# INNOVATIVE GRADING FOR DESIGN EXERCISES
## - A CASE STUDY FROM AEROSPACE ENGINEERING

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## ABSTRACT

**Individually grading group design exercises is a difficult thing for lecturers to carry out. This becomes even more complicated if many different lecturers are involved. One way of ensuring uniform assessment is the use of rubrics. This article relates to an innovative form of grading using rubrics in the grading of the capstone design project of the Faculty of Aerospace Engineering at Delft University of Technology. The article will address the advantages of using rubrics, the development of a rubric specific to this exercise, experiences so far as well as its reliability and conclusions on the suitability of the use of rubrics in grading group design exercises.**

**Keywords: Assessment, rubrics, group design exercises.**

## INTRODUCTION

Over the last decade the use of problem based learning and in particular project based education has increased in engineering education (de Graaff & Kolmos, 2003). This teaching format has become extremely popular in discipline of design. Design is considered as the discipline in which all other mono-disciplines are brought together in an integrated way. Project based education is a format which allows for students to proof and improve their ability in these synthesizing skills.

Teaching design in a project based education format has as added advantage that students can be taught more skills than just core engineering skills. Teaching skills such as working in teams, oral and written communication skills, ability for life-long learning as well as time and workload management skills can also be included in a natural fashion. A third advantage is that the educational situation mirrors industry practice, thus making students more prepared for the workplace.

Although in many universities across the world design education was often already carried out by having student design an object in small groups with the introduction of project based education a paradigm shift took place. Before the introduction of project based education, the assessment took place on basis of the quality of the design or the product only, and therefore often resulted in a group grade.

In the current climate of ever stringent accreditation criteria when it comes to assessment, enshrined into law, an ever increasing need for accurate and fair individual grading is becoming apparent. An example of such policies are the fact that in Denmark all work must be graded on an individual basis (Aalborg University, 2011) and that in the Netherlands and Belgium an institute must score a mark of 'sufficient' or higher on the assessment part of their accreditation review else their accreditation will be cancelled forthwith (Eerste Kamer, 2010).

Individual grading is therefore rapidly becoming the norm. Next to that an individual students will be rewarded for the work he/she gas done within the project and will not be penalized when other team members have not contributed to the work.

This paper describes the solution implemented at the Faculty of Aerospace Engineering at Delft University of Technology in the Netherlands to give individual grades in a reliable way making use of the assessment format of Rubrics (Stevens and Levi, 2005). In the paper the set up of the exercise will be discussed as well as the theory behind rubrics as a

grading method, the implementation of rubrics in the exercise, the reliability of the created rubric as a grading tool and the experiences with the use of the tool and lessons learned.

## DESIGN/SYNTHESIS EXERCISE

The curriculum of the BSc at the Faculty of Aerospace Engineering at Delft University of Technology is very design orientated and aims to recreate the design life cycle in its curriculum (Kamp, 2011). Design projects and design education are core part of the curriculum. These culminate in the third-year Design/Synthesis Exercise (DSE), which gives students a chance to apply the analysis techniques learned in their more fundamental courses.

With this design project the Bachelor curriculum is concluded. It can be considered the capstone design experience referred to by Accreditation Board for Engineering and Technology (Engineering Accreditation Commission, 2000.).

The exercise serves as final proof of competence of a BSc student, not dissimilar to an apprenticeship piece from the era of the guilds. Design topics include aircraft designs, space craft designs, design of space missions and the design of earth observation missions including the design of the necessary hardware such as for example satellites (Melkert, 2010 and earlier).

The exercise has been running for more than 10 years and has been well received in several accreditations (Faculty of Aerospace Engineering, 2002 and QANU, 2008) and in 2003 won the Ritsema – van Eck award for excellence in teamwork by both staff and students.

