

Subjective causality model for postgraduate research

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Short abstract

While there are many perspectives on postgraduate research, the systematic modelling perspective is poorly represented in this area, and models of postgraduate studies are scarce. This paper develops a system model of the learning process itself, the cognitive development, the intersection of the loci of effort of the main protagonists (Student and Supervisor), and the research methodologies used to further the venture. It represents the causal factors that are surmised to affect student success. It also provides a theoretical framework within which to interpret the body of knowledge. One of the central concepts that emerges from this model, is that of the strand of purpose. This flows through the whole research venture: setting up the research proposal, guiding the research, providing personal motivation, and finally becoming the golden thread that runs through the thesis, terminating in the conclusions.

Document and revision: 2011_Rs-0_Research_E1.09.doc

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Abstract

While there are many perspectives on postgraduate research, the systematic modelling perspective is poorly represented in this area, and models of postgraduate studies are scarce. This paper applies a modelling process borrowed from the area of process-engineering. By process-engineering we do not refer to mere flow diagrams of the administrative processes, but to a deeper systematic modelling of the learning process itself, the cognitive development, the intersection of the loci of effort of the main protagonists (Student and Supervisor), and the research methodologies used to further the venture. When epistemic uncertainty is high, as in this case, then models necessarily have to represent what knowledge is available, which tends to be qualitative data bound together with subjective relationships, hence a 'subjective causality diagram'. It represents the causal factors that are surmised to affect student success. It also provides a theoretical framework within which to interpret the body of knowledge. Also, it is straightforward to extract implications for the protagonists. It is thus a deployable model. One of the central concepts that emerges from this model, is that of the strand of purpose. This flows through the whole research venture: setting up the research proposal, guiding the research, providing personal motivation, and finally becoming the golden thread that runs through the thesis, terminating in the conclusions. Without that purpose, everything frays, and the quality, being fitness-for-purpose, is decreased. This paper makes the contribution of introducing to this particular field a method of systematic modelling. This has the potential to add value by contributing diversity to understanding the research process. Second, it introduces a novel conceptual model of the research process, in the form of a subjective causality model, with implications for further research as well as application by practitioners.

1 Introduction

While there are many perspectives on postgraduate research, the intellectual process is seldom analysed from a systematic process-perspective. This is strange, since postgraduate research is a process after all, both for the Student and the Supervisor. They each have different activities to do, and follow their own locus of effort for large parts of the project. Yet it is essential that those process-streams combine smoothly at the correct times so that the overall purpose of the venture is achieved. This situation is similar to any production engineering system, except that rather than producing cars or products, the output of the postgraduate process is the developed knowledge represented in the thesis. Even the industrial engineering concepts of quality, fitness for purpose, and

dimensions-of-value are potentially transferrable: the quality of a thesis being measured by the intellectual contribution to the body of knowledge.

The *practice* of postgraduate research might be generally understood in an individual subjective way, but the *theory* thereof is largely absent. From a practitioner's perspective, both the student and supervisor, this is a problem because many research projects create a great deal of stress for the participants, and some even fail. Better theories would at least help us understand why, and perhaps even give us new solutions. This paper applies a systematic modelling method, which is adapted from the production-engineering area, to create a novel conceptual model of the research process. We term this a subjective causality model.

Lest there be any doubt, by process-engineering we do not refer to mere flow diagrams of the administrative processes, but to a deeper systematic modelling of the learning process itself, the cognitive development, the intersection of the loci of effort of the main protagonists (Student and Supervisor), and the research methodologies used to further the venture.

2 Existing approaches

Unfortunately there is a scarcity of general system-models of the postgraduate process. This is a reflection of the state of the body of knowledge: it is not known with any certainty what variables determine success, or how the relationships of causality operate. Some of the variables have been identified, for example one study identified five requirements: 'trust, theories, tools, training and time' (Emilsson & Johnsson, 2007) (p163). These were extracted subjectively from descriptive survey responses. Institutions survey their own students, so there is some understanding of what makes for effective supervision at the practitioner level. Standardised surveys of undergraduate perceptions are emerging, e.g. the Australasian Survey of Student Engagement (ausse.acer.edu.au) but the field is weaker for postgraduates.

The systematic modelling tradition is particularly poorly represented in this area, the only known model of substance being Meyer's model (Meyer, 2007), which is a type of contingency-model. He suggested that learning outcomes arise from prior knowledge, the learning process, and a variety of personal factors (motivation, culture, locus, among others). It was proposed that relationships existed between these variables, though these were not detailed. Meyer was familiar with the difficulty of modelling this area, commenting that 'student learning is a complex multi-dimensional and multivariate phenomenon that cannot be decontextualised. There is thus an immediate and acknowledged difficulty in attempting to reduce considerable complexity into a two-dimensional figure in a manner that preserves important detail' (Meyer, 2007) (p1105).

The residual problem is that no integrative theory has yet emerged describing and predicting the causal relationships that lead to successful outcomes from the postgraduate study process.

If empirical research is sparse, and institutional findings proprietary, is there other information that could be constructed into a system model, or other perspectives of what the barriers to successful study might be? Strangely, yes, and from an unexpected quarter.

Humour provides a powerful alternative perspective, the site www.phdcomics.com being a case in point. The fact that these cartoons are funny shows that they capture truths and ironies. Moreover, cartoons indicate, albeit subjectively, what needs to be included in a system model. For example, recurring themes are difficulty of finding a topic, pressure on students, difficulty of sustaining motivation, indifferent supervision quality, difficulty of writing the thesis, and manipulative labour practices using students. Several of these themes also appear in magazine article sources (Economist, 2010).

For example, the cartoons identify a specific problem of getting started with writing the thesis. The cartoon identifies the richly nuanced context that underlies the problem: distractions, pressure of tutorial duties, manipulative faculty employment practices, personal revulsion, and perhaps low self-efficacy. The cartoon is every much a comment on the issues facing students as any empirical study.

Issues that students themselves report (www.postgraduateforum.com) include:

- Bored of the thesis topic (but trapped by time): *'I hate working on it because it no longer interests me at all.'*
- Feel like a fraud, e.g. *'I'm almost at the end of this long, dark tunnel (I need to finish by mid-August) and still feel insecure, incompetent and a fraud.'*
- Procrastination and difficulty focussing: *'I have been procrastinating a lot lately.'*
- Difficulty prioritising work when multiple things are urgent and important.
- Relying on others: *'I have circulated my draft paper to my co-authors and having given them over a month to come back with comments, the deadline has passed and I have not heard back from some.'*
- Supervision: *'I am too afraid to call my supervisor'*
- Stress of reviews: *'I have to go through this every 6 months - the last one, although apparently very successful and wonderful etc was a nightmare and I felt so discouraged afterwards. I have another in about 10 days time and I'm dreading it.'*
- Workload stress: *'working 18 hours a day'; 'burn yourself out working too hard at weekends'*
- Summarising a large literature: *'I did my literature review this year so the pain is still quite acute'*

- Writing: *'I am now writing my introduction, this should be straightforward but I am having real problems writing anything that I feel sets up my thesis in a good enough way to do it justice'*
- Editing text; *'I found revising chapters thoroughly depressing'; 'I cannot stand reading over my chapters again. especially the early ones - I now think they are complete rubbish, but no time to change.'*
- Juggling studies and family, especially for mature students: *'I am completely worn out, I also have 3 children, I cooked a roast dinner this evening for 5, the kitchen is a mess, there is lego all over the sitting room floor, and I cant be bothered to move.'*
- Managing self-expectations: *'I'm really struggling with my own standards - nothing I write is good enough - and I'm too embarrassed to show anything to my supervisor. I can't handle any criticism. I feel really guilty though because he is a great guy and really supportive.'*
- Potentially dropping out: *'disillusionment and lack of faith in the system'*
- Career disruption: *'Having to restart career progression on a return to industry.'*

Clearly the situation, especially for PhD students, is uniquely ambiguous, being neither employment nor studies, undergraduate nor staff, novice or expert, and simultaneously all of those things. How do we help them navigate through those constraints to a successful outcome?

Need for better models

There is a general lack of theories in the field. What theories exist are fragmented and there is no integration between them. Consequently there is a need for more holistic and integrative theories of the research and supervision process. Ideally there would be models that represent the causal relationships from input variables through to successful (or failed) postgraduate outcomes. However there are significant challenges to achieving this, because the variables are incompletely identified, and likewise the relationships between them, i.e. a situation of high epistemic uncertainty. It is not a simple case of taking existing 'facts' and gluing them together to make a model. Even the modelling methods are poorly established. Given the dearth of models of this type, and even the raw materials, it is to be expected that much work will have to be done to achieve the eventual objective.

This paper makes a start, by demonstrating a method for representing subjective causality. It then uses this approach to produce a conceptual model for the postgraduate research process.

Why system models?

The purpose of any system-model is to represent causality, or at least to propose relationship of cause-and-effect.

The intended use of such models from the practitioner perspective is to predict the outcomes in a specific situation, and to change the design of the situation as necessary to maximise the outcomes. The practitioner wants to know: 'What are the variables that affect the outcomes, and which ones can I control?' This corresponds to being able to identify the independent and dependent variables. Certain research methods actively encourage the thinking that there exist variables that are truly independent. By comparison the system perspective accepts *a priori* that the causality could be complex, and that independence must be proven rather than assumed.

Individual empirical studies can be difficult to apply without a system-model. This is because most studies are limited in scope to a few variables, and specific situations. Consequently they tend to be difficult to apply to other situations, because the specific changes required for a particular situation are unknown: the contextual variables (contingencies) are indeterminate.

The models in the hard sciences can often be represented mathematically, or by the correlation of variables. However the modelling approach becomes progressively more difficult as human behaviour is involved. Thus lemmas and linguistics have been used to create theoretical models in some disciplines (Turner, 2006). However when epistemic uncertainty is high, then models necessarily have to represent what knowledge is available, which tends to be qualitative data bound together with subjective relationships. We term this 'subjective causality' and represent it with a particular type of method and model, as described below.

3 Method

A system-modelling approach was used. These have been successful in other production-engineering domains for modelling the behaviour of complex systems. The basic approach is to decompose the complex system into components and describe the relationships between them in a structured manner, thereby providing a synthesis of the behaviour of the whole.

Other flowchart notations, as typically used in the management and social sciences literature, are limited in ability to represent complex processes. They typically fail to differentiate between the different components (e.g. activity and object), and the different types of input to an activity. They adequately show broad conceptual associations between variables but cannot provide the requisite capability for documenting complex processes like those under consideration here.

The following modelling approach was used. The author refers to this as 'dynamic process analysis' (DPA) as it is designed to capture changeable effects under high uncertainty. The basic approach was to decompose the complex system into components and describe the relationships between them in a structured manner, thereby providing a synthesis of the behaviour of the whole. The method uses a structured, deductive process to

decompose the process being analysed into multiple sub-activities (functions) and for each deduce the initiating events, the controls that determine the extent of the outputs, the inputs required, the process mechanisms that are presumed to support the action, and the outputs. The model was then inductively reconciled with elements of the existing body of knowledge on this topic, and successively refined, even redefined, until it provided the requisite explanation of the observed real system behaviour.

Activities may be further decomposed as necessary to depict the level of detail required. The resulting model is expressed as a series of flowcharts using the integration definition zero (IDEF0) notation (FIPS, 1993; KBSI, 2000).

With IDEF0 the object types are inputs, controls, outputs, and mechanisms (ICOM) and are distinguished by placement relative to the box, with inputs always entering on the left, controls above, outputs on the right, and mechanisms below. The box itself describes a function (or activity), and the arc (line arrow) describes an object. In most other flowchart notations arrows represent sequence of activities. However, with the present notation it is important to note that arrows should be interpreted as conveying objects to activities (blocks), see Figure 1.

An activity may begin autonomously when its required inputs are available and its constraints permit. Consequently, the notation provides that multiple activity boxes can be simultaneously active, i.e. concurrent or parallel. Sequenced activities (series) can still be readily modelled where necessary. Text descriptions are provided below, but a rich content remains in the diagrams, where subtle effects (such as feedback loops) may be observed although not always described in the text. The numbers in the text refer to the numbered activities on the figures.

The result is more than simply a graphical model: it is a theory, because it represents the causal relationships between the elements. Hence the term 'subjective causality model'.

4 Results

The primary outcome is a set of diagrams, representing a conceptual model for the processes of undertaking the venture of a research project. The primary focus is on the student perspective, and the situation under analysis is engineering postgraduate research programmes as opposed to other types of research. The thinking process was thus graphical-logical. Text descriptions are a secondary output and provided to assist the interpretation and to interface the model to the works of others. However, a rich content remains in the diagrams, where subtle effects (such as feedback loops) may be observed although not always described in the text. The numbers in the text refer to the numbered activities on the figure.

Notes to assist interpretation of diagrams

Figure 1 explains the object types. An activity may begin autonomously when its required inputs are available and its constraints permit. Consequently, the notation provides that multiple activity boxes can be simultaneously active, i.e. concurrent or parallel. Sequenced activities (series) can still be readily modelled where necessary.

Of necessity the following description starts with one of the activities, but this should not be taken to infer priority or order of events. Conceptually the model assumes that multiple activities will be simultaneously active, even if that activity is only partial or intermittent. For example, some precursor planning of the project might occur before the customer accepts the project. In other situations, or even later in the same project, the activities may be reversed and planning might wait until the contract is finalised.

The locus of effort is not a fixed arrow of causality, but a set of multiple threads that can iterate, change direction, and stop/start. This might seem like an unsatisfactorily vague expression of causality on which to build a theory. However, the models employing simple linear causality do not explain all aspects of actual research practice, so the present method deliberately seeks to explore rather than prescribe causality, hence the complexity of the results.

Even without a complex subject matter, a valid criticism of this method is that it produces high information density and complex diagrams that are effortful to interpret. Therefore to aid comprehension the results are presented in a top-down manner, since the concepts are simpler initially.

4.1 Top-level model: Conduct research (Rs)

The top level of this model shows the overall research process, in the context of postgraduate studies. The main activities relevant here are to initiate the research programme (1), and to produce research outcomes (2). These are detailed below. Additional activities are applied research in industry (5), and closure of the research (4). The last activity at this level, are the processes for modelling system behaviour (3), this being relevant as research generally involves identifying new relationships of causality between variables, and there is usually uncertainty in the variables and their relationships, so there is a question of epistemic uncertainty to deal with. However the scope of the present paper is limited to activities (1) and (2).

It might look like this is heading down the well-trodden route of creating administrative process maps: fill in this form, obtain that approval, pay fees here. That is not what this is about. Here we are primarily interested using process methods to better understand the cognitive processes, and to do so from the *perspective of the postgraduate student as protagonist*. What emerges in the detailed models following is a complex set of intersecting factors. For example, personal motivation is seen to be an

important factor. To the extent that this model represents the reality of postgraduate study, then it suggests that there are many pitfalls that the unwary student or supervisor could fall into.

While this is a simply model at this stage, it serves to introduce the system-modeling approach, which otherwise can be difficult to grasp. The Reader is encouraged to study the diagram and see how the above textual description maps into the model. Furthermore, the model shows right from the outset that the purpose of research is not simply curiosity (that is instead part of the personal intrinsic *motivation*) but the award of a *qualification*, and often also the publication of *research outcomes*, at least in the academic environment. In the commercial environment, not detailed here, the objective is instead a new creative idea (product) or industrial technology. The research project only exists to the extent to which it continues to have the potential to deliver these benefits.

A brief description of the sub-models follows. Even without a complex subject matter, a valid criticism of this method is that it produces high information density and complex diagrams that are effortful to interpret. Therefore to aid comprehension the results are presented in a top-down manner, since the concepts are simpler initially. Space does not permit a full elaboration here, and the Reader is referred to the schematic diagrams for additional insights.

4.2 Initiation of the research programme

Initiation of postgraduate study is a time of great uncertainty for the student. There are several threads occurring simultaneously for the student: complex personal decision-making, cognitive challenges, navigating the possibly opaque administrative processes, and adjusting to the new environment. This situation is modelled in Figure Rs-1.

Select programme, topic, and supervisor

The primary decision-making activity for the student is the selection of programme, topic, and supervisor (1). Part of this is the career-related decision-making component of selecting the broad study area, since a degree of specialisation is inevitable at postgraduate level, and the relevant courses. This decision may be informed by personal passion & interest, just as much as availability of funding.

There is also the decision of selecting the supervisor. This activity occurs before, partially concurrent, or after selecting the topic. Academics may feel that they are the ones doing the offering, and certainly there is an element of institutional power and usually seniority, in their position. Nonetheless the matter is ultimately one of student choice, as most supervisors are aware. There are a number of potential mechanisms for making the decision: the obvious ones being personal affinity: perceived fit between student and supervisor, and shared interest in the topic.

There is also the matter of scholarship funding offered: in engineering it has come to be expected. A less obvious criteria is the project management experience of the supervisor, with the ability to keep the student on track, help determine possible solution paths, provide motivation to the student during the inevitable tough times, while still permitting the student the freedom to make choices. The present model also suggests another attribute that is desirable in the supervisor, this being the ability to identify the intellectual criteria for a sufficient outcome. For example, a PhD needs to show a conceptual contribution to the external body of knowledge, i.e. to reduce epistemic uncertainty. One way of doing this is to identify causal relationships, e.g. identify the key characteristics of the system and how they affect the overall system behaviour. Simply collecting data is not enough: there needs to be a conceptual contribution before or after the data are collected. It is the supervisor's responsibility to apply this to the specific topic area, and identify how the conceptual contribution *could* be made. Students need guidance on this, because they are not yet in a position to make that judgement themselves, yet it materially affects their lives. Clear guidance, appropriate to the expectations of that particular discipline, and contextualised to the specific research question at hand, is valuable yet curiously difficult to find.

There is one part of the decision-making that appears to be particularly prone to being overlooked or left to the subconscious, and that is to clarify the reasons for doing postgraduate study. Academics are so embedded in the university system that they might find it difficult to even raise this question with prospective students. But the reality is that postgraduate study is not always everything it is sometimes made out to be. For a start, in many countries, including New Zealand, the earnings premium for study is negative: from a long term financial benefit it would have been better to have just got a job. Secondly, postgraduate study, particularly doctoral, leads mainly to an academic career and less so a commercial one. Unfortunately the number of PhD graduates far exceeds the number of new tenured faculty positions available, so graduates risk subsequently finding themselves stuck in the no-man's-land of poorly paid post-docs. The career sustainability of postgraduate studies is not always robust (Bube, 1989; Riley, 2009).

Students will often not think, in a deliberately conscious way, about why they want to do postgraduate study. In some cases the reasons are soundly based on personal aspirations and a prudent assessment of the career opportunities, but the reasons in many other cases seem more based on convenience: buying time before tackling the problem of getting a job, continuation of student lifestyle, or simple inertia. It is often surprising to see what topics students will select, and after they have completed the programme only then wonder what the career prospects might look like.

Although only advice rather than empirical evidence, the following questions may be useful when contemplating an academic career:

Do you love to read, write, and do research? Are you willing and able to make graduate school one of the top priorities in your life? Are you willing to work much harder than you did as an undergraduate? Can you afford graduate school? Are you willing to be poor for a while? Do you meet the requirements for admission to graduate programs? Do you have a tangible reason for wanting to go to graduate school? Are you doing this because you don't know what else to do? (Rockler-Gladen, 2006).

There are books and various internet articles on the topic 'so you want to be a professor': the mere existence of so many indicating that misplaced expectations are a risk-factor.

This is not to belittle the sense of personal accomplishment and building of self-efficacy that postgraduate study can provide, but the point is neither students nor academics consistently clarify the reasons for doing postgraduate study, at least not in a deliberate way. The model suggests this is a problem because maintenance of personal motivation later in the programme requires a conscious awareness of *personal purpose* (addressed later in the model).

A series of diagrams further elaborates in a hierarchical fashion: Figures Rs-1-1, Rs-1-1-1, and Rs-1-1-4.

Frame the research question

The *research question* provides the purpose for the project. All the work that is done during the project is ideally directed at answering the research question.

The research question will usually be stated at the outset, and reframed as the project unfolds. Coming up with a specific research topic is a significant activity of its own. Consequently it can be an entry barrier to students, particularly where there are no ready-to-go projects available and the student has to come up with the topic him/herself. Mature students, who are not familiar with the university, are perhaps particularly at risk here.

The research question needs to state the potential intellectual contribution from the work, as the previous part of the model showed. The challenge is deciding *a priori* what is the right question to be asking. This is difficult since the work is not-yet-done, the solution path is uncertain, and the protagonists may have incomplete knowledge of the existing body of knowledge. How can the research question be stated under all this uncertainty: are there any methods to assist? Apparently not. Instead each institution has its own processes, templates, and expectations for what the document should *look like*. However there does not appear to be any integrative model identifying *how* to create a research question or the cognitive principles involved. As a starting point to fix this problem, we offer the theoretical model shown in Figure Rs-1-2.

The first activity is to identify the conceptual contribution required (1). This is based on the regulations for the degree and the size of the expected research component. In particular, masters programmes tend to expect students to apply their knowledge to solving a problem that has not previously been solved but where the solution methodology mostly already exists. Alternatively, to the collection of data and its statistical analysis for correlation and implications. Doctoral programmes expect a thesis that contributes significantly to an improved understanding of the situation. Usually the solution method (e.g. experimental hardware, system model) has to be substantially created by the researcher - this is an element of novelty. However it is not the novelty *per se* that is important for the qualification, but the conceptual contribution. This might be through demonstrating a way (methodology) for modelling a situation (which will usually be calibrated against empirical data), or a new theoretical model (usually a conceptual model validated by data), or an explanation of a phenomenon. There are many possible ways to make a conceptual contribution, and they all involve contributing to a better understanding of system behaviour; in other words to the reduction of epistemic uncertainty. As a previous part of the model identifies, this needs the supervisor to identify the required conceptual contribution, contextualise it to the situation, and communicate it to the student. This is a challenging task, and we have to consider the possibility that perhaps universities don't do this consistently well.

A second chain of activities is to state the problem (or need, or unknown situation), and why the problem is worth solving. The existing approaches need to be identified, based on a preliminary literature survey of the research journals. The approaches used by others are identified, and the limitations of their outcomes. This leads to the identification of the knowledge gaps in the situation, and thus to the specific objectives of this particular research project.

All research, including commercial, needs to have a purpose. In the case of postgraduate studies the corresponding activity is to identify the conceptual contribution that might be made to the worldwide body of knowledge. Sometimes this is easy, being provided by an extant research question from the supervisor's project. Alternatively it may arise from personal curiosity, conjecture, or intuition: it is asking the question, 'I wonder whether phenomenon A could be behind observed outcomes (system behaviour) B?' The gaps previously identified in the literature may also be a stimulus to identifying the possible local contribution. The research question may include specific statistical hypotheses, but this is variable. All systems have epistemic uncertainty: we don't fully understand how they work, what the input variables are and how they interact to produce the outcome. The purpose of research is to reduce that epistemic uncertainty: blow away the fog. Research adds value in proportion to the amount of epistemic uncertainty it reduces (or the amount of new knowledge it adds), and the importance or usefulness of that knowledge (applicability). The prospective conceptual contribution also has to be checked against the literature, to make sure the project does not have a spurious purpose.

At this point the *research question* has been established. Note that the research question is primarily a statement of *what* the Researcher is attempting to achieve, i.e. the *intellectual proposition of value*. Institutions usually also require that the *research methodology* be identified at the outset. This involves the experimental method, type of data collected, type of analysis that will be used. An ethics application may be required at the outset.

All this information feeds into the process of formally stating the research proposal. In particular, the proposal needs an identification of the purpose (the problem and why it is worth solving), a critical review of the existing literature (at least a preliminary version), the research question, and the intended research approach (research design). The risk here is over-prescription: some institutions require research proposal to be so detailed regarding process, even down to demanding that the Researcher define the entire statistical methodology beforehand, including the survey questions, that it seems the intellectual proposition of value is trivialised and swamped by the bureaucracy of deployment. It might well be the *easiest* to quantify, but the problem is that on its own it fails to capture the *purpose*.

Even after the research proposal has been formally accepted there will generally be adjustments to the research question and the method. These result from a natural firming up of the research question with time. It may also result in new information, e.g. from the literature or own work. Perhaps the problem can't be solved, or someone else has already solved it: these situations invalidate the purpose and therefore require an adjustment to the research question. Also, there is sometimes not much difference between a good masters and a weak doctorate thesis, and the latter may require additional work to demonstrate the conceptual contribution.

As with all of this modelling notation, the timing is not specified in the model, and activities can run independently of the others. Any activity may start at any time that its constraints permit, inputs are available, and mechanisms are active. Most of the activities occur early in the whole postgraduate study process, but some occur sporadically throughout the life of the project, and in extreme cases it may be necessary to totally redefine the research question after a substantial time into the project.

A series of diagrams further elaborates in a hierarchical fashion: Figures Rs-1-2, Rs-1-2-2, and Rs-1-2-3.

Implications for practitioners: students

It may be helpful to view the proposal as having three stages of iteration: first a broad definition of the research question sufficient to gain admission to the programme; second a detailed research design that occurs after enrolment and before the work commences in earnest; and third an adjusted research question and modified approach as the project

gets underway and situations develop. As this shows, several of the activities may be traversed multiple times to various degrees of completeness.

This completes the discussion of the initiation stage. The next focus is on the execution.

4.3 Producing research outcomes

The process of doing the research is of course the bulk of a postgraduate programme. It results in tangible research outcomes, and for the student as protagonist, focussed academic proficiency (specialised subject-knowledge), scholarship, and personal skills. The activity is outlined in Figure Rs-2. Research projects are varied in how they operate, so what works in one situation will not necessarily transfer to another. Nonetheless it is possible to identify several sub-activities, and these are briefly described in the order in which they are numbered, which is not necessarily the order of execution.

An early stream of work is to develop skills in the research methodology (1). This typically involves learning the statistical analysis methods and experimental procedures. It may also involve formal training in research methodology.

Reading and summarising the literature (2) occurs before and throughout the project. It helps inform the initial research question, and provides clues for possible solution-paths to explore. At the end, the project outcomes will contribute back to the literature: they will add to the body of knowledge, and thus make the necessary *intellectual contribution* on which the thesis is judged. Consequently the written report will need summarise the existing literature when defining the problem and the method, and later show how the work fits into that literature. But the literature can be large, and it can be a formidable task to read it, let alone understand it. Clearly it can be a major difficulty for students. It involves developing the cognitive skills of being able to read and comprehend the research literature (journals). Also, each body of knowledge has its styles and assumed precursor knowledge, so getting started on a new topic can be difficult.

Are there any methods to assist? Apparently not: people just find various ways that work for them. Nonetheless, it is possible to identify generic components: the search itself, analysis thereof, critical evaluation of the successes and limitations of the body of knowledge. From this emerge the implications for the project at hand. Figures Rs-2-2, Rs-2-2-1, and Rs-2-2-1-4 elaborate: they describe a process that is relatively well-known and so no further elaboration is provided here. Nonetheless they are included here for completeness.

