Student Research and Publishing Program in Secondary School Science: Description of the Program and Model for Implementation

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Introduction

In order to effectively implement the Student Research and Publishing Program in a new Secondary School Science Program, we must first establish the value of the SRPP and develop an understanding of what a successful SRPP looks like. I have thus started with a brief overview of the value of the SRPP. Next I outline the successfully established Student Research and Publishing Program at International School Bangkok (ISB). Finally, I describe in detail the Model for Implementation. The claims and model in this document are based on evidence gathered from surveys and interviews of those involved in the SRPP currently established at International School Bangkok. In the interest of brevity I will not cite all the supporting evidence in this document.

Value of the Student Research and Publishing Program

The Student Research and Publishing Program in Secondary School Science established at ISB has been shown to have a significant impact on students over a wide range of areas. For students, the SRPP improves all areas of skills in scientific research, including researching and understanding theory, designing and conducting investigations, and analysis and interpretation of results. It improves student writing and presentation skills. The SRPP has been shown to improve student understanding of the process of scientific discovery, and gives experience and confidence in their ability to participate in the scientific community, leading to increased levels of participation in research at university. It increases enthusiasm for science in general.

The SRPP also raises the general level of performance in classroom scientific investigations, as it increases motivation and offers opportunity for students to authentically challenge themselves. Finally, for those who publish papers, the SRPP further increases their scientific writing ability, their understanding of the process of science and gives them a sense of pride and accomplishment as a result of their publishing a paper. Authors have the experience of participating as authentic members of the scientific community, having published in the ISB Journal of Science, whose papers are regularly cited by papers published in professional scientific journals. Authors also have had the opportunity to present their papers at regional science conferences. The SRPP is seen as a valuable addition to the science program at ISB by students, teachers, and administrators.

The Student Research and Publishing Program

The process of science can be understood to consist of three basic parts. The first step in doing science is **mastering current knowledge**. This involves learning about what we already know about the world, understanding current theory. This step is crucial and time-consuming, and without it, there is no science. Once scientists have mastered current knowledge, they attempt to **create new knowledge** through scientific investigation. Finally, if their investigations yield valid new knowledge, scientists **publish** their newly created knowledge, sharing it with the rest of the scientific community so that it becomes part of the body of current knowledge.

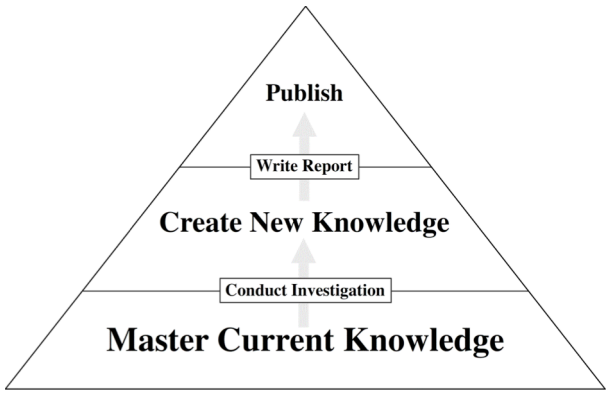

Figure 1 Simplified SRPP model of the Scientific Process

Most Secondary School Science programs focus almost exclusively on the first step, mastering current knowledge. Students spend almost all their time learning from textbooks about what we already know, laboratory investigations tend to be confirmatory exercises of current theory. In the Student Research and Publishing Program, we use this three-part understanding of the scientific process as a model for our science classes. Most of the time in our classes is spent covering the typical content of high school science courses around the world, but our students understand that this "mastering current knowledge" is not the final goal of the course, but a crucial foundation for the important next steps in the scientific process. Students in our science courses use the knowledge they have gained from the course content to create new knowledge through designing, conducting, and reporting on, original scientific investigations. Finally, students whose investigations have yielded valid and reliable results are invited to publish a paper in the peer-reviewed academic journal, the ISB Journal of Science.

The Student Research and Publishing Program is most easily understood if we look at the Research part of the program separately from the Publishing part. I will start with the Research part of the program.

Research in the Student Research and Publishing Program

Original scientific research is an integral part of the science program at ISB. Starting in grade 9, all students are required to conduct one piece of original scientific research each semester. In each course, students experience a scaffolded series of laboratory investigations, starting with guided-inquiry and leading to open-inquiry types of investigations. These expose them to, and help them master, the skills needed to design, conduct, analyze, and report on independent, original investigations related to the content of the course. Students are supported in this with an on-line "Writing Guide" which describes and explains the skills needed in scientific investigations and reporting, and offers exemplars for the students to use as models. Near the end of the course, students are required to conduct an original, independent research project (IRP), which, as an extension of the content covered in

the course, explores an unknown corner of the world, asking a question to which no one completely knows the answer. While the questions investigated by students are usually quite unimportant in the grand scheme of things, they *are* questions that no one knows the answer to, and therefore count as 'creating new knowledge'. Students in courses that are part of the SRPP are made aware of the Journal of Science and told that they will be offered the chance to publish a paper on their IRP if their results are original, reliable and valid. They choose their topic of investigation with this in mind. While few grade 9-10 students are capable of work at the level necessary to produce publishable research, occasionally one of them will produce and publish a paper on their IRP in the ISB Journal of Science.

In grades 11 and 12, students enroll in two-year IB science courses. The curriculum consists of a prescribed theoretical content along with a required number of hours spent doing laboratory investigations, with students required to show competence in the design, conduct, analysis and presentation of scientific investigations. As with grades 9 and 10, students in courses that are part of the SRPP think in terms of the three-part model of the scientific process. They understand that the mastering of the course content is the necessary foundation for the next steps of creating new knowledge and publishing. They are made aware of the Journal of Science and the opportunity to publish research that is of an adequate standard. Lab experiences in the course are scaffolded to continue to help the students develop the skills needed to conduct scientific research. Students again have access to a Writing Guide for the IB Science courses. The course lab experiences lead to a series of several IRP's, which must be grounded in course content, that are conducted in the latter part of the course. Before each IRP, students are reminded of the opportunity to publish if their work yields original, reliable, and valid results.

Students in the SRPP develop the knowledge and skills needed to design, conduct, analyze, and report on original scientific research. They do this through mastering course content and experiencing an appropriately leveled series of laboratory investigations during the course progressing from guided-inquiry to open-inquiry. Students then demonstrate their ability to create and report on new scientific knowledge through the Independent Research Projects that they conduct in each course.

Publishing in the Student Research and Publishing Program

The ISB Journal of Science is an on-line, peer-reviewed, entry-level scientific journal dedicated to publishing the original research of ISB students. The Journal is a registered publication with ISSN 2286-8038. The Journal is published on an annual basis, with papers published on a rolling basis as they are completed.

Publishing a paper is an opportunity that is presented to all students. It is not a part of the course: students write and edit the paper outside of class time and receive no class credit for publishing. Typically, about 10-20% of students publish a paper during the two years of their SRPP-based IB science course. The following section describes the process by which student research is selected and externally reviewed, and the paper is written, revised and published.

Selection and Peer Review

After students have completed their IRP's in a course, the teacher reviews them and selects any which fit the publishing criteria, which are:

Originality The research must be original. It must not be a repeat of a well-known principle or an investigation that yields a trivial, predictable result.

Validity The results must lead to a valid conclusion. The results must show a clear trend that fits applicable theory.

Confidence The uncertainties in the results are small, giving the conclusions a reasonably high level of confidence.

Continuity The research suggests further areas of worthwhile investigation.

Importance The work does not need to be particularly important, as long as it adds a small piece of valid and reliable knowledge to the current human store.

Once the teacher has selected potential IRP's for publishing, the teacher consults with the authors of the IRP's to ensure that they have the desire, ability, and time needed to publish their work. Once the teacher has completed the IRP selection process, the IRP reports are forwarded to the Editor of the Journal.

The Editor reviews the selected IRP's to ensure that they meet the criteria and then forwards the IRP reports to appropriate external reviewers. The reviewer looks at each IRP and determines whether the work matches the criteria for publishing. It is important to note that the Reviewer does not know the identity of the authors. The Reviewer sends the submitted IRP's back to the Editor with an explanation of the decision on each.