*LEARNING OBJECTIVES*

The exercise has the following learning objectives. At the end of the exercise the student must be able to:

- Design a multi-disciplinary (sub) system or inventive arrangement of system elements using techniques from systems engineering and taking into account societal, environmental & ethical considerations.
- Autonomously acquire additional knowledge required for obtaining the solution to the design problem posed.
- Communicate their design and its process to their peers, the aerospace engineering academic staff and informed third parties
- Function as a member of a team and be able to reflect on their performance in such a team

*SET UP*

These learning objectives are achieved by having students work in a practice-mirroring design environment (Brügemann et al., 2005). The DSE is a ten week, full time activity for groups of ten students. It takes half a semester to complete. The study load is 15 credits in the European Credit Transfer System which equates to a work load for the student of 400 hrs.

Translating this to a working environment it means that a group of students in the exercise carry out an equivalent work load of 2,5 FTE. The exercise is being organized twice a year and in total handles approximately 300 students per year.

Students work together in groups of ten, in large project rooms, each hosting 4 – 8 design teams. Each student design team is supported throughout this project by a principal tutor and two coaches from the aerospace engineering faculty, each with different aerospace fields of specialism to ensure the multi-disciplinarity of the design. The principal tutor is responsible for the design assignment. All design groups have different design assignments to work on. This makes the designs challenging for the students but also hard to compare and thus grade.

During the exercise, the whole process of designing is addressed, from the list of requirements up to the presentation of the design. Typical aspects of real design processes, such as decision making, optimization and coping with conflicting requirements are therefore encountered. Acquiring experience often means going through iterative processes, so design decisions must be continuously

reviewed to make sure that the design requirements are met. During the exercise, the educational staff reviews the students' decision processes and overall management of the project. Aspects of design methodology and design management are also reviewed.

The educational staff also provides technical assistance for aspects of the projects where the students lack sufficient background. This means that the staff is playing several roles throughout the project. One time they are the client another time they are the expert in the field and yet another time they are the teacher that grades the student. The students have to distinguish between these roles which may be confusing in the beginning.

The exercise provides the students with the experience of working in a team for an extended period of time. This means that the students must learn to co-operate, schedule and meet targets, manage the workload, and solve conflicts in a group setting.

*ASSESSMENT*

The assessment of the design work of the students and the design process is done throughout the whole duration of the exercise. Each student will receive an individual grade for the exercise. This grade is given by the principal tutor and their coaches. The grade consists of a group component (40%) reflecting on the quality of the design and the process and communication of the group as a whole as well as individual component (60%) relating to the individuals understanding of the design, the methods used and the quality of their individual contribution as well as their effort, communication skills and team working skills.

The team of coaches will meet with the students in a scheduled and a non-scheduled way. At least once per week there are planned progress meetings. Furthermore there are three formal reviews throughout the exercise (base line review, mid term review and final review). On the basis of these meetings and reviews the coaches are required to formally assess and grade the students twice throughout the exercise.

The first grade, handed out after the Mid term review, only serves as feedback to the students, the second grade is given at the end of the exercise and is the final grade. Next to that the students are required to perform a peer and self evaluation. The results of this evaluation will serve as input for the coaches in the coaching and grading process. (Andernach and Saunders-Smits, 2006 and van den Bogaard & Saunders-Smits, 2008).

In the past principal tutors and their coaches were given limited instruction with regards to grading the exercise. It was assumed that each staff member was more than qualified to judge designs. This was mainly caused by the initial small set up of the exercise (8 – 10 teams per year) run by a small group of experienced, well attuned group of lecturers.

As the number of students studying aerospace engineering slowly increased from a first year intake of 150 students per year in 1996 to more than 500 in 2011 so did the number of project groups and tutors. The need for a more uniform, easy to implement and more reliable system arose. This has led to the introduction of rubrics as an assessment tool.

## RUBRICS

Rubrics are an assessment tool for the assessing of and giving feedback on a student's performance in papers, essays, projects, presentations and other open ended assignments (Stevens and Levi, 2005). It is effectively a set of criteria and standards which are directly linked to the learning objectives. Rubrics are intended to ensure accurate, fair and universal grading. They have as an added advantage that it provides students with instant, detailed feedback and its use saves lecturers time otherwise spend on detailed grading and feedback.

The reliability of rubrics as a measurement scale is well excepted and wide spread use of them is made in the United States of America. There are many reliable websites, listed in Stevens and Levi (2005), available in which educators share their rubrics. It is for these reasons that rubrics were selected as the new assessment tool for the DSE

## RUBRICS DEVELOPED IN DSE

For the DSE a comprehensive set of rubrics were developed. They were split into two sets: one set of rubrics for the group work, resulting in the group component of the grade and a set of rubrics relating to the individual student's contribution and ability. Based on the learning objectives from the exercise a set of criteria was developed. The final list of these criteria also known as dimensions is listed in table 1. They can be distinguished in criteria for the group performance and the individual performance.

For each of these criteria a 5-point scale was developed describing the desired level for each point of the scale. As a start point a set of rubrics was used which have been developed at the United States Air Force Academy for their capstone Engineering 410/430 course, see table 2. The developed rubrics are given in table 4 in the appendix to the paper.

*IMPLEMENTATION*

It was decided in order to ensure a fair and uniform use of the rubrics that the grading meetings would from then on be chaired by one of the six members of the organizing committee, thus ensuring uniform application of the rubrics across the board. These meetings would typically last one hour.

*TRIAL RUN*

The initial set of rubrics consisted of 40 criteria for the group component of the grade and 14 criteria for the individual grades. This was road tested in the spring semester of 2010 and afterwards design iterations took place reducing the number of criteria for the group component to 30 and the number of criteria for the individual component to 12.

This was done based on the feedback given by the 10 groups of lecturers who took part in the trial. Changes included:

- merging similar criteria into one criterion,
- shifting criteria from group to individual grade,
- creating higher level criteria to avoid over-focusing on certain criteria such as the reporting criteria and doubling up by using the same criterion twice, once for the group and once for the individual.

| **Design** |
|---|
| • Originality of the solution |
| • Consistency of the design |
| • The quality of each sub design |
| • Interface management (i.e. is the input of 1 subsystem consistent with the output of a connected other subsystem) between sub designs |
| • Feasibility analysis of the final design (requirements check) |
| • Sensitivity Analysis |
| • Trade-off & Motivation |
| • Market and/or Cost Analysis |
| • Sustainability Awareness (The level to which students are aware of the impact of their design, not whether the design is sustainable!) |
| • Risk |
| • Budget management (e.g. mass, power, money) |

| **Process** |
|---|
| • Communication within the Group |
| • Use of resources (e.g. other members of staff, coaches, computer resources, facilities, use of team members, library, external contacts, museums, company visits and contacts etc.) |
| • Integrated use of systems engineering |
| • Internal quality procedure |
| • Integration of sub disciplines (i.e. the different aerospace disciplines) |
| • Show of unity during reviews |

| **Communication** |
|---|
| • Weekly meetings |
| • Loose staff and/or external contacts |
| • Dealing with feedback in meetings and reviews |
| • Coherence and completeness of report |
| • Academic reproducibility of the results |
| • Consistency of terminology and symbols |
| • Quality and use of references in reports |
| • Conclusions & recommendations in reports |
| • Representiveness during presentations |
| • Structure and coherence of the presentations |
| • Contents of presentations |
| • Coherence between presentations & reports |
| • Ability to answer staff questions |

| **Individual component** |
|---|
| • Quality of technical work done |
| • Physics basis behind the design |
| • Dealing with feedback |
| • Showing of understanding of subject matter |
| • Ability to answer staff questions |
| • Identifiable output/ job performance |
| • Attitude |
| • Initiative |
| • Management of resources |
| • Communication within group and towards staff |
| • Coherence and completeness of individual contribution to report |
| • Academic reproducibility of individual contribution to report |

*Table 1: Grading criteria*

## EXPERIENCES WITH THE USE OF RUBRICS

In November of 2010 the new grading system was formally introduced using the Rubrics. All staff and students were formally informed of the changes through meetings and course manuals.