Researching the problem (3) is of course is the main activity: applying the intended approach against the *Research question* identified above. Typical

outputs are data, models, and concepts. Correlations and associations may be included. There are so many different ways that research is done, that a customised system model would be required for each area. Nonetheless a generic model for engineering research is shown in Figure Rs-2-3. This identifies the main methods used, namely physical experiment, theoretical modelling, survey data-collection, and eventually constructing a model of causality.

4.4 Document the research

Finally we come to the documentation of the research, and the writing of the thesis. On the way it is generally necessary to produce progress reports, papers, or presentations. However we focus directly on the thesis, because this is ultimately the only output which determines whether the degree is awarded (at least this is the practice in the English-based education system). More than anything else, the thesis causes distress to students. They don't know where to start, they struggle to communicate well.

Supervisors find this perplexing. After all, the chapter headings of a thesis are well known: introduction, literature review, method, results, discussion, conclusion. It all seems so obvious; just get on with it and write some material under each of those headings. The challenge is in knowing what to write under these headings, and how to start. This issue is a recurring thread of difficulty for students, as seen in the cartoons and forums.

But students struggle nonetheless. The present model suggests this is because *structure* is insufficient on its own. Instead it is necessary to understand the purpose of the thesis,

The purpose is not always as obvious to students. The thesis is not a personal journal, or an elaboration of the work breakdown structure. Instead it is an answer to the original *Research question*, accompanied by a body of evidence validating that solution. The whole research project is driven by purpose. The methodology is selected to give the best chance of achieving the objective, and all the work that is done during the project is (ideally) directed at answering this research question. That's why it's important to adequately frame the research question at the outset, and to reframe it as the project unfolds. The research question provides a sense of initial purpose, and the thesis shows the extent to which that purpose has been met. The purpose drives the personal motivation too.

With the purpose understood, the structure of the document itself becomes easier to plan. The general structural headings are well-known: introduction, literature review, method, etc. The specialist chapter headings are then added to explain how the purpose has been fulfilled. The model, shown in Figure Rs-2-4/b shows a typical outline, and elaborates *how* the student might fill this, i.e. the type of content expected. It also provides a simple example.

In particular, it seems that the *Discussion* chapter is particularly perplexing for students. They tend to confound it with either the *Results* or the *Conclusions*. The present model offers a way of clarifying these three areas. Thus the *Results* described the outcomes (e.g. data and charts) and provides interpretative text that helps the reader see the meaning therein. The *Discussion* critically reviews those outcomes, and the ambiguities and doubts therein. Four sub-headings are suggested as necessary and sufficient: What has been achieved? What are the implications for practitioners? What are the limitations in the work? What are the implications for further research? The diagram elaborates. By comparison, the *Conclusions* simply closes the circle by stating how the outcomes meet the original purpose.

There is also a strategic dimension to a thesis: the student wants to pass, and the supervisor wants research outcomes. Strategy is the mechanisms people deploy to maximise the satisfaction of needs, and this can be a perfectly legitimate, even sensible, way to understand what is happening in a thesis. This variant of the model is shown in Figure Rs-2-4/c. This answers the question, 'why are these various components of the thesis important?', or conversely, 'what is the risk to me if I leave this chapter out or present it poorly?'

The diagram, the details of which are left to inspection, shows how practitioners have unsatisfied NEEDS that cause them PAIN. The thesis identifies the KNOWLEDGE GAPS that are causing this problem, this analysis being evidence of SCHOLARSHIP. The PURPOSE of the project is thus to reduce this pain, and it is clear that there is VALUE in doing so (the problem is serious). The resulting DATA are INTERPRETED for the reader. This helps the reader understand the OUTCOMES. The final step, and this is where the strategic magic occurs, is to show that those OUTCOMES meet the NEED. It is difficult to deny passage to a thesis that shows that a significant practitioner need has been SATISFIED, and an INTELLECTUAL CONTRIBUTION made to the field. The structure of the thesis is therefore a strategic design-variable. Sections like the Discussion are vital. The common problem with student theses is not so much a lack of work, but a difficulty in communicating how their outcomes fulfil the original purpose. A thesis is not an archive of the work done, but a description of outcomes and evidence of intellectual contribution. The model shows how this strategic outcome can be developed in the structure.

The third perspective offered by this model is assessment. At the end of the project, the thesis will be examined. How is that done? The answer is: subjectively. There do not seem to be any established criteria, at least not widely adopted. Of course examiners tend to know a good thesis when they see one, but the residual problem is inconsistency arising from the subjective nature of the process. The same problem is evident in journal reviewers: one judge likes some things and dislikes others, and the next judge has a different set of preferences. And how are new examiners trained up if the criteria are vague?

The present model offers a solution for this problem, as a natural extension, shown in Figure Rs-2-4/e. It is a series of questions that explore not so much the topic headings but the rationale behind each. Conceptually it is an extension of the strategic dimension, mapped back to the structure.

Finally, there is the matter of the reader's locus of effort through the thesis. This is important as it determines how the various sections are written. Students commonly make the mistake of believing that others will read the document in the same order as it is presented. The reality is often closer to that shown in Figure Rs-2-4/f. As this shows, the starting point is typically the abstract. The whole front of the document might then be skipped in favour of going straight to the results and discussion. Some people might not read anything more, especially if they are not examiners. Others will only read the parts that particularly interest them (see the NEED concept in the strategic model). The implications for the student are that the thesis needs to be written to allow the reader to still comprehend the outcomes and their importance, even if only the abstract and discussion are read. Going back to the strategic perspective, the ultimate purpose of the thesis is to lead one particular set of readers, the Examiners, to the point (#16) of seeing the academic contribution in the work. The thesis structure is a storyboard for achieving that communication objective. However, unlike a movie where viewers are forced to sit down and accept the information in the order set by the producer, the readers of a thesis can jump about the storyboard.

5 Discussion

5.1 Outcomes: What has been achieved?

One of the central concepts that emerges from this model, is that of *purpose*. This is a strand that flows through the whole research venture. The *purpose* is needed for the research proposal, it guides the research, it provides personal motivation, and finally becomes the golden thread that runs through the thesis, terminating in the conclusions. Without that *purpose*, everything frays. This is not a new insight per se, but the model suggests that *purpose* is very much more important than is generally recognised. Also, that *purpose* could be articulated much clearer than commonly occurs, and doing so would likely facilitate execution of the project. Note there is a small but subtle difference here: project-management thinking places great emphasis on complete prior description of the *scope*, and most research proposal do this passably well. However here we are suggesting that articulation of the *purpose* is more important than *scope*. The model is able to go further than merely identifying the importance of *purpose*: it also provides practical suggestions for how *purpose* can be contextualised to the situation.

Elaboration through to operational processes

This illustrates a novel feature of this model: the ability to represent abstract concepts, and at the same time readily be worked-down to provide detailed guidance. This is a useful feature because it enhances the relevance for practitioners. It also means that we now have a way of integrating abstract and concrete processes into one model, rather than having them as disparate systems. This demonstrates that it is possible to integrate the theory proposed here with practice. No other existing models provide this vertical integration: they tend to be either abstract or focussed on administrative processes, but not both.

Another defining characteristic of this model is that it offers a definition of 'postgraduate research', in terms of *intellectual contribution*, as described next.

Defining postgraduate research

What exactly determines whether a project is at certain level, e.g. masters or doctoral? More importantly from the perspective of a prospective student, 'How will I know when I have done sufficient work for the degree?' or 'What are the pass criteria?'

These are valid questions, particularly when considering the psychology of motivation. There is an element of fore-thought to effort, and 'people can initially raise their level of motivation by adopting goals before they receive any feedback regarding their beginning effort' (Bandura, 1989, p1179). Goal setting theory is widely accepted as an explanation of this behaviour. It is known that high motivation is strongly associated with specificity of goals (i.e. not vague) (Locke, 1968) and the difficulty of the goals (Locke & Latham, 1990; Robbins, Millett, Cacioppe, & Waters-Marsh, 2001, p208), providing several conditional factors are met. These include commitment to the goal, high self-efficacy, and a high intrinsic need for achievement.

Therefore it is advantageous to be specific beforehand about the goals of study. It is not only students who sometimes struggle to understand the requirements for successful completion: Supervisors can also find it hard to articulate the requirements. They generally have their own expectations, but these are tacit and it is not always easy to express these explicitly. Furthermore, expectations can vary between Supervisors, and between Examiners. Also, it is not always immediately clear what the difference is between masters and doctorate studies other than the duration.

Most approaches to this problem treat it by giving a definition of each degree. Some of these are shown in Appendix A, relevant to New Zealand and the engineering area. Note in passing that undergraduate engineering education is required to have a research component, so there are actually three levels of student research that need to be differentiated.

However most definitions struggle in one or more aspects: they are relatively complex and difficult to comprehend without hindsight; they lack specificity especially from the perspective of the prospective student; they are statements of assessment to be used at the end of the work rather than guidelines for use at the outset; or they rely on an intractable subjective assessment, along the lines of 'I can't exactly define what is required to earn a PhD, but I know it when I see it'.

There is a place for these definitions, but the present model suggests that it is possible to capture the essential attributes of postgraduate research in a simpler and more elegant way, one that is potentially more useful at the *outset* of a research project when the research question is being framed. Thus:

Postgraduate research is required to make a novel intellectual contribution, and demonstrate scholarship in the process.

Note the emphasis on:

Novel: as in something new; the extent of novelty determines the difference between undergraduate, masters and doctoral level research

Intellectual: the outcomes are expected to be intellectual in nature, i.e. contribute to growth of knowledge; an outcome that only had commercial gain or intellectual property (IP, e.g. patent) could be research, but is neither necessary nor sufficient for a postgraduate degree

Contribution: there will be a benefit to the body of knowledge; the zone of effect varies for the different types of degrees

Scholarship: the work will include a critical review of own and others' work.

The above definition is only of postgraduate research. There are other forms of research such as commercial and industrial research, and also new product development. These involve the development of novel technology or product, and the 'contribution' is the commercial value created. Scholarship is not required. But all forms of research involve the creation of new knowledge.

Applying this to the relationship between student and supervisor, it is the supervisor's responsibility to provide clear guidance about the expectations of that particular discipline for *intellectual contribution*, at the level of the desired degree. Also, to give a preliminary assessment of the likelihood that the intended *purpose* could be achieved with the proposed research method, and that doing so would result in an adequate *intellectual contribution*.

Value created

The present concept makes a novel contribution in several ways. The first contribution is the presentation of a candidate theory for the process of research, one that integrates horizontally between cognitive, administrative, and motivational factors, and also vertically with praxis.

A second contribution is that it pilots a different way of looking at the subject, using a method that is fundamentally graphical in origin. Creating conceptual diagrams is not new, but the present model goes beyond existing models in the field, in terms of its specificity and detail.

The process-engineering perspective is uncommon in the literature on postgraduate research, but has the potential to add value by contributing diversity to understanding the research process.

A third contribution is that the model provides a theoretical framework on which to place new knowledge and empirical findings as they emerge. In turn the model can be changed to be reconciled with those findings. A system model thus provides a useful mechanism for convergence of conceptual ideas and empirical research into increasingly powerful models of causality. The modelling notation permits complex causality to be represented: real causality will not necessarily be uni-directional, but instead reverse-causality may exist, or feedback effects.

This particular method is known for its complexity, however this is not a limitation but simply a constraint. The graphical model is a type of language of its own, and on superficial perusal can seem either impenetrable or trivial. Fortunately the hierarchical nature of the model permits further elaboration within the sub-models, and it is there that the implications for practitioners become apparent, and the specific research questions emerge. There are thus multiple entry points into the developing theory.

5.2 Implications for practitioners

The work is of a conceptual nature, and builds towards a theory of research ventures. In several places it gives specific practical recommendations for practitioners, both supervisors and students. For example there is the concept of *purpose* and specific guidelines on how to develop that into a research proposal; the concept of *intellectual contribution* along with guidelines on differentiating between degrees; specific guidance on how to structure a thesis to address the *purpose*; and recommendations for assessing a thesis.

5.3 Limitations of the present work

The benefit of the modelling process is that it identifies candidate relationships of causality, and does so across multiple fields. However the detriments are that the model is tentative and exploratory, i.e. the

relationships of causality are of uncertain validity. Therein lie implications for further work. On the positive side, the model is transparent about its statements of causality.

5.4 Implications for further research

Several lines of further research emerge. The present model is at a high level of abstraction, and there is the potential to elaborate it further. Another line of research could be to collect empirical survey data on the various sub-activities and analyse that to identify factors and create correlations. A benefit of this theory is that it explicitly proposes qualitative relationships of causality at each activity block, and this simplifies the extraction of testable hypotheses.

6 Conclusions

Postgraduate research is an exciting opportunity to further develop specialist skills in specific technology, scholarship, or research methodologies. However the opportunity also comes with threats: stress, confusion, and the possibility of not completing at all. Having a theoretical model of the process has great potential to help maximise the opportunities and minimise the threats, and thereby benefit both students and supervisors.

This paper makes a start, by demonstrating that a method can be found for representing subjective causality. It then uses this approach to produce a conceptual model for the postgraduate research process. It synthesises various aspects of the research process into a larger integrative model. At this point the causality is subjective rather than validated, but there is hope that future work will be able to refine and tighten that up. Already the model captures some interesting effects including the idea of the *strand of purpose*, which weaves through the whole intellectual venture. Nor is the model limited to abstract concepts: it provides specific guidance on writing and assessing a thesis, for example. The *strand of purpose* must ultimately be embodied in a thesis. That thesis is the evidence on which the degree is awarded.

From the production perspective taken here, quality is fitness for purpose, not quality at any cost. An intellectual venture like a postgraduate research project needs, according to this perspective, to have a clear understanding of the purpose, at the outset. That initial statement of purpose becomes the strand that weaves through the whole venture, and holds it on track.

A Appendix: Definitions of research

Undergraduate research projects

For undergraduate projects, the international expectation is that Engineers will be capable of *complex problem solving* at graduation. This is defined as follows:

<i>Engineering problems which cannot be resolved without in-depth engineering knowledge and having some or all of the following characteristics:</i>
<ul style="list-style-type: none">• <i>Involve wide-ranging or conflicting technical, engineering and other issues</i>
<ul style="list-style-type: none">• <i>Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models</i>
<ul style="list-style-type: none">• <i>Requires in-depth knowledge that allows a fundamentals-based first principles analytical approach</i>
<ul style="list-style-type: none">• <i>Involve infrequently encountered issues</i>
<ul style="list-style-type: none">• <i>Are outside problems encompassed by standards and codes of practice for professional engineering</i>
<ul style="list-style-type: none">• <i>Involve diverse groups of stakeholders with widely varying needs</i>
<ul style="list-style-type: none">• <i>Have significant consequences in a range of contexts</i>
<ul style="list-style-type: none">• <i>Are high level problems possibly including many component parts or sub-problems</i>

Table 1: Definition of complex problems (IEM, 2007)

So a graduate in professional practice is expected to make an intellectual contribution by solving applied problems that have not previously been solved, by application of existing knowledge: (*fundamentals-based first principles analytical approach*). The complexity lies in the multiple dimensions to the problem. The point is that the basic principles of analysis already exist – the Engineer does not have to create those.

Postgraduate masters research projects

For masters level research, the expectation is higher. The British expectation is:

‘Students will have shown originality in the application of knowledge, and they will understand how the boundaries of knowledge are advanced through research. They will be able to deal with complex issues both systematically and creatively, and they will show originality in tackling and solving problems.’²

They also state that students are expected to have demonstrated:

‘i a systematic understanding of knowledge, and a critical awareness of current problems and/or new insights, much of which is at, or informed by, the forefront of their academic discipline, field of study, or area of professional practice;

² <http://www.qaa.ac.uk/academicinfrastructure/FHEQ/EWNI/default.asp> accessed 25 Feb 2010

ii a comprehensive understanding of techniques applicable to their own research or advanced scholarship;

iii originality in the application of knowledge, together with a practical understanding of how established techniques of research and enquiry are used to create and interpret knowledge in the discipline;

iv conceptual understanding that enables the student:

- *to evaluate critically current research and advanced scholarship in the discipline; and*
- *to evaluate methodologies and develop critiques of them and, where appropriate, to propose new hypotheses.*

The New Zealand definition is:

'A graduate of a masters degree programme is able to:

- *show evidence of advanced knowledge about a specialist field of enquiry or professional practice;*
 - *demonstrate mastery of sophisticated theoretical subject matter;*
 - *evaluate critically the findings and discussions in the literature;*
 - *research, analyse and argue from evidence;*
 - *work independently and apply knowledge to new situations;*
- and*
- *engage in rigorous intellectual analysis, criticism and problem-solving.*³

The Researcher is expected to make a novel *applied* intellectual contribution. One way to do this is to apply an existing methodology (analytical or solution approach) to an area where it has not been applied before, i.e. to extend the application of the methodology. In this case there will typically be a critical assessment of the efficacy of the method for this type of case, and implications for future development. A contribution has been made to the body of knowledge, because now other people can come after and apply the method to similar situations and have a good chance of success, i.e. graduates could now apply it.

Doctoral research projects

For doctorate level research, the expectation is higher still. The British expectation is:

*'Doctorates are awarded for the creation and interpretation of knowledge, which extends the forefront of a discipline, usually through original research. Holders of doctorates will be able to conceptualise, design and implement projects for the generation of significant new knowledge and/or understanding.'*⁴

They also state that students are expected to have demonstrated:

³ <http://www.nzqa.govt.nz/publications/docs/theregister-booklet.pdf> accessed 25 Feb 2010

⁴ <http://www.qaa.ac.uk/academicinfrastructure/FHEQ/EWNI/default.asp> accessed 25 Feb 2010

'i the creation and interpretation of new knowledge, through original research or other advanced scholarship, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication;
ii a systematic acquisition and understanding of a substantial body of knowledge which is at the forefront of an academic discipline or area of professional practice;
iii the general ability to conceptualise, design and implement a project for the generation of new knowledge, applications or understanding at the forefront of the discipline, and to adjust the project design in the light of unforeseen problems;
iv a detailed understanding of applicable techniques for research and advanced academic enquiry. '

The New Zealand definition is:

*'The doctorate is awarded on the basis of an original and substantial contribution to knowledge as judged by independent experts applying contemporary international standards.'*⁵

The Researcher is expected to make a novel *conceptual* intellectual contribution. There are several ways to do this: develop a new (or substantially improved) method for application to certain situations; create a new theory; verify a new relationship between variables. There is also a greater expectation for scholarship than at masters level. This refers to critical thinking: the ability to discern the value in the work of others; from the extant literature create new proposed models of causality; not be deceived by the results of others but able to see the limitations in their works; write in a non-condemnatory style about other's works. The evidence for it is most easily found in the literature review and any published papers.

⁵ <http://www.nzqa.govt.nz/publications/docs/theregister-booklet.pdf> accessed 25 Feb 2010

List of figures

Figure 1

Conduct research (Rs)

Initiate research programme (Rs-1)

Select programme, topic, and supervisor (Rs-1-1)

Decide on postgraduate study area (Rs-1-1-1)

Select postgraduate courses (Rs-1-1-4)

Frame the research question (Rs-1-2)

State the problem or need or unknown situation (Rs-1-2-2)

Explicitly state the research question (Rs-1-2-3)

Produce research outcomes (Rs-2)

Research the literature (Rs-2-2)

Search the literature (Rs-2-2-1)

Filter the results to find relevant papers (Rs-2-2-1-4)

Research the problem (Rs-2-3)

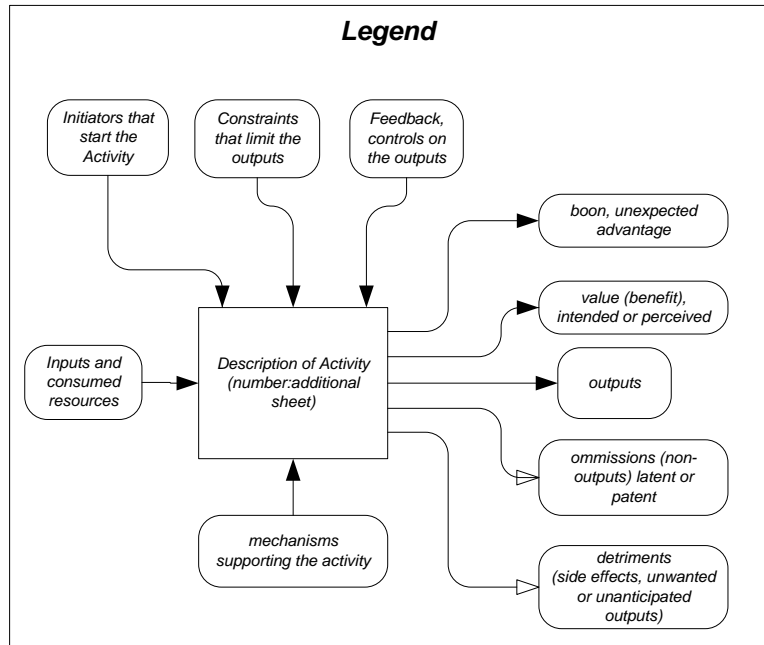
Document the research findings (Rs-2-4)/b Basic structure with example

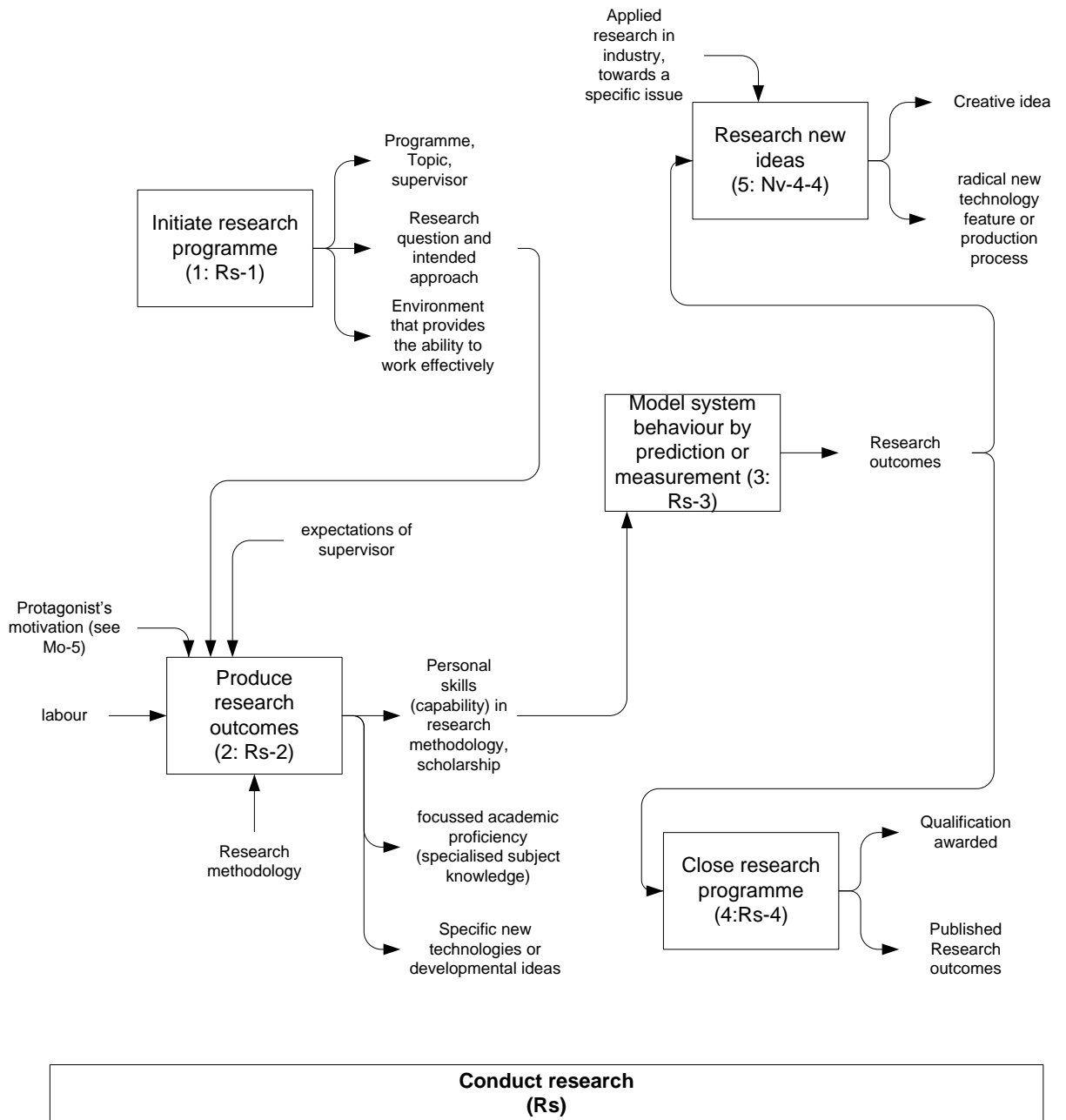
Document the research findings (Rs-2-4)/c Strategic value

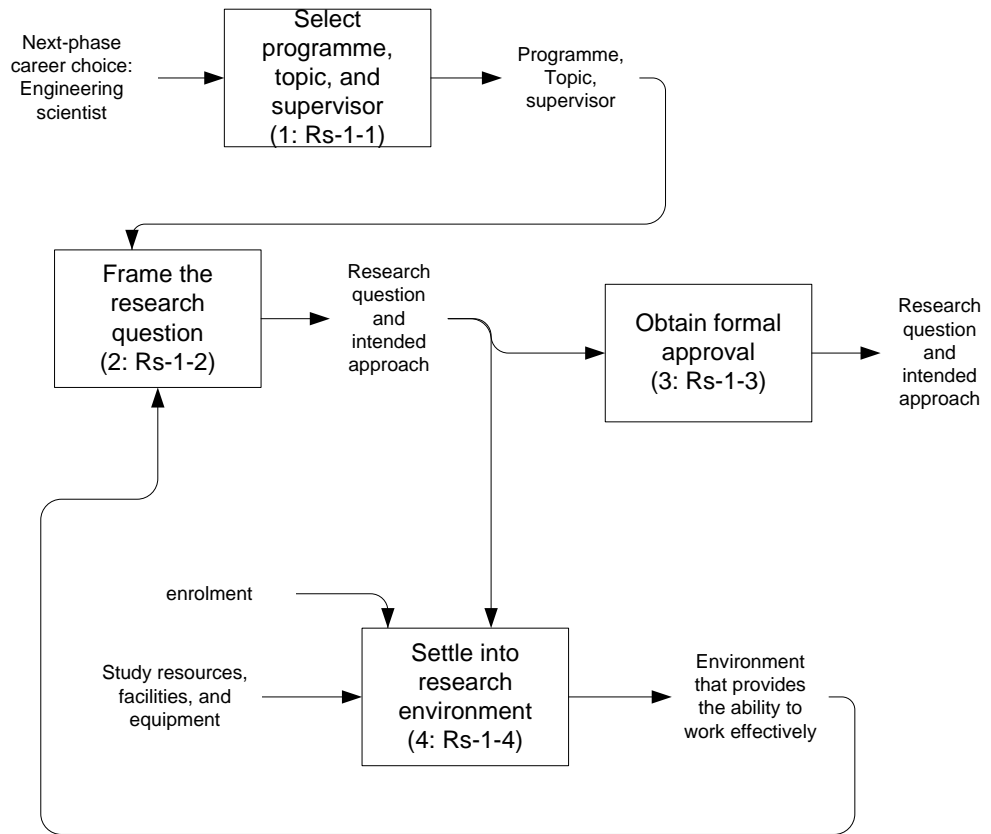
Document the research findings (Rs-2-4)/e Assessment

Document the research findings (Rs-2-4)/f Reading locus

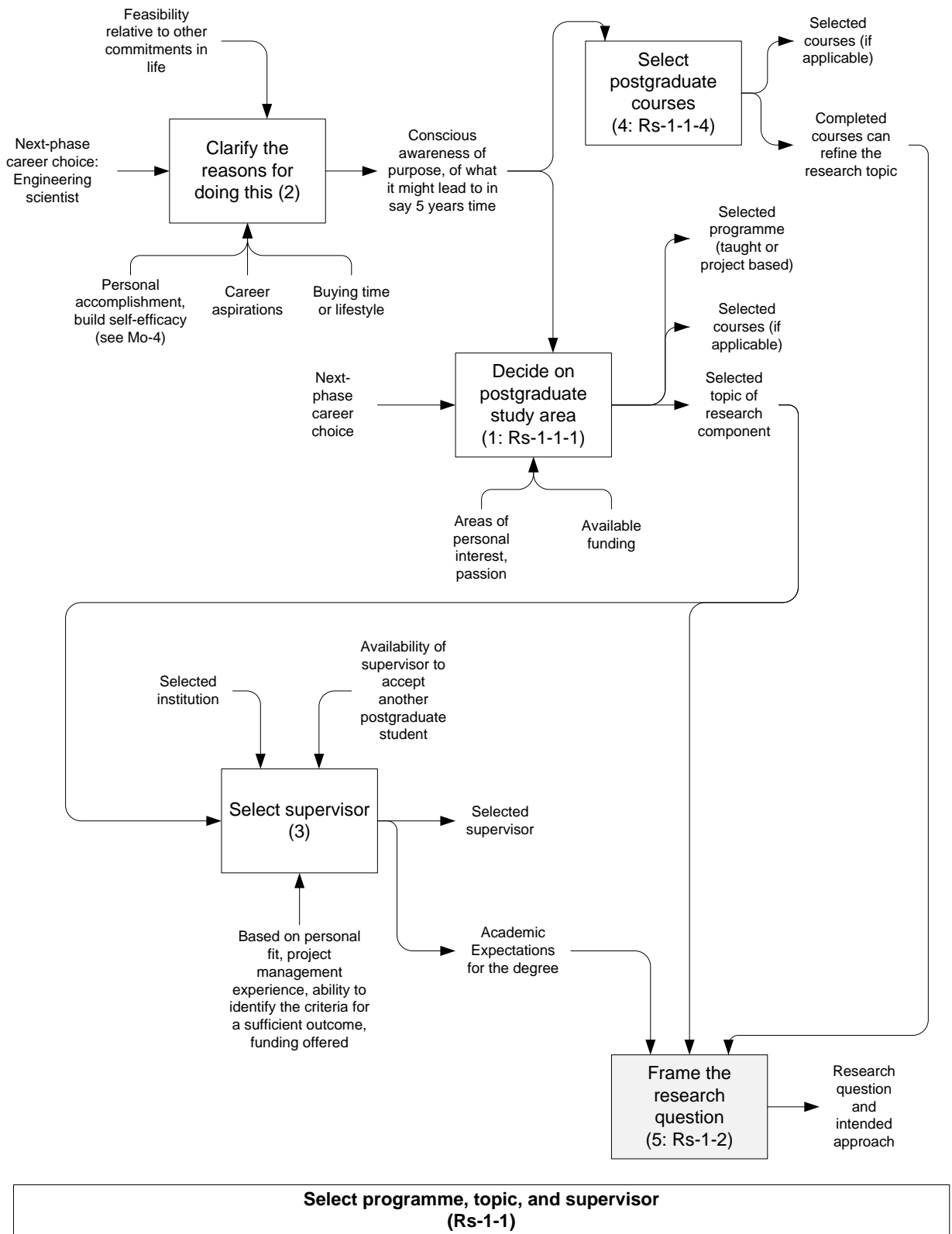
Figure 1: The object types are inputs, controls, outputs, and mechanisms (ICOM), and are distinguished by placement relative to the box, with inputs always entering on the left, controls above, outputs on the right, and mechanisms below. The box itself describes a function (or activity), and the arc (line arrow) describes an object. In most other flowchart notations arrows represent sequence of activities. However, with the present notation it is important to note that arrows should be interpreted as conveying objects to activities (blocks) and not as sequence.

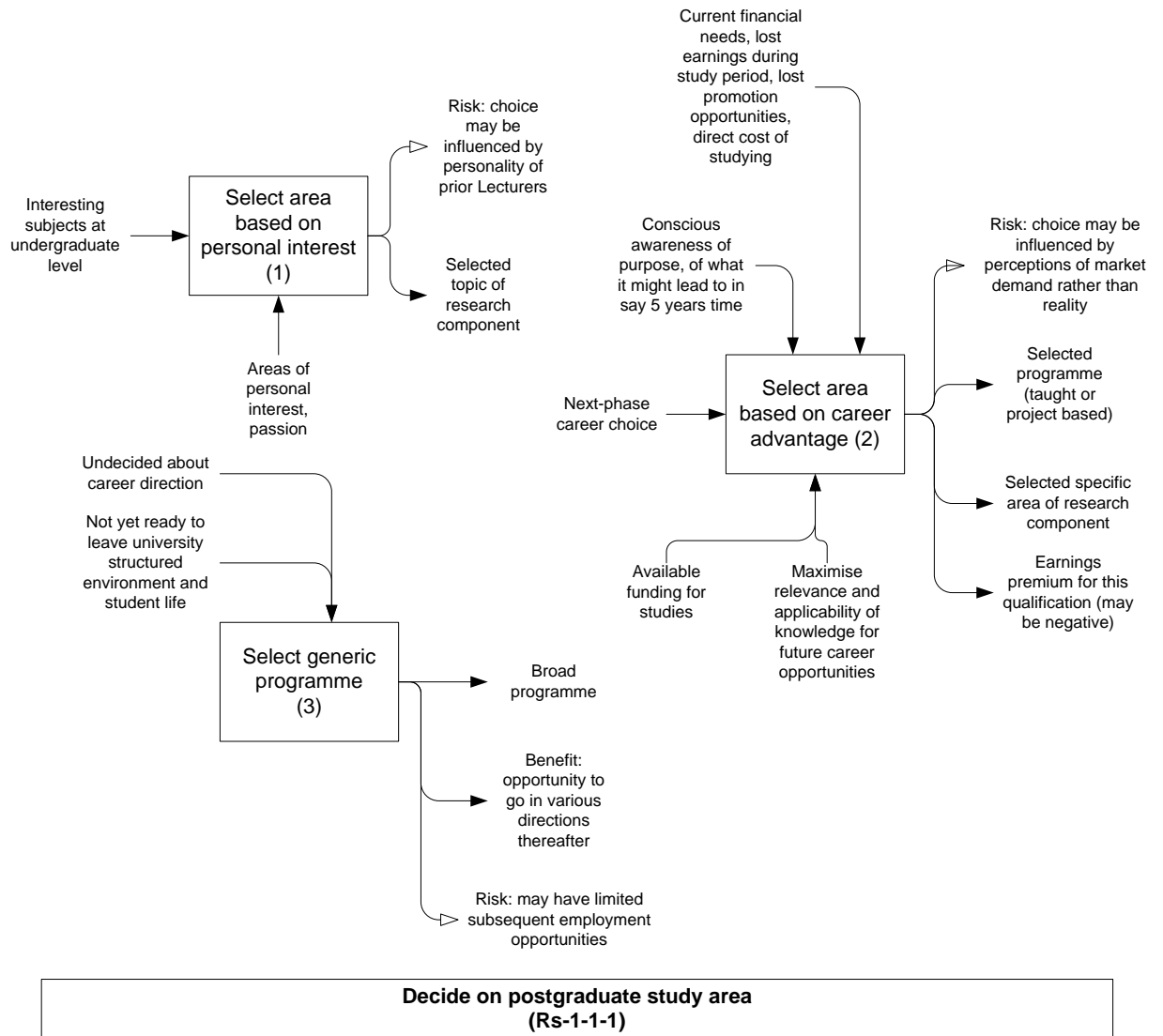


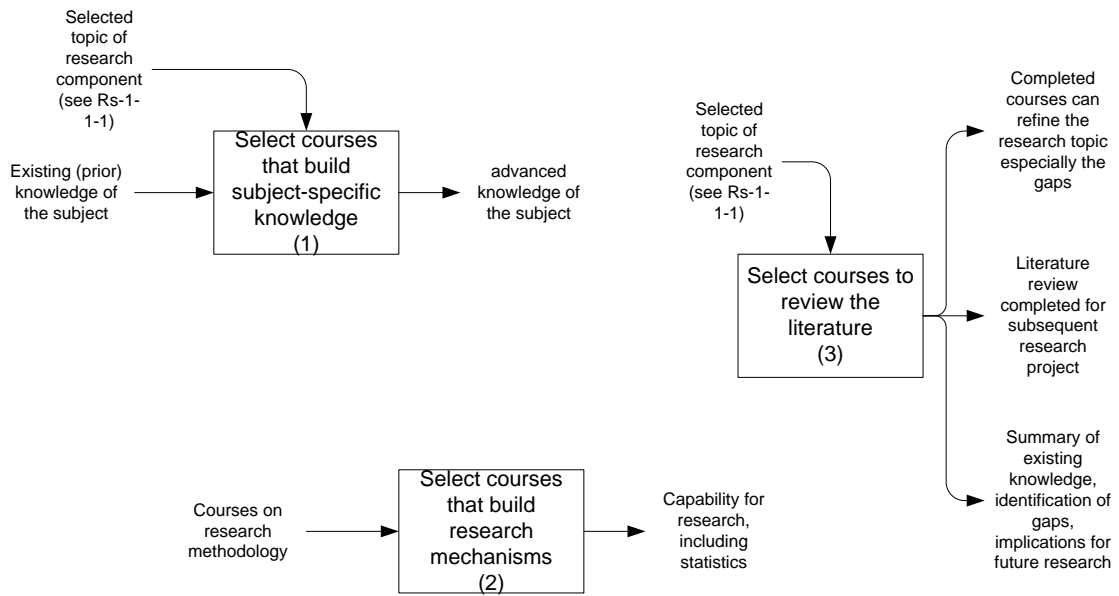




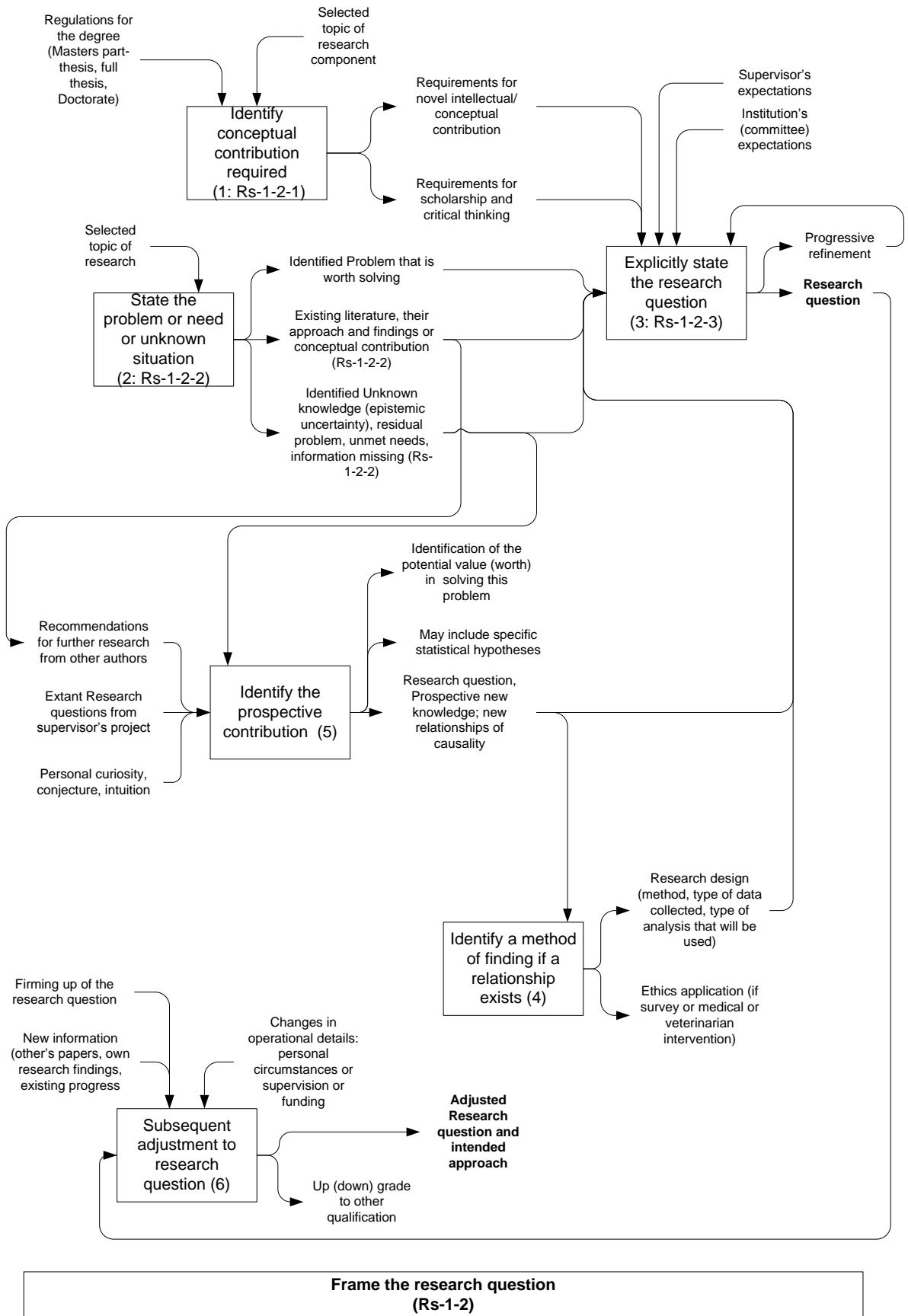
Initiate research programme (Rs-1)

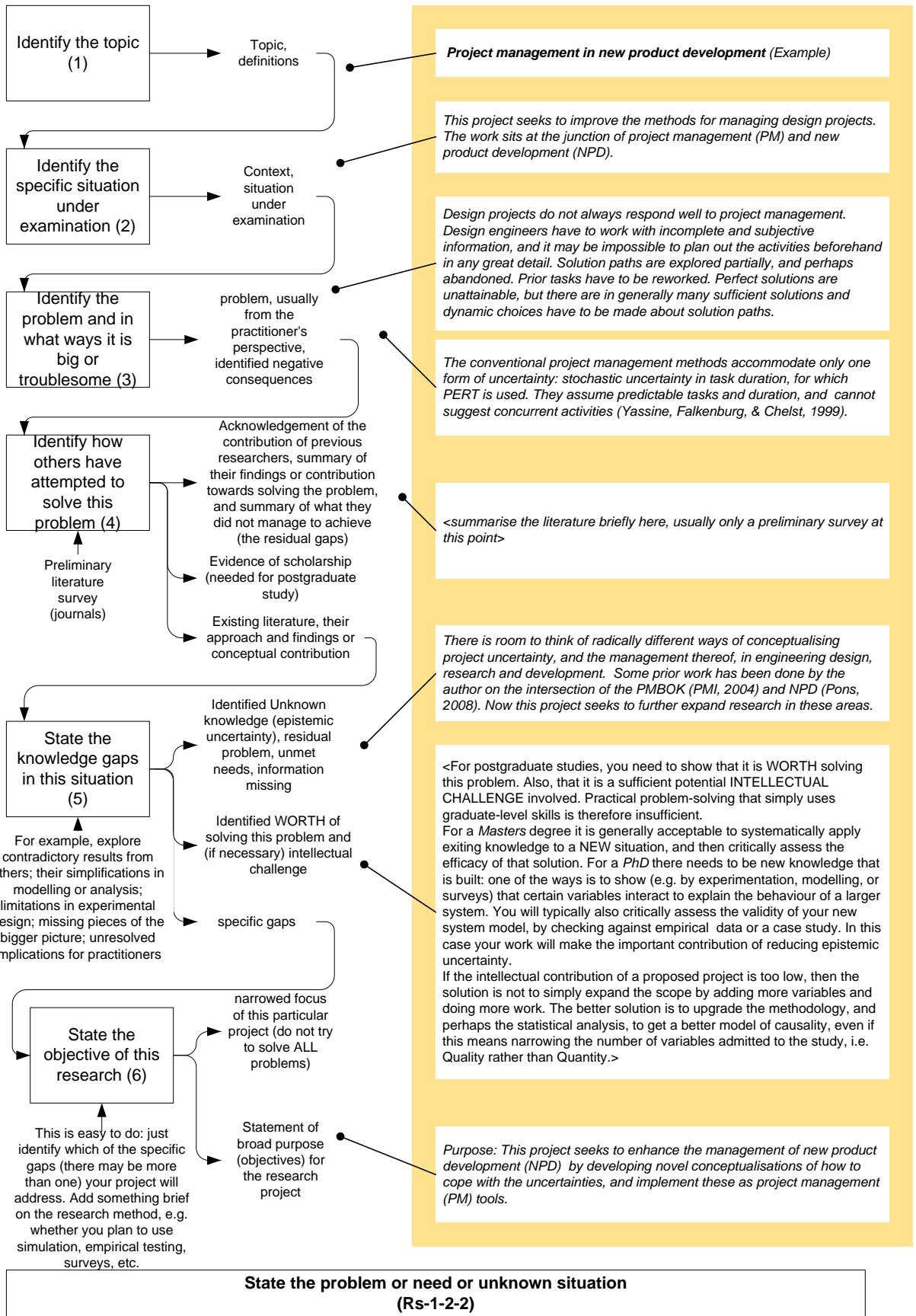


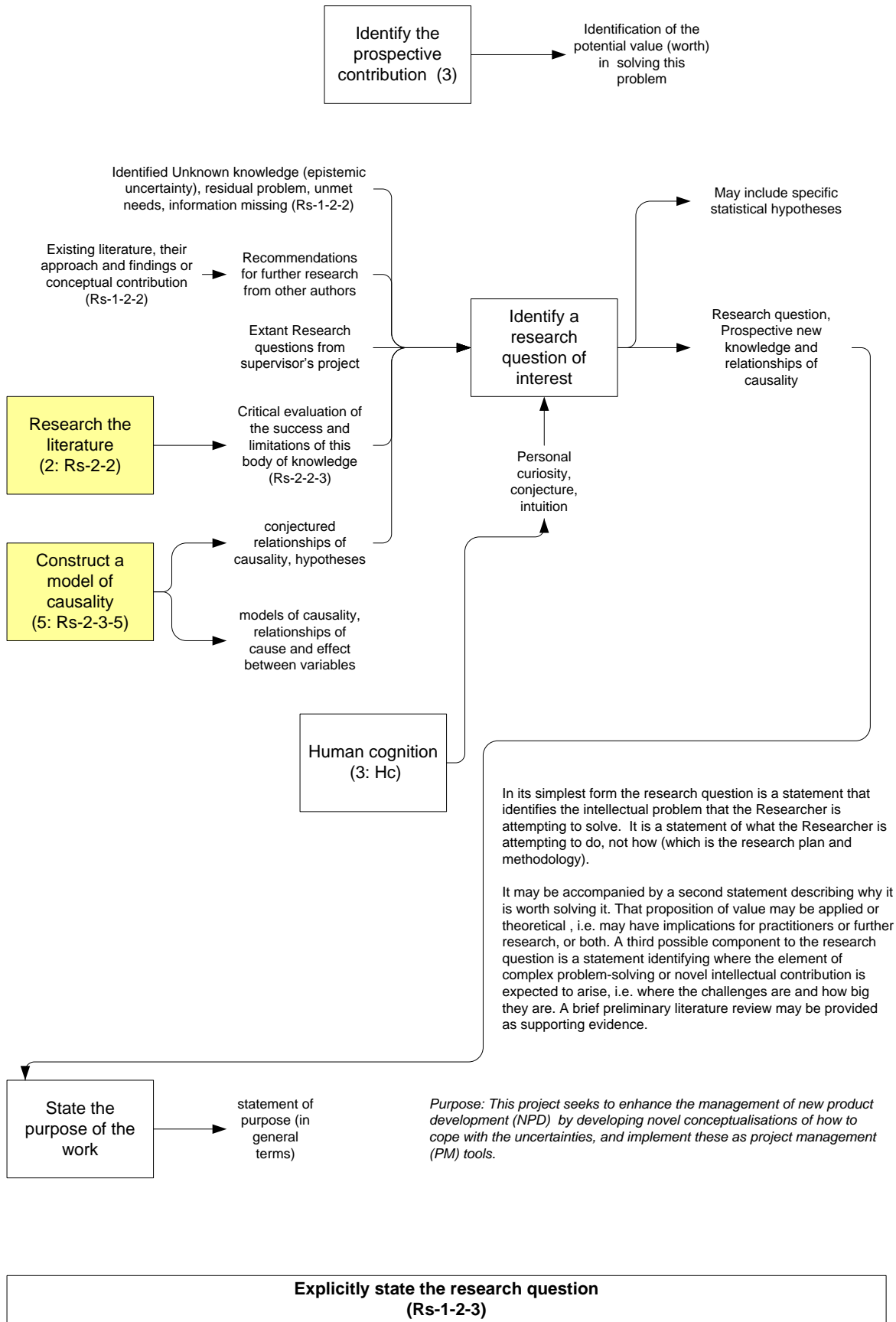


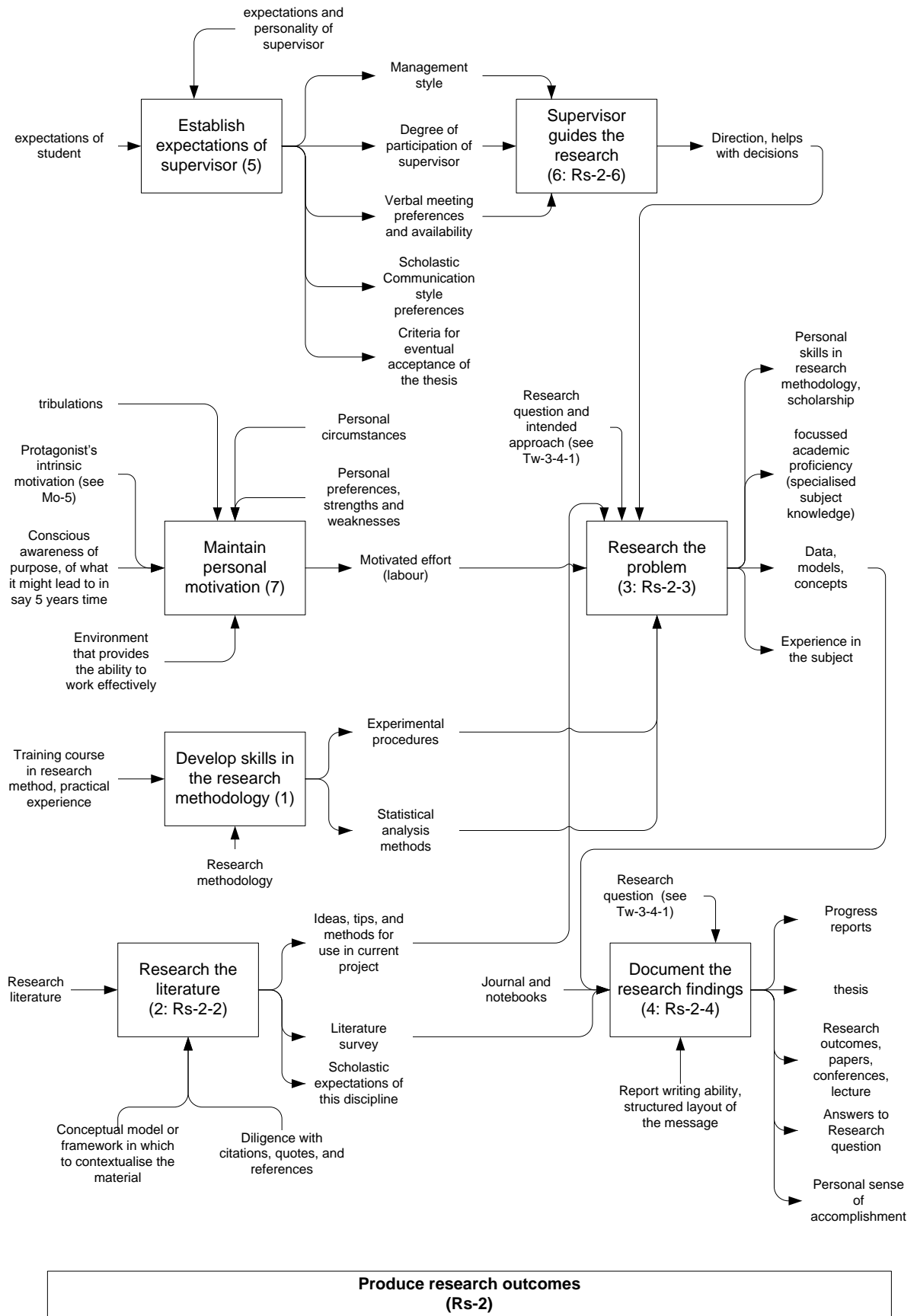


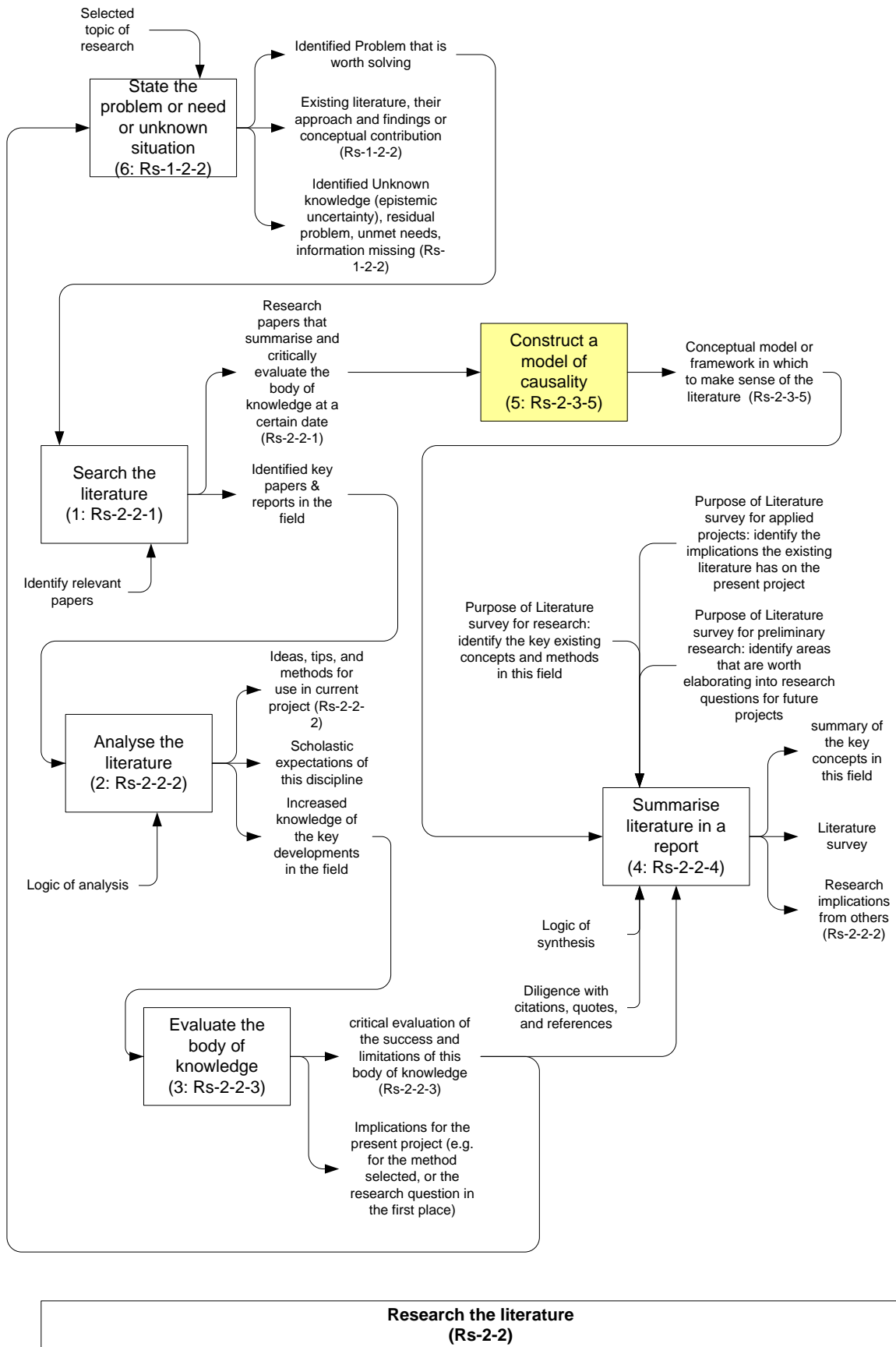
**Select postgraduate courses
(Rs-1-1-4)**

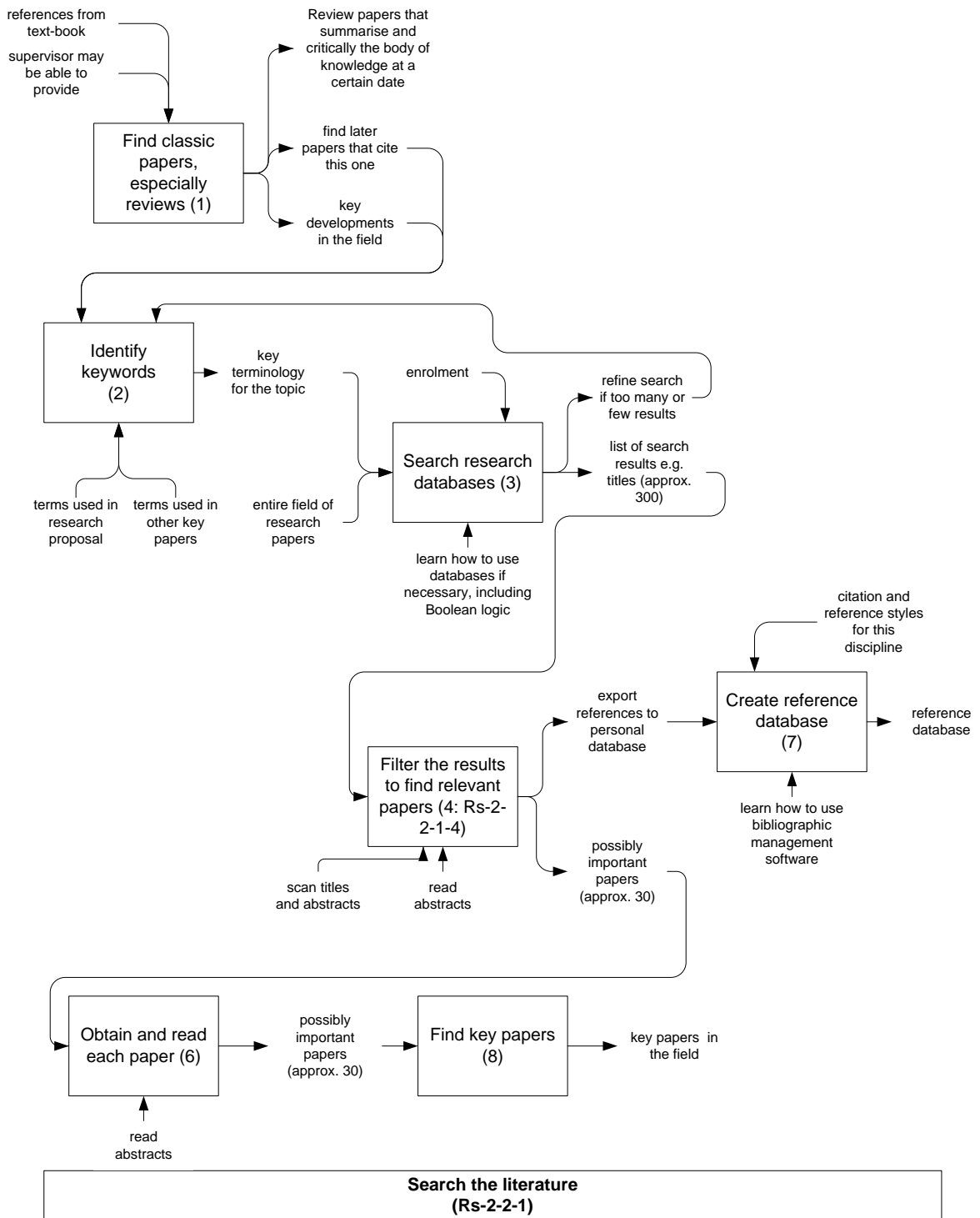


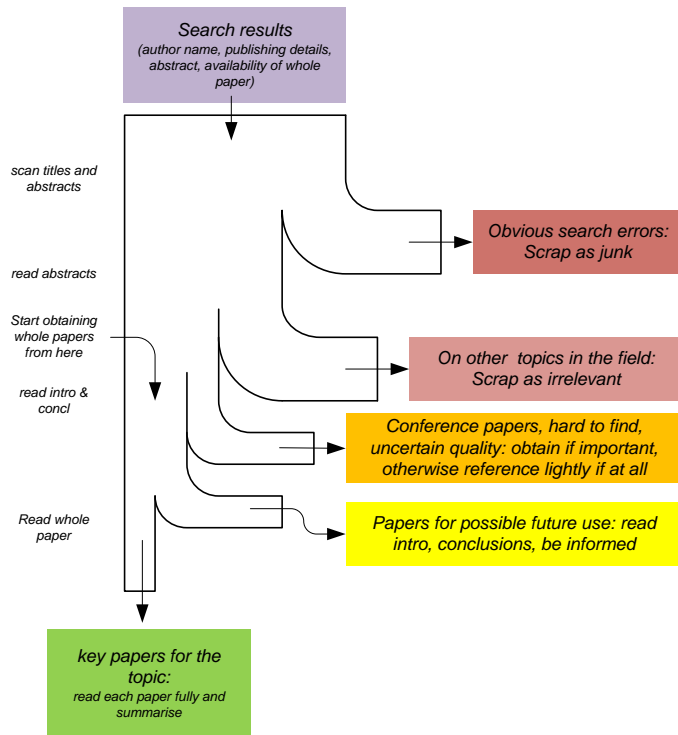




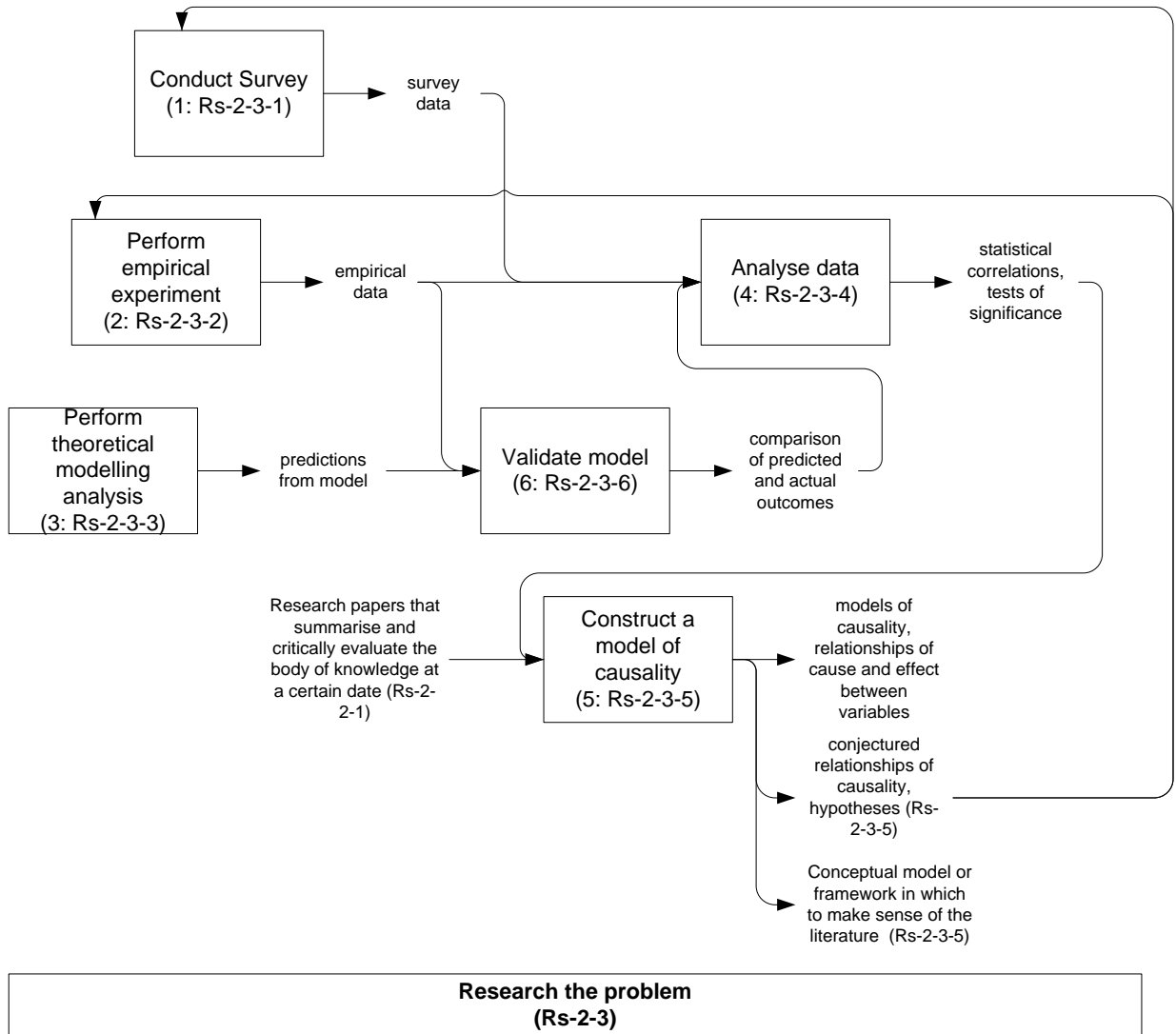


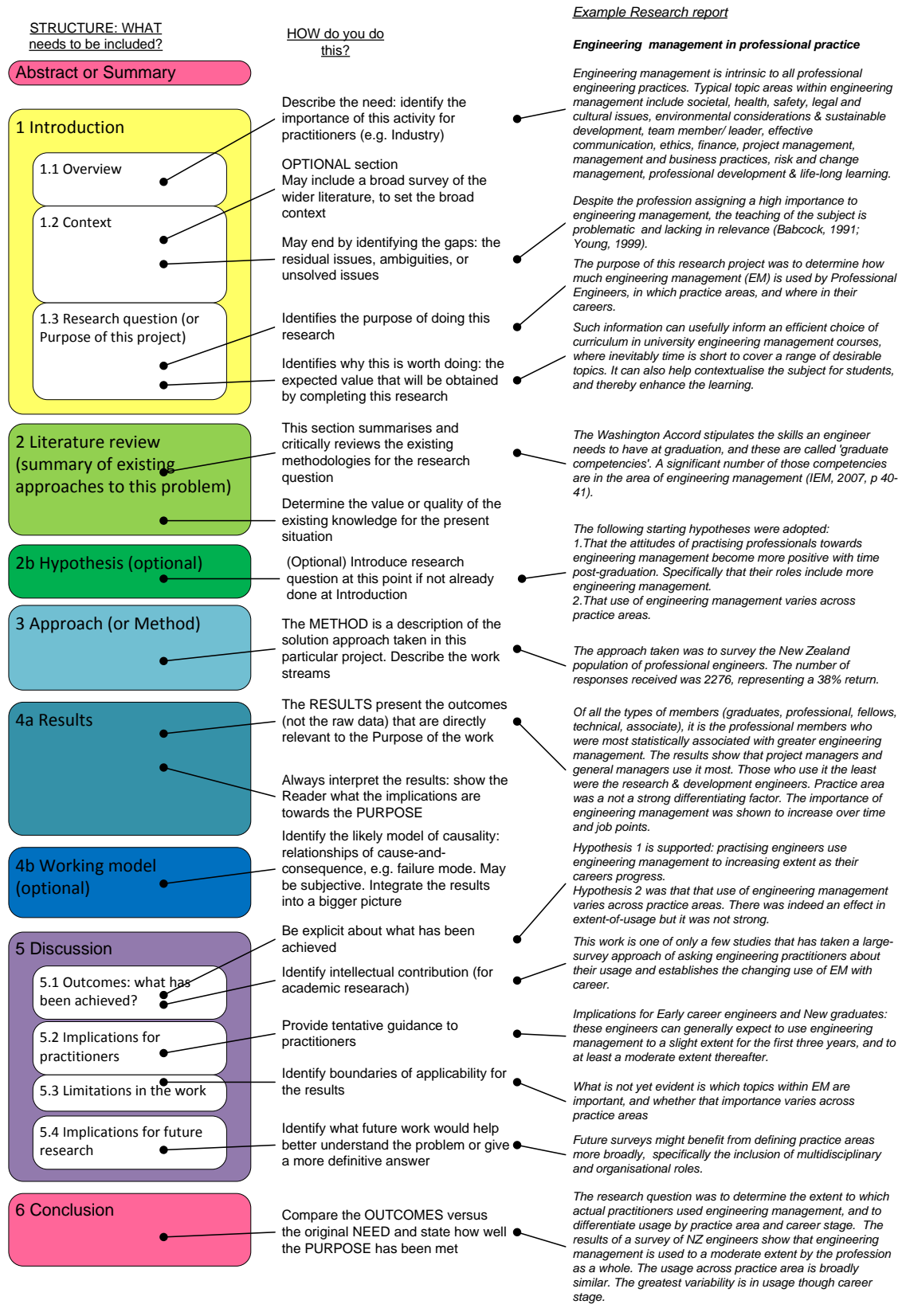




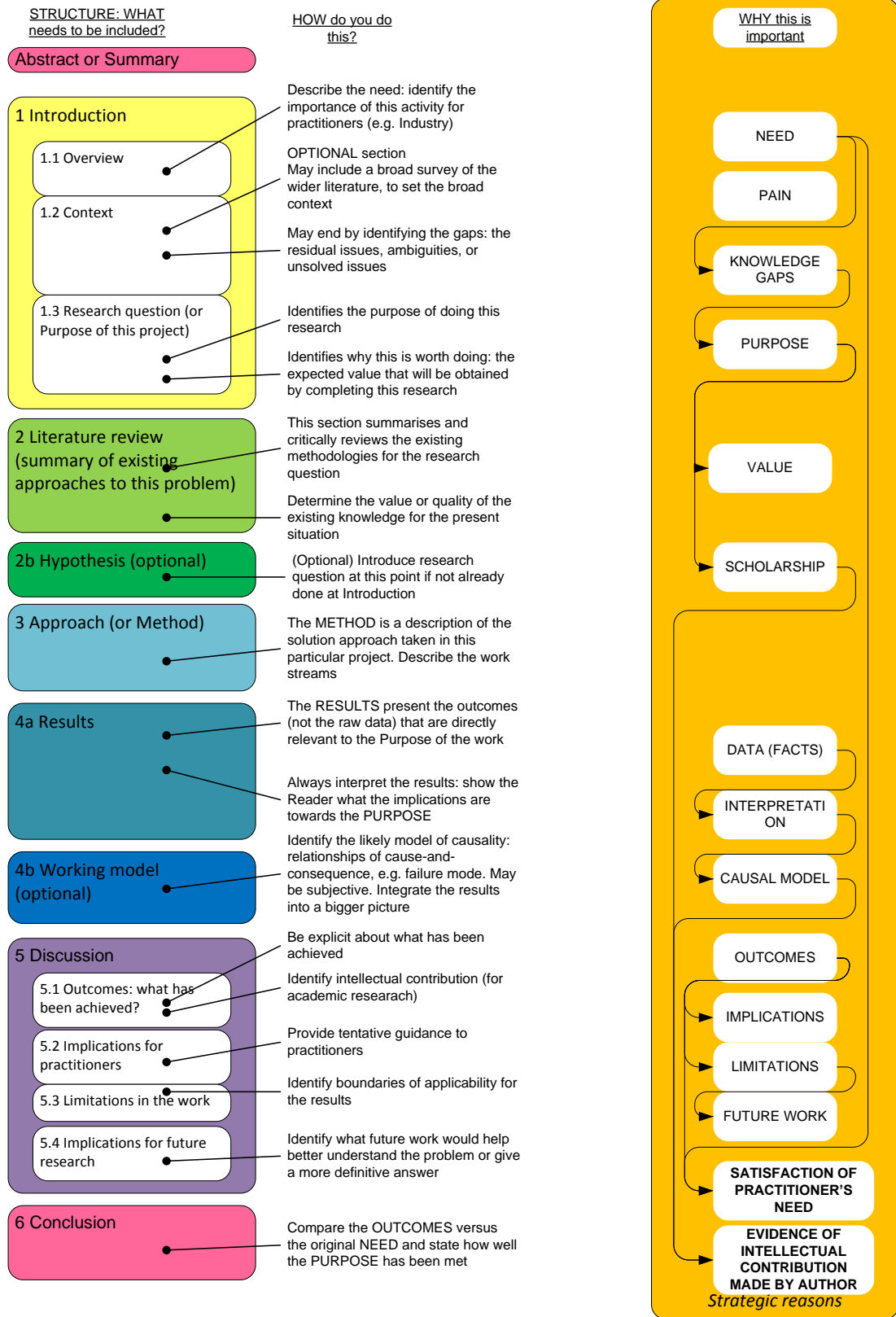


Filter the results to find relevant papers (Rs-2-2-1-4)





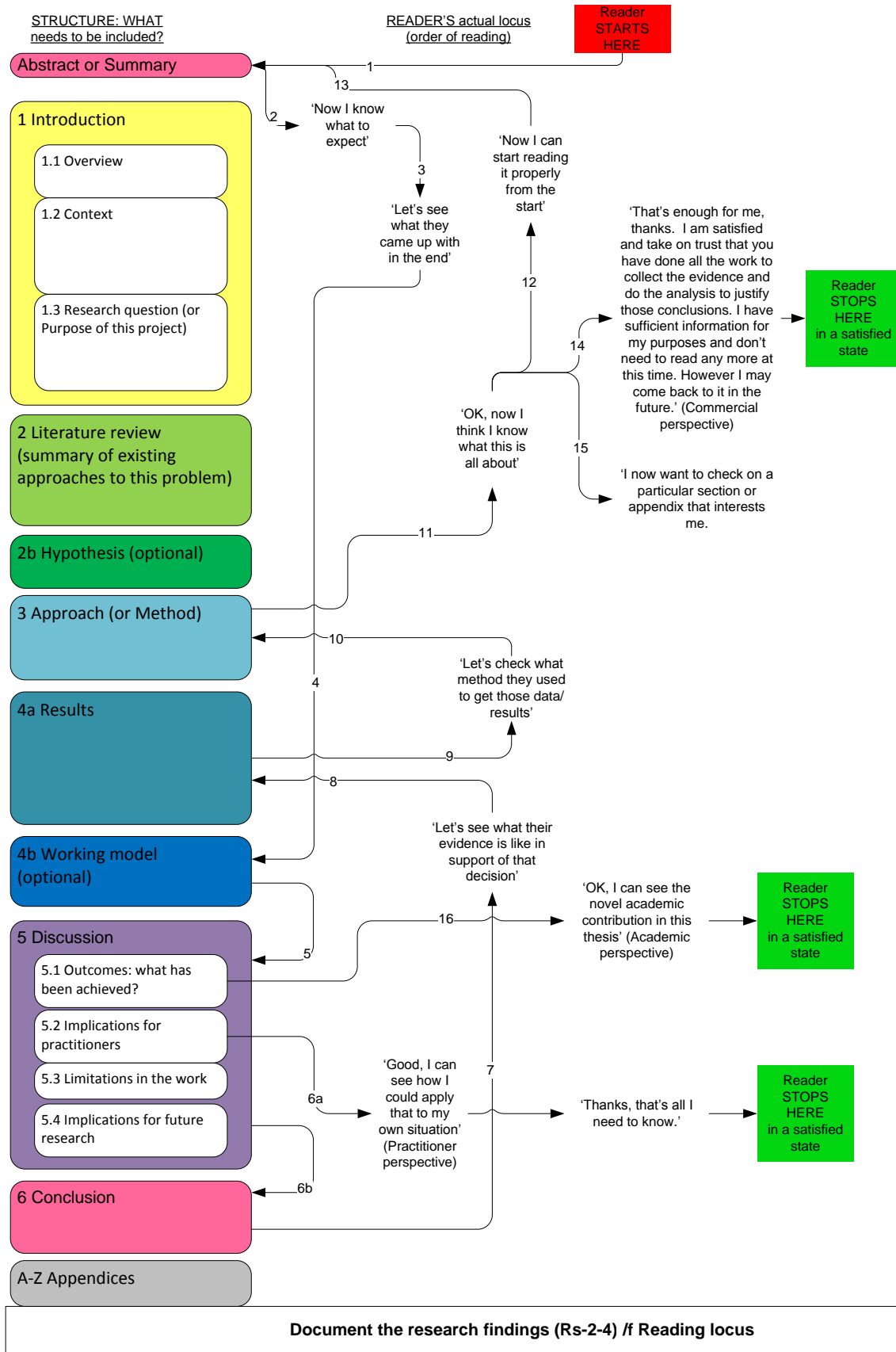
Document the research findings (Rs-2-4) /b Basic structure with example



Document the research findings (Rs-2-4) /c Strategic value

STRUCTURE: WHAT needs to be included?	HOW do you do this?	Marking Schedule	1: Deficient 3: Sufficient 5: Excellent
Abstract or Summary			<input type="checkbox"/>
1 Introduction 1.1 Overview 1.2 Context 1.3 Research question (or Purpose of this project)	Describe the need: identify the importance of this activity for practitioners (e.g. Industry) OPTIONAL section May include a broad survey of the wider literature, to set the broad context May end by identifying the gaps: the residual issues, ambiguities, or unsolved issues Identifies the purpose of doing this research Identifies why this is worth doing: the expected value that will be obtained by completing this research	1 Format: To what extent is the Presentation, grammar, spelling contributing to comprehension? 2 Context: To what extent is the (e.g. Industrial) situation-under-examination clear? 3 Focus: Of the many problems in this situation, to what extent is it clear why this particular sub-problem is being studied? 4 Completeness: To what extent are the existing methods identified? (No missing literature of significance) 5 Cognitive Weaving: To what extent has the Author woven the threads of other's work together into a bigger picture that is relevant to this Context? (More than simple independent listing of other's work).	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
2 Literature review (summary of existing approaches to this problem)	This section summarises and critically reviews the existing methodologies for the research question Determine the value or quality of the existing knowledge for the present situation	6 Scholarship: To what extent have the ambiguities and inadequacies in the existing body of knowledge been graciously identified? 7 Critical analysis: To what extent are the limitations and gaps in the existing body of knowledge identified?	<input type="checkbox"/> <input type="checkbox"/>
2b Hypothesis (optional)	(Optional) Introduce research question at this point if not already done at Introduction	8 Justification: To what extent is the rationale well-expressed for the residual research question?	<input type="checkbox"/>