It should be noted that the external review process is crucial to ensuring the accuracy and validity of the published work. Without a strict review process, the Journal would be nothing more than a place to post student work.

Writing and Editing the Paper

Once an IRP has been approved for publishing, the teacher works with the student authors, in consultation with the Editor, to write and revise the paper. Given that the style for scientific papers is very different from that for school lab reports, the students are provided with exemplars to help them write the paper. The teacher works with the students, in consultation with the Editor, to write and revise the paper. This process typically takes three to four drafts before a final paper is produced.

Final Review and Publishing

The final draft of the paper is submitted to the Reviewer for final approval. The Reviewer either approves the paper for publication or suggests modifications. After addressing the Reviewer's suggestions as necessary, the paper is published in the current issue of the Journal.

Model for Implementation of a Student Research and Publishing Program in Secondary School Science

The Student Research and Publishing Program in Secondary School Science has been shown to yield positive results over a range of student research and publishing abilities and attitudes. It is expected that schools that are made aware of this program may be interested in implementing it. The following is a model that can be followed by secondary schools during implementation of a Student Research and Publishing Program in science. It is expected that using this Model for Implementation at a school will result in a successfully established Student Research and Publishing Program at that school. A successfully established Program is defined as having the characteristics and outcomes of the currently established SRPP described in detail earlier. This includes using the simplified SRPP model of the Process of Science as a focusing structure for the course. It also includes having Independent Research Projects (IRP's), where students conduct authentic, original experimental research, integrated into all courses participating in the Program, as well as Journal papers being published regularly. A successful SRPP will have student outcomes similar to those described in the first four objectives addressed in this chapter.

The Model for Implementation of the Student Research and Publishing Program is divided into four phases, described in detail in the following pages. A visual representation of the Model for Implementation is shown in Figure 2, to help readers gain an understanding of the model as a whole.

Phase 1: Decision to Adopt - *Determining the Suitability of the Student Research and Publishing Program for a School*

The first step in the implementation process is to verify the suitability of the SRPP for a particular school. It is clear that this program is not suitable for all schools and that not all schools have the capacity to successfully implement it. It is thus necessary for a school to conduct a study to determine whether the SRPP could be successfully implemented.

Organizational Characteristics

The following are the characteristics of a school that is likely to benefit from the SRPP and at which implementation has a higher chance of success.

Administrative Flexibility. The administrative structure of the school must be quite flexible. Schools that allow teachers and students the freedom to experiment and innovate are more likely to succeed. Schools which are rigid in the curricular and program requirements, which have tightly prescribed programs, and at which new programs require approval from many levels of the organization are unlikely to succeed in, or benefit from, implementation of the SRPP.

Curriculum. The curriculum at the school must be one that allows for significant time to be devoted to lab work. Open-inquiry must be a regular feature of the secondary science courses at the school.

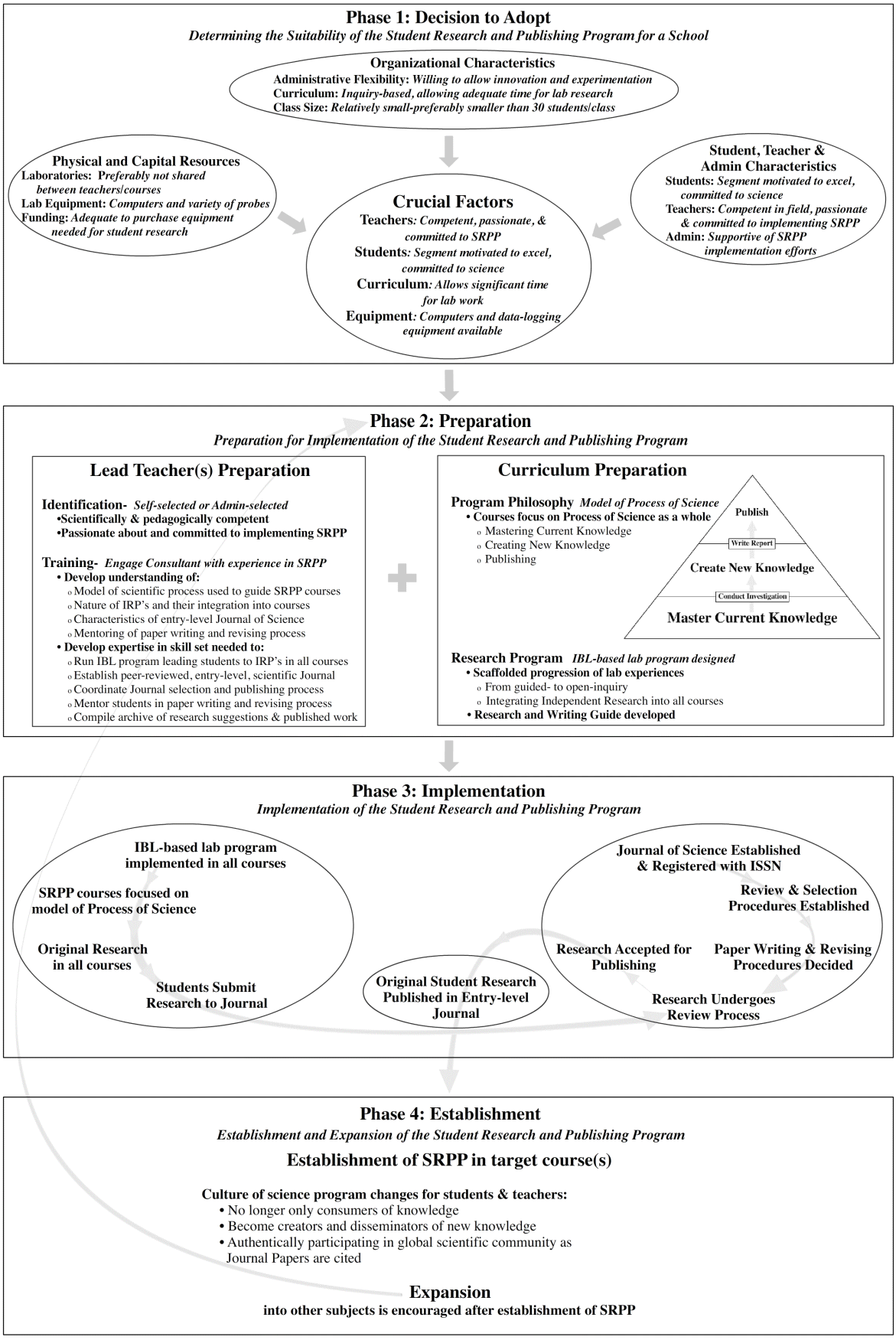

Figure 2 Overview of the Model for Implementation of the SRPP.

Class Size. Class sizes at the school must be small enough so that teachers have the time to institute Independent Research Projects as part of the curricular program. In a class of 40 students it would be impossible to run IRP's, and the time required to grade the reports would be untenable for the teacher. Class sizes of 25 or less are recommended for successful implementation of the SRPP.

Physical and Capital Resources

Laboratories. While having one lab for each teacher is an advantage, the SRPP can be implemented in schools where teachers share lab rooms.

Lab Equipment. Any school that has science labs furnished to a standard typical of schools in developed countries, with computers and peripherals for data collection, is capable of implementing the SRPP. The ability to source a variety of non-typical equipment on short notice is an advantage, as that allows students to follow their interests when conducting Independent Research Projects.

Funding. The school must have the funding to support the SRPP. While not excessive, funding is needed for the purchase of a variety of equipment for IRP's. Funding for teacher stipends may also be considered.

Student, Teacher and Administrator Characteristics

Students. There must be a significant proportion of students at the school who value education and are interested in pursuing science as a career. It is not necessary to be a selective school with gifted students. Students who are motivated to excel and are committed to science are all that is needed to be able to implement a successful SRPP.

Teachers. The school must have one or more teachers who are well-trained in their disciplines. They must be skilled in teaching open-inquiry in science and familiar with the process of scientific research. They must be passionate about teaching science, able to inspire and engage their students. Finally, and it must be emphasized that this point is crucial, the teacher(s) selected to implement the program must be passionate about, and strongly committed to, implementing the Student Research and Publishing Program. If these key criteria are not met, it is not expected that a school will be successful in implementing the program.

Administrators. Administrators at the school should understand the SRPP and see the value in it, commit adequate resources to supporting it, and, if necessary, work to clear any institutional roadblocks to implementing the program. Given that the SRPP is primarily teacher-driven, there is little requirement for direct administrator action beyond this.

A summary of the factors to be considered in determining the suitability of a school for implementation of the SRPP is shown in Table 1, below, with an estimation of its relative importance in determining the success of the program.

If conditions at the school are in reasonably close alignment with those outlined above, it can be concluded that the Student Research and Publishing Program would be highly beneficial to the students and its implementation stands a high chance of success. It must be emphasized that the lack of any factor rated crucial in Table 1 is expected to lead to failure in the implementation of the SRPP, and implementation is not recommended.

Level of Importance	Factor
Crucial	Lead teacher who is competent, passionate about, and committed to the SRPP
	Segment of students motivated to excel and committed to science
	Curriculum that allows significant time for lab work
	Computers and data-logging equipment available
Important	Administrative flexibility
	Small class sizes
	Funding to support program
Helpful	Administrators committed to the program
	Well-equipped labs
	Dedicated labs
	Ability to quickly source non-typical equipment

Table 1 Factors to be considered in the decision to implement the SRPP.

Phase 2: Preparation - *Preparation for Implementation of the Student Research and Publishing Program*

> Note: For this part of the Model, it will be assumed that the school meets all the crucial criteria outlined in Phase 1. If a school is lacking in any specific area, it is recommended that the issue be addressed **before** implementation of the SRPP. The details of the remediation process needed in any particular area are beyond the scope of this Model and will not be addressed here.

The preparation necessary for implementation of the SRPP varies with the school. Each school will find itself in a unique situation, so each school will have a unique path to implementation of the SRPP. However, certain general areas of preparation can be identified.

Identifying the lead teacher(s) for implementation of the SRPP

This can occur in one of two ways. If the administration of the school is the driving force behind implementation, they need to approach a teacher or group of teachers that meet the criteria with a proposal to implement the SRPP and obtain their commitment to the program. This commitment may take some time to obtain, depending on the school and the teachers. It is also possible for implementation of the SRPP at a school to be teacher-driven. In this case one or more teachers will see the value of the SRPP and commit to implementing the program. They would need to approach the administration to obtain their commitment to support the program as necessary.

This is probably the most difficult step in the whole process. Given that the drivers of this program are teachers, it is impossible to implement without the leadership of a teacher who is scientifically and pedagogically competent, and is passionate about, and committed to, establishing the SRPP at the school. This point cannot be emphasized strongly enough.

Training the lead teacher(s)

Implementation of the SRPP will be most efficient and have the highest chance of success if a consultant with experience in running a successful program is engaged to train the lead teacher(s).

The details of how the training is conducted are highly dependent on the circumstances of both the lead teacher and the consultant. The training may take the form of a short initial workshop, followed by continued support via electronic communication. If the consultant or a school with an established SRPP is close to the implementing school, it may be more effective to have a series of exchange visits over the course of implementation.

Whatever the form of the training, the consultant will need to ensure that the lead teacher(s):

- Understand the benefits of the program, including expected student outcomes and long-term changes in school culture.
- Develop an in-depth understanding of the details of the program, including:
  - the nature of the scientific model used to guide teacher and student thinking,
  - the nature of IRP's and how they are integrated into the courses,
  - the establishment of the Journal and the criteria for selection,
  - and the paper writing and revising process
- Develop expertise in the skill set needed to implement and run the program, including:
  - using a scaffolded series of lab investigations, from guided-inquiry to open-inquiry, to prepare students for IRP's,
  - running an IRP program in each course,
  - coordinating the Journal selection and publishing process
  - mentoring students in the process of writing and revising a paper.
  - compiling an archive of exemplars and published work at the appropriate level, along with suggestions for general topics likely to be suitable for the level of the students and the equipment available.

The use of an established program as an exemplar of all the components and processes involved in the SRPP would be beneficial in this process. The lead teacher(s) could study all aspects of that program as part of the training process.