The experiences overall were very positive. Staff members overwhelmingly indicated that they felt this system was much better, both in quality, and speed. It allowed them to be fair to each student, and gave them the feeling of being more objective. Also they found it much easier to give the students individual feedback both in terms of the content of the feedback as well as the acceptance of the feedback.

This was especially the case for the often less experienced coaches, who are typically PhDs and post-docs, for whom the DSE is often their first teaching experience whilst their own design experience is still limited. Staff members also felt that having these detailed criteria allowed them to steer the group more effectively when they go off track and to observe the students with the criteria in mind.

From a student point-of-view we have noticed a much greater acceptance of grades. In the past there would often be discussion on whether every tutor used the same criteria or applied them equally. These discussions have disappeared. Also student feel that the grades are much better motivated and feel that sufficient feedback is given.

## RELIABILITY

There was some concern that upon introduction of the new grading methods a significant difference in the height of the grades would occur. To see if this was the case the grades from the DSE run in the spring of 2009 was compared to the grades in the fall of 2010.

For this an independent t-test was carried out and it was found that the average grade in the fall of 2010 was 8.13 with an SE of 0.94 compared to 8.06 in the spring of 2009 with an SE of 0.25 with no significant difference found ($t(60.82) = -0.738$, $p > 0.05$. However the effect size $r = 0.09$ which is small so more research is needed over the next few years to see if this conclusion can become more substantive.

There was also an interest to see if the scales used (Design, Process, Communication and Individual Contribution) were reliable. In order to judge this Cronbach's alpha for each of the scales were calculated using the scores of the fall 2010 DSE. Cronbach's alpha measures the reliability of the scale.

For ability scales such as grades values of Cronbach's alpha of more than 0.7 are deemed reliable (Field, 2005). The results can be seen in table 3.

| Scale | Cronbach's alpha | N |
|---|---|---|
| Design | 0.78 (see below) | 6 |
| Process | 0.90 | 6 |
| Communication | 0.88 | 6 |
| Individual Contribution | 0.91 | 54 |

*Table 3: Cronbach's Alpha score of the Rubrics*

As can be seen from table 3 the scales are very reliable and well above the 0.7 mark. This means these scales have a good underlying construct.

There are some comments to be made to the results found. These calculations have been carried out using data from only 6 groups so more data points will need to be added later to improve the reliability calculations. A problem already occurred for the design scale as all 6 groups gave the same score for originality of the design, which leads to a zero variance for that scale item.

This means that the Cronbach's alpha for the Design scale excluded originality of design in its calculations. This would indicate that this scale item does not measure anything as it is not distinct enough. In order to be sure of this the item has been kept in for one more exercise to see if this remains the case. If so it will be deleted.

## CONCLUSIONS AND RECOMMENDATIONS

Overall the implementation of the new grading system has been very successful. Although initially it has been a lot of work, it pays itself back in its ease of use. Rubrics are an excellent tool to individually grade students who carry out design work in groups with diverse assignment topics though shared learning objectives. Once developed it is easy to instruct new lecturers in the system and the resulting grades have high acceptance amongst students.

Statistical analysis so far has found that there has been no significant change in the average grade given and that the scales used are reliable instruments of measurement, although more research is needed as the current data set is still a little small.

The authors whole-heartedly recommend the use of Rubrics for open answer design exercises, although sufficient time must be taken to develop the rubrics to the required level.

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| Job Performance | Attitude | Leadership/Initiative | Management of Resources | Communication |
|---|---|---|---|---|
| Consistently does more than required. Work is of exceptional quality. | Positive and professional attitude which favorably influences other company members. | Takes initiative to seek out work, concerned with getting the job done. Very involved in the technical project. | Uses time effectively in and out of group and works to get others to do the same. All tasks completed on or ahead of schedule. | Oral and written skills excellent. Very effective within the group and to reviewers. |
| Sometimes does more than required. Work is of high quality. A producer. | Positive attitude toward project and the team. | Readily accepts tasks, sometimes seeks more work. Gets involved in the project. | Uses time effectively in and of group. Completes all tasks on time. | Usually effective. |
| Performs all assigned tasks. Quality of work is acceptable. | Neutral attitude. | Gets involved enough to complete tasks. Does his/her share. | Wastes some time in group, but works hard when a deadline is near. Most tasks completed on time. | Generally gets the point across. Tries to improve in weak areas. |
| Performs all assigned tasks. Work must be redone or repaired to meet standards. | Negative attitude toward project and/or project. | Tends to watch others work. Gets involved only when necessary. Volunteers to help when it will look good. | Wastes most of group time. Seldom seen doing productive work. Some tasks completed late. | Skills ineffective. Makes an effort to improve. |
| Performs some assigned tasks. Work must be redone by others to meet standards. | Negative attitude which adversely affects other company members or project. | Lets others do the work; does the minimum he/she thinks is needed to get by. | Does little useful work in group or out; wastes his/her time and others. Work is constantly late. | Skills ineffective. Makes little or no effort to improve. |

*Table 2. Rubric developed for the Engineering 410/430 course at the United States Air Force Academy which served as a starting point for our Rubric Development.*

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## APPENDIX: RUBRICS

| Criterion | Poor 1pt | Marginal 2pts | Average 3pts | Good 4pts | Excellent 5pts |
|---|---|---|---|---|---|
| Originality of the solution | Solution copied from external sources, but not understood | Solution copied from external sources, but reasonably well implemented | Solution copied from external sources, and well implemented | Solution is a combination of existing solutions and some own ideas | Solution is well thought out with hardly any use of existing solutions or optimally used existing solutions |
| Consistency of the design | Inconsistencies on system level are present | The design is not consistent due to poorly designed or missing sub-systems | Sub-system design is there but misses detail to allow for consistency check | Design is consistent from top level to sub-system level | Design is consistent from top level to detailed sub-system level |
| The quality of each sub design | Sub-system design is missing | Sub-system design is not complete | All critical sub-systems have been designed but details are missing | All critical sub-systems have been designed with sufficient detail. | All sub-systems have been designed in great detail. |
| Interface management (i.e. is the input of 1 subsystem consistent with the output of a connected other subsystem) between sub designs | No interface management between sub designs. Design will not function | Poor interface management between sub designs. Design will probably not function. | Interface management between sub designs has been done, but some interfaces overlooked. Design will function most of the time | Interface management has been properly done for all sub designs. Design will work. | Interface management has been done for sub designs and sub-sub designs. |
| Feasibility analysis of the final design (requirements check) | Most top-level requirements (i.e. requirements set by the principal tutor) are not met. | Some top-level requirements (i.e. requirements set by the principal tutor) are not met. | Only top-level requirements (i.e. requirements set by the principal tutor) are met | All top level requirements (i.e. requirements set by the principal tutor) and most derived (by the student) requirements are met | All top-level and derived (by the student) requirements are met (i.e. requirements set by the principal tutor). The list with derived requirements is extensive and covers all sub systems. |
| Sensitivity Analysis | no sensitivity analysis has been performed | Only one or two off-nominal conditions have been studied to check the system's behaviour | Only a few system parameters have been varied over a limited range to study the system sensitivity | For the most important system parameters a detailed sensitivity analysis has been executed | All system parameters have been addressed in a complete sensitivity analysis. Conclusions w.r.t. robustness have been drawn. |
| Trade-off & Motivation | A single concept has been presented with no trade-off | A concept from 2-3 possible designs has been chosen, with limited motivation and/or incorrect trade-off criteria | The best concept has been chosen as the result of a limited trade-off process using limited or incorrect trade-off criteria. Slightly changing the criteria could give a different outcome. | A complete and consistent trade-off process has been done for a limited number of potential design solutions | A complete and consistent trade-off process has been done for a large number of potential design solutions |
| Market and/or Cost Analysis | no market and/or cost analysis performed | In the design the market and/or cost analysis has been touched upon slightly | A sufficient market and/or cost analysis has been performed | The market and/or cost analysis shows all the relevant steps and has been a valuable tool for the design | The market and/or cost analysis shows all the relevant steps with lots of detail and has been a valuable tool for the design throughout the whole process. |
| Sustainability Awareness (The level to which students are aware of the impact of their design on sustainability, not whether the design is sustainable!) | sustainability awareness has not been addressed | Sustainability awareness has gotten some marginal attention | Sustainability awareness has been addressed sufficiently | Sustainability awareness has been addressed well | Sustainability awareness has been addressed very well and it has been integrated in the design throughout the whole process |
| Risk | There is no risk assessment made | The topic of risk assessment has only been touched upon | A reasonable risk assessment has been made | There has been a thorough risk assessment | Risk assessment has been integrated in the design throughout the whole design process |
| Budget management (e.g. mass, power, monetary) | There is no budget management performed at all | The topic of budget management has been addressed but only marginally. The added benefit for the design has not been made clear | Sufficient care has been taken of the budget management | Budget management has been taken into account well. | Budget management has been take into account throughout the whole design process. This has resulted in a detailed budget overview. |

*Table 4a Design Rubric*

| Criterion | Poor 1pt | Marginal 2pts | Average 3pts | Good 4pts | Excellent 5pts |
|---|---|---|---|---|---|
| Communication within the Group | Communication skills ineffective. Little or no effort to improve communication procedures | Communication skills ineffective. Effort is made to improve communication procedures | Generally gets the point across. Tries to improve in weak areas. | Communication usually effective. Only minor improvements in communication procedures needed | Communication very effective. |
| Use of resources (e.g. other members of staff, coaches, computer resources, facilities, use of team members, library, external contacts, museums, company visits, company contacts etc.) | No resources have been used, or have been wrongly used | Only a few resources have been used, but not exhaustive | Most resources have been used, but not fully exploited | All resources have been used, and mostly efficiently | All resources have been fully exploited in an efficient way |
| Integrated use of systems engineering | System engineering principles are missing | System engineering principles have been used sparsely | System engineering principles have been used, but not consistently | In general, system engineering principles have been used | System engineering principles have been used at large and were fully integrated in the design process |
| Internal quality procedure | There was no internal quality procedure | An internal quality procedure was established but not adhered to | An internal quality procedure was established but not always adhered to | An internal quality procedure was established and generally adhered to | An internal quality procedure was established and adhered to and corrected where necessary |
| Integration of sub disciplines (i.e. the different aerospace disciplines) | There is no integration of the subdisciplines, all topics are stand alone topics | There is marginal integration of the subdisciplines, all topics seem to be more or less stand alone topics | the subdisciplines show a reasonable amount of integration | The subdisciplines are integrated, there is a consistent coherence in the results achieved | The subdisciplines are integrated well, there is a very consistent coherence in the results achieved |
| Show of unity during reviews | Group appears to be 10 individuals with different opinions | Group members do not always share the same views | Overall the group members present the work as a team, with some individual touches | The group members present the work as a team. | Group acts as one individual in presentation, support and understanding |

*Table 4b Process Rubric*

| Criterion | Poor 1pt | Marginal 2pts | Average 3pts | Good 4pts | Excellent 5pts |
|---|---|---|---|---|---|
| Weekly meetings | Weekly meetings are held but no agenda and/or minutes are made | Weekly meetings are held and token agenda and/or minutes are made | Weekly meetings are held and to the point agenda and/or minutes are made | Weekly meetings are held and to the point agenda and/or minutes are made which are adhered to | Weekly meetings are held and to the point agenda and/or minutes are made and action points from meetings are followed up correctly |
| Loose staff and/or external contacts | staff and/or other were never contacted outside of staff instigated meetings and should have been and/or were improperly dealt with | staff and/or external contacts were seldom contacted outside of staff instigated meetings and should have been. | staff and/or external contacts are occasionally contacted. Contact could have been better | staff and or external contact is frequent and satisfactory | staff and/or external contact is frequent and to the point |
| Dealing with feedback in meetings and reviews | Feedback is not accepted by the group at all | Feedback is accepted but ignored by the group | Feedback is accepted by the group and an attempt is made to account for it | Group shows serious interest in understanding the feedback and accounting for it. | Feedback is accepted by the group and is optimally used |
| Coherence and completeness of report | The report is a collection of individual contributions without coherence and consistency. Essential parts of the report are missing | The report is a collection of individual contributions with some coherence and consistency. Not all parts of the report are present | The report is a collection of individual contributions with reasonable coherence and consistency. Some minor parts of the report are missing | The report is complete in the process and design description of the chosen design. The report is coherent and consistent, although some individual touches can be seen. | The report is complete in the process and design description, and provides the reader with sufficient material to cross check the results and check the alternatives.The report is coherent and consistent, and appears to be written by one person. |
| Academic reproducibility of the results | The results cannot be reproduced as they are false | The results cannot be reproduced as data is missing | Most results can be reproduced. Only some data is missing | The results can be reproduced with little effort | Results are fully reproducible |
| Consistency of terminology and symbols | No consistency in terminology and symbols. List of symbols is missing. | Some consistency in terminology and symbols. Many symbols are missing from list of symbols. | Sufficient consistency in use of symbols and terminology. Most symbols are accounted for in list of symbols. | Good consistency in use of symbols and terminology. Complete list of symbols | Excellent consistency in use of terminology and symbols with complete list of symbols with clear explanations. |

| | | | | | |
|---|---|---|---|---|---|
| Quality and use of references in reports | Hardly any references given in report. References given are of poor quality | Insufficient references are given. Quality of references should be improved. | Sufficient references are given, most are of sufficient quality | Appropriate use of references of good quality | Excellent use of references of high quality |
| Conclusions & recommendations in reports | Conclusions and/or recommendations are missing | Poorly formulated conclusions and recommendations. Not based on evidence in report. | Most conclusions and recommendations are present and based on evidence from report. Some improvement needed. | All conclusions and recommendations are present and based on evidence from report. | Well formulated and argued conclusions and recommendations, based on evidence from report. |
| Representiveness during presentations | Group appears uninterested. Their appearance is untidy. Team members are contradicting each other and cannot reach consensus | Group's appearances are untidy. They try to express interest but could do better. Team members are contradicting each other but after discussion will reach consensus. | Group appearance is tidy and appear interested with room for some minor improvements. Team members are usually consistent with their answers but occasionally "slip" | Group has a unified look and shows interest. Team members give consistent answers, but do not always help each other out. | Group pays great attention during presentation and has a unified look and comes across professionally. Team members give consistent answers, and add to each other in a supportive and structured way |
| Structure and coherence of the presentations | Structure and coherence are missing | Presentation is a collection of individual presentations with not much coherence | Presentation is mostly structured, but coherence is partly missing | Presentation is structured and coherent, but "individual touches" can still be seen | Presentation is very structured and coherent, as if made and given by a single person |
| Contents of presentations | Presentation lacks detail and does not support conclusions. Irrelevant information presented | Presentation lacks detail, although information is relevant, but not sufficient to support conclusions | Presentation lacks detail, and is barely enough to support conclusions | Presentation has sufficient detail to support conclusions | Presentation has the right level of detail to support the conclusions and to understand the recommendations |
| Coherence between presentations & reports | There is no coherence between report and presentation | The coherence between report and presentation is poor and needs serious improvements. | The coherence between report and presentation is acceptable. Minor improvements needed. | The coherence between report and presentation is good | The coherence between report and presentation is excellent |
| Ability to answer staff questions | Group is not able to answer staff questions as they do not understand the subject matter | Group is barely able to answer staff questions due to poor understanding of the subject matter | Group is generally able to answer staff questions showing an average understanding of the subject matter | Group is able to answer staff questions with some detail due to a good understanding of the subject matter | Group is able to answer staff questions in detail due to an excellent understanding of the subject matter |

*Table 4c Communication Rubric*

| **Criterion** | **Poor 1pt** | **Marginal 2pts** | **Average 3pts** | **Good 4pts** | **Excellent 5pts** |
|---|---|---|---|---|---|
| Quality of technical work done | Work must be redone by others to meet standards | Work must be redone or repaired to meet standards | Quality of work is acceptable. | Work is of high quality. A producer | Work is of exceptional quality |
| Physics basis behind the design | shows no understanding of the physics behind the design question | shows only marginal understanding of the physics behind the design question | Has proven a reasonable understanding of the physics behind the design question | shows a good understanding of the physics behind the design question which has led to a good design | has understood the physics behind the design question completely. Based on this understanding has come up with new insights leading to new unexpected solutions. |
| Dealing with feedback | Feedback is not accepted by the individual at all | Feedback is accepted but ignored by the individual | Feedback is accepted by the individual and an attempt is made to account for it | individual shows serious interest in understanding the feedback and accounting for it. | Feedback is accepted by the individual and is optimally used |
| Showing of understanding of subject matter | Student does not understand subject matter | Student shows poor understanding of subject matter | Student shows average understanding of subject matter | Student shows good understanding of subject matter | Student shows excellent understanding of subject matter |
| Ability to answer staff questions | Student is not able to answer staff questions | Student is barely able to answer staff questions | Student is able to answer staff questions | Student is able to answer staff questions with some detail | Student is able to answer staff questions elaborately |
| Identifiable output/ job performance | Hardly ever performs the assigned tasks | Performs almost all of assigned tasks | Performs all assigned tasks | Sometimes does more than required. | Consistently does more than required. |
| Attitude | Negative attitude which adversely affects other company members or project. | Negative attitude toward project and/or team | neutral attitude towards project and team | Positive attitude toward project and the team | Positive and professional attitude which favorably influences other company members |

| | | | | | |
|---|---|---|---|---|---|
| Initiative | Lets others do the work; does the minimum he/she thinks is needed to get by | Tends to watch others work. Gets involved only when necessary. Volunteers to help when it will look good. | Gets involved enough to complete tasks. Does his/her share | Readily accepts tasks, sometimes seeks more work. Gets involved in the project | Takes initiative to seek out work, concerned with getting the job done. Very involved in the project. |
| Management of resources | Does little useful work in group or out; wastes his/her time and others. Work is constantly late | Wastes most of group time. Seldom seen doing productive work. Some tasks completed late. | Wastes some time in group, but works hard when a deadline is near. Most tasks completed on time. | Uses time effectively in and of group. Completes all tasks on time. | Uses time effectively in and out of group and works to get others to do the same. All tasks completed on or ahead of schedule. |
| Communication within group and towards staff | communication skills ineffective. Makes little or no effort to improve | Communication skills ineffective. Makes an effort to improve. | Generally gets the point across. Tries to improve in weak areas. | Communication usually effective. Only minor improvements needed | Communication very effective. |
| Coherence and completeness of individual contribution to report | The contribution shows no coherence at all. Essential items that should be discussed are missing. | The contribution shows marginal coherence at best. Not all items that should be discussed are present | The contribution shows moderate coherence. Only some minor items are missing | The contribution is coherent. This part of the report is complete in the process and design description of the chosen design. | The contribution is coherent and all topics addressed are placed in a logical relation with respect to each other. This part of the report is complete in the process and design description, and provides the reader with sufficient material to cross check the results and check the alternatives. |
| Academic reproducibility of individual contribution to report | The results cannot be reproduced as they are false | The results cannot be reproduced as data is missing | Most results can be reproduced. Only some data is missing | The results can be reproduced with little effort | Results are fully reproducible |

*Table 4d Individual Rubric*