it is useful to prepare "probe" or "prompt" questions to use if participants do not address the area you are interested in.
General to Specific - Start with a general question that you expect all participants to be able to comment on. Then move to more specific questions.
Natural Flow - Ask questions in a conversational style using terminology familiar to participants and introduce questions as you would in the flow of a natural conversation
An appropriate number of questions in your focus group script. 6 questions is a good guide for a one hour focus group. – Prepare your main questions with follow-up prompts or "probes" where applicable.

In developing questions the following matrix could be used to help "focus" your purpose and the area you wish to investigate, model questions are also provided as an additional guide

Deep Approach to Learning Inquiry experiments seek to encourage students to: • Examine new facts critically • Make numerous links between ideas and information • Analyse data • Understand and retain concepts • Have a curiosity in the subject material • Engage in active learning • Relate to new material • Build a wider perspective on the role of science	**Relevance to Students Professional Development** Inquiry experiments seek to encourage students to: • Apply scientific concepts to real world problems or issues • Develop experimental design skills • Build knowledge of subject material • Utilise data analysis techniques • Engage in the comparison of models to data • Engage in effective teamwork • Develop strong measurement skills
Development of students lifelong learning skills Skills include but are not limited to: • Ability to seek out and interpret information • Critical thinking • Information technology and literacy skills • Lateral thinking • Problem solving • Ability to project plan and manage • Ability to act autonomously • Ability to evaluate alternatives	**Development of students generic skills** Skills include but are not limited to: • Written communication • Oral communication • Critical and analytical thinking • Teamwork • Interpersonal skills • Independent learning • Information literacy

Model Focus Group Questions

1. Questions for focus group sessions following trial of experiment with senior students and/or demonstrators

1. What did you think of the experiment?
(This question will elicit both negative and positive views and it likely to create a great deal of conversation.)

Follow up Prompts

- What did think were the best things about the experiment?
- What could have made it better?
- How did this experience affect your learning of the subject material, and of science more broadly?

2. How relevant was this experiment to your degree, or your major?
Follow up Prompts

- Can you explain how? Or give an example? (of the relevance)
- How relevant was the experiment to the 'real world' – How important is that?

3. As a "student", what was the benefit of the experiment to you – did you think that it helped you develop any skills?
Follow up Prompts

- Prompt with specific examples of lifelong learning and generic skills, such as problem –solving, communication skills, teamwork, or whatever you believe is relevant and has not been volunteered by students responding to the earlier question.
- Did this experiment offer the opportunity to develop skills which you have not had the opportunity to develop in other experiments?
- In what way?

4. What did you think of the background explanation and pre work?
Follow Up Prompts

- How easy was it to understand and or complete?
- What did the pre-work add to the experiment, if anything?
- Was anything confusing?
- What could be better?

5. What would it be like to be the demonstrator for this experiment?
Follow Up Prompts

- Are there any problems you can anticipate?
- What sort of training would demonstrators need?
- How do you think new students would respond to this experiment?

6. Is there anything that you think the developer of the experiment should address before running the experiment with 'real' students?

2. Questions for focus group sessions following trial of experiment with 'real' students

1. What did you think of the experiment?
(This question will elicit both negative and positive views and it likely to create a great deal of conversation.)
Follow up Prompts

- What did think were the best things about the experiment?
- What could have made it better?
- What did you learn?
  How did this experience affect your learning of the subject material?

2. How relevant was this experiment to your degree, or your major?
Follow up Prompts

- What is your degree/ major?
- Can you explain how? Or give an example? (of the relevance)
- How relevant was the experiment to the 'real world' – How important is that to you?

3. Do you think you have developed any skills from doing the experiment?
Follow up Prompts

- What skills?
- Prompt with specific examples of lifelong learning and generic skills and check if those skills were developed?
- Did this experiment offer the opportunity to develop your skills more than other experiments you have done this semester – In what way?

4. What did you think of the background explanation and pre work?
Follow Up Prompts

- How easy was it to understand and or complete?
- What did the pre-work add to the experiment, if anything?
- Was anything confusing?
- What could be better?

5. What do you think the lecturer was trying to achieve with this experiment?
Follow up Prompts

- Did it meet those expectations? How?

6. Would you recommend to the developer that this experiment runs again next semester?

Classroom Observation List

Classroom Observation	Consistently	Occasionally	Not observed	N/A
DEMONSTRATOR				
At the start of class the demonstrator: Encourages and assists students to present pre-work answers to peers				
Uses examples drawn from real-world applications to explain the application of the experimental principles in different disciplinary contexts				
Clearly and concisely introduces enough of the purpose and initial stages of the experiment for students to commence their own inquiries				
Encourages students to suggest appropriate hypotheses/procedures				
Encourages students to discuss and plan the experiment with peers				
During the experiment the demonstrator:				
Continuously moves around the room, questioning and interacting with students				
Encourages students to explain and clarify their opinions/observations before offering comment				
Encourages students to explain their observations and procedures using open-ended questions and questions where there is more than one correct answer				
Assists students to keep to time by monitoring progress of each student/group				
At the end of class the demonstrator:				
Encourages students to present their methods and findings to the class				
Facilitates a class discussion comparing the different methods and results of various groups				
Discusses relevance of results to the aims of the experiment				
Discusses relevance of results to real-world examples				
Generally:				
Appears prepared and organised				
Appears confident				
Manages class time effectively				

Is clear and audible when addressing comments to the entire class				
Shows enthusiasm for the subject				
Has a good rapport with students				
STUDENTS				
At the start of class students:				
Share pre-work results				
Ask questions to clarify the experimental process				
During the class students:				
Are actively engaged in inquiry and problem solving				
Are taking the initiative by developing an experimental method and hypothesis				
Work cooperatively in their groups				
Work actively to complete each stage of the experiment				
Discuss aspects of the experiment with their team				
Encourage peers to complete the work and keep to time				
By the end of class students:				
Present their methods and findings to the class				
Discuss how their results compare to findings of the other groups				
Have a positive experience of learning in the laboratory				
ENVIRONMENT AND EQUIPMENT				
Resources available are sufficient to carry out the experiment				
Adequate technical support was available throughout the lab				
Layout of the lab allows for effective student presentations and class discussion				

Comments: