Biology 2019 v1.2

IA2 high-level annotated sample response

July 2018

Student experiment (20%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

2. apply understanding of biodiversity or ecosystem dynamics to modify experimental methodologies and process primary data
3. analyse experimental evidence about biodiversity or ecosystem dynamics
4. interpret experimental evidence about biodiversity or ecosystem dynamics
5. investigate phenomena associated with biodiversity or ecosystem dynamics through an experiment
6. evaluate experimental processes and conclusions about biodiversity or ecosystem dynamics
7. communicate understandings and experimental findings, arguments and conclusions about biodiversity or ecosystem dynamics.

Note: Objective 1 is not assessed in this instrument.

Instrument-specific marking guide (ISMG)

Criterion: Research and planning

Assessment objectives

2. apply understanding of biodiversity or ecosystem dynamics to modify experimental methodologies and process primary data
5. investigate phenomena associated with biodiversity or ecosystem dynamics through an experiment

The student work has the following characteristics:	Marks
• informed application of understanding of biodiversity or ecosystem dynamics to modify experimental methodologies demonstrated by - a considered rationale for the experiment - justified modifications to the methodology • effective and efficient investigation of phenomena associated with biodiversity or ecosystem dynamics demonstrated by - a specific and relevant research question - a methodology that enables the collection of sufficient, relevant data - considered management of risks and ethical or environmental issues.	5–6
• adequate application of understanding of biodiversity or ecosystem dynamics to modify experimental methodologies demonstrated by - a reasonable rationale for the experiment - feasible modifications to the methodology • effective investigation of phenomena associated with biodiversity or ecosystem dynamics demonstrated by - a relevant research question - a methodology that enables the collection of relevant data - management of risks and ethical or environmental issues.	3–4
• rudimentary application of understanding of biodiversity or ecosystem dynamics to modify experimental methodologies demonstrated by - a vague or irrelevant rationale for the experiment - inappropriate modifications to the methodology • ineffective investigation of phenomena associated with biodiversity or ecosystem dynamics demonstrated by - an inappropriate research question - a methodology that causes the collection of insufficient and irrelevant data - inadequate management of risks and ethical or environmental issues.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis of evidence

Assessment objectives

2. apply understanding of biodiversity or ecosystem dynamics to modify experimental methodologies and process primary data
3. analyse experimental evidence about biodiversity or ecosystem dynamics
5. investigate phenomena associated with biodiversity or ecosystem dynamics through an experiment

The student work has the following characteristics:	Marks
• appropriate application of algorithms, visual and graphical representations of data about biodiversity or ecosystem dynamics demonstrated by correct and relevant processing of data • systematic and effective analysis of experimental evidence about biodiversity or ecosystem dynamics demonstrated by - thorough identification of relevant trends, patterns or relationships - thorough and appropriate identification of the uncertainty and limitations of evidence • effective and efficient investigation of phenomena associated with biodiversity or ecosystem dynamics demonstrated by the collection of sufficient and relevant raw data.	5–6
• adequate application of algorithms, visual and graphical representations of data about biodiversity or ecosystem dynamics demonstrated by basic processing of data • effective analysis of experimental evidence about biodiversity or ecosystem dynamics demonstrated by - identification of obvious trends, patterns or relationships - basic identification of uncertainty and limitations of evidence • effective investigation of phenomena associated with biodiversity or ecosystem dynamics demonstrated by the collection of relevant raw data.	3–4
• rudimentary application of algorithms, visual and graphical representations of data about biodiversity or ecosystem dynamics demonstrated by incorrect or irrelevant processing of data • ineffective analysis of experimental evidence about biodiversity or ecosystem dynamics demonstrated by - identification of incorrect or irrelevant trends, patterns or relationships - incorrect or insufficient identification of uncertainty and limitations of evidence • ineffective investigation of phenomena associated with biodiversity or ecosystem dynamics demonstrated by the collection of insufficient and irrelevant raw data.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Interpretation and evaluation

Assessment objectives

4. interpret experimental evidence about biodiversity or ecosystem dynamics
6. evaluate experimental processes and conclusions about biodiversity or ecosystem dynamics

The student work has the following characteristics:	Marks
• insightful interpretation of experimental evidence about biodiversity or ecosystem dynamics demonstrated by justified conclusion/s linked to the research question • critical evaluation of experimental processes about biodiversity or ecosystem dynamics demonstrated by - justified discussion of the reliability and validity of the experimental process - suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence.	5–6
• adequate interpretation of experimental evidence about biodiversity or ecosystem dynamics demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of experimental processes about biodiversity or ecosystem dynamics demonstrated by - reasonable description of the reliability and validity of the experimental process - suggested improvements and extensions to the experiment that are related to the analysis of evidence.	3–4
• invalid interpretation of experimental evidence about biodiversity or ecosystem dynamics demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of experimental processes about biodiversity or ecosystem dynamics demonstrated by - cursory or simplistic statements about the reliability and validity of the experimental process - ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and experimental findings, arguments and conclusions about biodiversity or ecosystem dynamics