Preparing the curricular research program

It is essential that the philosophy and organization of the science program be aligned with the SRPP. Each course must be (re-) designed to focus not only on content mastery, but on the process of science as a whole. It is recommended that a

simplified model of the scientific process, like that shown in Figure 1, be used to help students understand.

Students must be reminded regularly that the mastery of the course content is the foundation for the knowledge creation and publishing processes. Mastering content for the sake of the content is not enough. New knowledge must be created and then published to add to the current knowledge.

The lab component of each course must prepare the student for the culminating Independent Research Project, in which students design and conduct original research within the context of the course content to create new knowledge, with the view to potentially publishing their results. The need for this (re-) design step will depend on the school, with some schools having Independent Research programs already established only needing minor tweaks while schools without a well-established IRP program will need more significant modifications to their programs.

It is also recommended that a resource be developed that guides students in how to design, conduct, and report on IRP's. This 'Research Guide' describes best-practice in designing and conducting IRP's, and gives detailed guidelines on the requirements for writing the report for the IRP. This resource should be available to all students and referred to regularly by the teacher to help students as they plan and conduct their research and report their findings.

Establishing appropriate teacher compensation and student recognition

A system offering compensation of some form for the teachers involved, whether it be financial or time-based, should be established in preparation for implementation of the SRPP. It is recommended that recognition of achievement protocols for students who publish their work be considered. The ways in which students are recognized will vary according to the school, but may take the form of recognition at assemblies or in school publications, or the issuing of certificates of achievement.

Phase 3: Implementation - *Implementation of the Student Research and Publishing Program*

Once the lead teacher(s) have been identified and trained, and the curricular research program has been designed, it is time to begin implementation of the Student Research and Publishing Program.

Research

Implementation of the SRPP should start with implementation of the in-course research part of the program, if it is not already well established. Courses must be implemented, starting with the first year in the upper secondary school, which have an IRP incorporated into them. Students in all courses need to be regularly reminded of the philosophy of the program, with its emphasis on the scientific process, and the IRP's focus on knowledge creation with a view to potentially publishing a paper. It must be emphasized in the program that publishing work depends on the results of the research, and not on the desire of the student to publish. The level of difficulty of this step is very much dependent on the situation in the school. As noted above, schools with well-established IRP

programs will need to spend little time on this step, while other schools might need to expend significant effort.

Publishing

After the research aspect of the program has been established in the science program for a year or more, it is expected that some students will begin to produce work that is worthy of consideration for publishing. Now is the time to establish the capacity to publish student work. In order to do this the *Journal of Science* must be established, then the publishing process must be established and teachers trained.

Establishing the Journal of Science. An online Journal requires a website. Whether this is designed and managed by the lead teacher or by a member of the tech department is unimportant. It is important that the Journal be registered with the ISSN center in the country of publication. This establishes legitimacy and allows other scientists and journal indexing sites to recognize the Journal as a legitimately published academic journal.

Selecting and training Reviewers. An important aspect of the current scientific publishing process is the review process. Having submitted papers reviewed and approved anonymously by outside experts is how the scientific community ensures the validity of published work. It is crucial that knowledgeable and respected reviewers be selected to participate in the program. Either the lead teacher or the consultant must then train the reviewers in their role. The training should brief the reviewers on the publishing guidelines, the process of reviewing the original submitted work, and then reviewing and approving the final paper. Reviewers may be current or former teachers, or experts in the field with links to the school. Reviewers must not know the identity of the students whose work they are reviewing, in order to ensure impartiality and integrity in the selection process.

Implementing the publishing process. The process of establishing publishing criteria and processes for an entry-level scientific journal, and then selecting, preparing, and publishing student work is probably the most unique and difficult process in this program. It is helpful if the lead teacher(s) has support from the consultant for this. Training, exemplars, and communication with the consultant during the first rounds of publishing will increase the efficiency of this process. The details of the training process for establishing publishing criteria, the selection process, and the paper writing and revision process are based on an exemplar Student Research and Publishing Program. These will not be discussed here, as they are beyond the scope of this Model for Implementation.