3 Approach (or Method)	The METHOD is a description of the solution approach taken in this particular project. Describe the work streams	9 Value: To what extent do I as the Reader understand why it is worth solving this problem? 10 Effective communication: To what extent do I as the Reader comprehend the need and feel fully informed about the strengths and weaknesses of existing approaches to this problem?	<input type="checkbox"/> <input type="checkbox"/>
4a Results	The RESULTS present the outcomes (not the raw data) that are directly relevant to the Purpose of the work Always interpret the results: show the Reader what the implications are towards the PURPOSE	11 To what extent are the references and citations done properly?	<input type="checkbox"/> <input type="checkbox"/>
4b Working model (optional)	Identify the likely model of causality: relationships of cause-and-consequence, e.g. failure mode. May be subjective. Integrate the results into a bigger picture	12 Is the solution-approach clear; the way the problem was approached?	<input type="checkbox"/>
5 Discussion 5.1 Outcomes: what has been achieved? 5.2 Implications for practitioners 5.3 Limitations in the work 5.4 Implications for future research	Be explicit about what has been achieved Identify intellectual contribution (for academic research) Provide tentative guidance to practitioners Identify boundaries of applicability for the results Identify what future work would help better understand the problem or give a more definitive answer	13 Clarity and quality of results and any analysis with them (e.g. uses appropriate statistical methods) 14 Helps reader comprehend the meaning in the data or outcomes 15 Reader knows what to do with the work and how to apply it 16 Candid statement of boundaries of applicability 17 (If applicable) Further work that could be done to further improve the solution	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
6 Conclusion	Compare the OUTCOMES versus the original NEED and state how well the PURPOSE has been met	18 To what extent has the PURPOSE of the work been met? To what extent do these results meet the need? 19 To what extent does the abstract/summary adequately describe the work, it's contribution, and the implications?	<input type="checkbox"/> <input type="checkbox"/>

Document the research findings (Rs-2-4)/ e Assessment



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