The student work has the following characteristics:	Marks
• effective communication of understandings and experimental findings, arguments and conclusions about biodiversity or ecosystem dynamics demonstrated by - fluent and concise use of scientific language and representations - appropriate use of genre conventions - acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and experimental findings, arguments and conclusions about biodiversity or ecosystem dynamics demonstrated by - competent use of scientific language and representations - use of basic genre conventions - use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

Task

Context
You have completed the following practicals in class: • Determine species diversity of a group of organisms based on a given index (mandatory practical). • Use the process of stratified sampling to collect and analyse primary biotic and abiotic field data to classify an ecosystem (mandatory practical). • Select and appraise an ecological surveying technique to analyse species diversity between two spatially variant ecosystems of the same classification (e.g. a disturbed and undisturbed dry sclerophyll forest) (mandatory practical). • Measure the wet biomass of producer samples. • Measure the population of microorganisms in Petri dishes to observe carrying capacity.
Task
Modify (i.e. refine, extend or redirect) an experiment in order to address your own related hypothesis or question. You may use a practical performed in class, a related simulation or another practical related to Unit 3 (as negotiated with your teacher) as the basis for your methodology and research question.

Sample response

Criterion	Allocated marks	Marks awarded
Research and planning Assessment objectives 2, 5	6	5
Analysis of evidence Assessment objectives 2, 3, 5	6	6
Interpretation and evaluation Assessment objectives 4, 6	6	6
Communication Assessment objective 7	2	2
Total	**20**	**19**

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

Key: Research and planning | Analysis of evidence | Interpretation and evaluation | Communication

Note: Colour shadings show the characteristics evident in the response for each criterion.

Research and planning [3–4]	Rationale	Communication [2]
a reasonable rationale for the experiment The rationale shows sound application of scientific concepts to the research question. However, the rationale does not discuss the transfer and transformation of solar energy, or the link between producing biomass and the interaction with carbon cycle components. The use of scientific theory in the response relates to Topic 2: Ecosystem dynamics (Functioning ecosystems) of the *Biology 2019* syllabus, but is not used to support the modifications or research question.	**Rationale** Biomass is defined as the amount of living matter per unit area and can be used as a fuel to generate electricity (IUPAC 2006). With increasing concerns about fossil fuels as a finite resource, microalgae are being investigated as a potential source of renewable, biomass fuel. Their ability to rapidly sequester carbon and grow quickly makes them a potential sustainable alternative (Dismukes 2008). Chlorella is a microalgae that has a fast growth rate (relative to other microalgae), is unicellular and lives in freshwater (Mohsen 2017). It is easy to cultivate, has a high chlorophyll content and contains oil that can be made into biodiesel (Chisti 2007). Like most plants microalgae are limited in growth by the presence of sunlight and water. They also require levels of nitrogen, phosphorus and potassium for optimum growth (Wen 2014). Greywater comes from used water in a building that has not come into contact with faeces but cannot be stored for more than 24 hours (Qld Govt 2016). Instead greywater diversion devices can be installed diverting this resource into irrigation. Many laundry detergents and dishwashing powders contain phosphorus. Consequently, this consideration led to question could greywater be used to grow microalgae?	**acknowledgment of sources of information through appropriate use of referencing conventions** The use of in-text referencing fits the purpose of a scientific report.

Research and planning [5–6]

a specific and relevant research question

The research question is clearly defined. The independent variable and the dependent variable are clearly stated.

The research question is connected to the rationale and enables effective investigation of Topic 2: Ecosystem dynamics (Functioning ecosystems).

Research question

'Does treatment with household grey water increase the biomass of *Chlorella* spp. in 168-hour fixed growth period?'

Original experiment

The methodology used has been adapted from:

- SAPS, A-level set practicals – factors affecting the rates of photosynthesis http://www.saps.org.uk/secondary/teaching-resources/1354-a-level-set-practicals-factors-affecting-rates-of-photosynthesis
- BTI Curriculum Projects in Plant Biology, Algae to Energy, Teacher Manual 2015 btiscience.org/wp-content/uploads/2015/12/b.-Algae-to-Energy-Teacher-Manual-2015.pdf

The original SAPS experiment used algal balls (algae suspended in sodium alginate) with a hydrogen carbonate bioindicator to investigate rates of photosynthesis. The BTI experiment used a photobioreactor. This experiment draws from both experiments and combines the use of algal balls and photobioreactors. The control will be tap water.

Research and planning [5–6]

justified modifications to the methodology

The response gives sound reasons for how the modifications to the methodology will refine, extend or redirect the original experiment, and includes strategies for achieving these modifications.

Research and planning [5–6]

a methodology that enables the collection of sufficient, relevant data

The methodology shows careful and deliberate thought. It enables collection of adequate data so an informed conclusion to the research question can be drawn.

Three repeated measurements for each trial are planned to allow a mean to be calculated. Five variations of the independent variable are planned to allow trends and relationships to be analysed and graphs to be drawn.

Modifications to the methodology

To ensure that sufficient, relevant data was collected the original experiment was changed to increase the number of samples and measurements, as the original experiment had a small sample size. The reliability of the data collected was improved by making changes to the original methodology (see refinements) and validity of the experiment was improved by narrowing the research question to investigate one independent variable (see extensions). To minimise error all other variables were controlled as per the original experiment.