Phase 4: Establishment - *Establishment and Expansion of the Student Research and Publishing Program*

It is important that a school that is implementing the Student Research and Publishing Program understand that this program changes the culture of a science program. Rather than being only *consumers* of science content, students and teachers become *creators* of new knowledge, actively and authentically participating in the global scientific community when a paper is published. As it represents a change of culture, the full embedding of the SRPP into the science program can be expected to take years. A long-term commitment to the program is required. Difficulties can be expected and should not be allowed to result in the abandonment of the program. Once the SRPP is well embedded within the science

subject(s) of the original lead teacher(s), the school may consider expanding the SRPP to other science subjects, or even to other courses which might conduct original research, such as Psychology. The expansion of the SRPP into new subjects can be done following the same process as outlined in this Model for Implementation.

Implementation Timeline

The timeline for implementation of the Student Research and Publishing Program at a school is highly dependent on the situation at that school. However, for planning and projection purposes, estimates of the time needed for each phase of the process can be made.

Phases 1 and 2 together, making the decision to adopt the SRPP and then preparing for implementation, would be expected to take approximately one to two years: one year for a school that had a science program with the IRP's already integrated into it, and two years for a school that needed to implement IRP's into their science program.

Phase 3, implementation of the SRPP, would be expected to take another one to two years, again depending on the situation of the school. A school that had a strong culture of research already established could probably see its first issue of a Journal after only one year, while a school where both teachers and students had little experience with independent research could be expected to take two or more years to publish its first papers.

Phase 4, embedding of the SRPP into the culture of the school, is expected to take between two and five more years, with consideration of expansion into other subjects recommended after that period.

Summary of the Model for Implementation

Implementation of the Student Research and Publishing Program in Secondary School Science can be broken into four phases, illustrated in Figure 3.

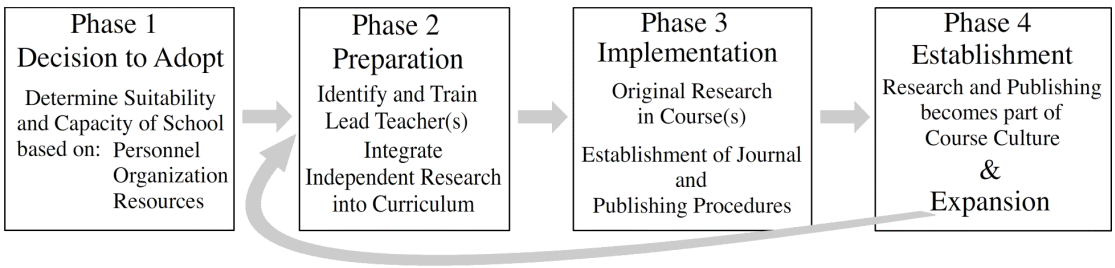

Figure 3 Summary of the Structure of the Model for Implementation of the Student Research and Publishing Program in Secondary School Science.

1. **Decision to Adopt: Determining the suitability of the Student Research and Publishing Program for a school.** The characteristics and capabilities of the school must be determined to be suitable for the implementation of the SRPP. Schools lacking key requirements are recommended not to implement the SRPP.

2. **Preparation for Implementation of the Student Research and Publishing Program.** This phase involves identifying and training the lead teachers who will implement the program, as well as ensuring that the curricular program includes an Independent Research component in courses at all levels.
3. **Implementation of the Student Research and Publishing Program.** This involves integrating original student research into all courses, with the awareness of the possibility of having work published. Then a Journal must be established, with its attendant selection, writing, and publishing processes defined and implemented.
4. **Establishment and Expansion of the Student Research and Publishing Program.** Over time, a culture of scientific research and publishing will be established within the school, and the expansion of the program into other subjects (assuming it was initially implemented in only one or two subjects) can be considered. Expansion into new subjects will follow a model similar to initial implementation.

The Model for Implementation of a Student Research and Publishing Program in Secondary School Science was constructed based on data gathered from students, teachers and administrators involved in a currently successful Student Research and Publishing Program in Secondary School Science. Use of the Model by a secondary school is expected to lead to the establishment of a successful Student Research and Publishing Program in the Sciences.