Refined by:

- using a ten-bottle photobioreactor (with a stone aerator connected to a pump), five bottles containing the control and five containing the treatment solution (see page 16 of Teacher manual) to address sources of sample bias. Each photobioreactor will have 10 algal balls. The mass of these will be measured every 24 hours (for the time period) using an electronic balance.
- five trials from each sample will be taken to ensure that there is sufficient data to calculate mean, standard error and establish a confidence interval.

Extended by:

- investigating greywater as a treatment, based on phosphorus being limiting factors of growth (Lohman 2014) to increase algal biomass (independent variable).

Research and planning [5–6]

considered management of risks and ethical or environmental issues

The response shows careful and deliberate identification and planning to handle risks and ethical or environmental issues in the experiment.

Safety and ethical considerations

- Adhere to safety considerations outlined in the original experiment.
- Review MSDS sheets in Risk Assess for using greywater, dispose of accordingly.
- Wash hands before and after using the photobioreactor to avoid contamination.

Processed data

For the analysis of this experiment the following data processing occurred:

- the mean was chosen as the most appropriate measure of central tendency
- standard deviation was calculated as a measure of central tendency and used to calculate standard error
- standard error was chosen as a measure of uncertainty and
- a confidence interval was chosen as a measure of reliability.

Table 1: Sample calculations

Calculation	*Example*
Percentage mass change	*Percentage mass change (Trial 1) = (2g – 0.5g)/0.5g x 100* *Percentage mass change (Trial 1) = 300%*
Mean percentage mass change	μ (control) = $\frac{441.67+733.33+581.82+733.33+445.45}{5}$ μ = 573 %
Standard deviation (SD) for a sample population	*Standard deviation was calculated in excel by using the STDEV function and the five mean percentage mass changes for each treatment.* *s* = 138
Standard error	*Standard error was calculated in excel by dividing the standard deviation by the square root of the sample size.* $SE_{\bar{X}} = \frac{s}{\sqrt{n}}$ $SE_{\bar{X}} = \frac{0.02}{\sqrt{5}}$ $SE_{\bar{X}} = 62$ where $SE_{\bar{X}}$ is the standard error of the mean *s* is the sample standard deviation and *n* is the size (number of scores) in a sample.
Confidence interval	*A confidence interval of 95% was calculated in excel using the CONFIDENCE.T function* $CI\ (95\%) = (0.05, s, n)$ $CI\ (95\%) = (0.05, 138, 5)$ $CI\ (95\%) = 171$ where CI is the confidence interval *s* is the sample standard deviation and *n* is the size (number of scores) in a sample.

Analysis of evidence [5–6]

correct and relevant processing of data

Raw data is manipulated accurately to provide evidence that is applicable to the research question.

Analysis of evidence [5–6]

collection of sufficient and relevant raw data

The raw data is adequate for forming a conclusion and has direct bearing upon the research question.

Communication [2]

appropriate use of genre conventions

Raw data is recorded with the associated uncertainties and expressed consistently to the correct number of significant figures.

The response uses units and symbols correctly.

Analysis of evidence [5–6]

thorough identification of relevant trends, patterns or relationships

The identification of trends, patterns or relationships is not superficial or partial. The trends, patterns or relationships are applicable to the research question.

Analysis of evidence [5–6]

thorough and appropriate identification of the uncertainty and limitations of evidence

The response suitably identifies uncertainty and limitations of the data in a way that is not superficial or partial. The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid.

Table 2: Processed data table for the effect of greywater on the growth of *Chlorella* spp. biomass

Treatment	Photobioreactor no.	*Chlorella* spp. mass (g±0.01)								Percentage change (%)
		0 h	*24 h*	*48 h*	*72 h*	*96 h*	*120 h*	*144 h*	*168 h*	
Control	1	0.12	0.15	0.20	0.25	0.40	0.65	0.65	0.68	467
	2	0.09	0.12	0.15	0.35	0.50	0.60	0.75	0.75	733
	3	0.11	0.15	0.18	0.40	0.30	0.72	0.75	0.72	555
	4	0.09	0.12	0.20	0.20	0.40	0.60	0.75	0.80	789
	5	0.11	0.15	0.18	0.31	0.40	0.70	0.70	0.70	536
	Mean	**0.10**	**0.14**	**0.18**	**0.30**	**0.40**	**0.64**	**0.73**	**0.74**	**616**
	Standard deviation	**0.01**	**0.02**	**0.02**	**0.08**	**0.07**	**0.06**	**0.04**	**0.05**	**±138**
	Standard error	**0.01**	**0.01**	**0.01**	**0.04**	**0.03**	**0.02**	**0.02**	**0.02**	**±62**
	Confidence interval (95%)									**±171**
Greywater	1	0.12	0.15	0.20	0.20	0.80	1.00	1.60	1.60	1233
	2*	0.09	0.12	0.15	0.60	0.60	0.60	0.50	0.40	344
	3	0.11	0.12	0.15	0.50	0.70	1.20	1.20	1.30	1082
	4	0.09	0.12	0.25	0.30	0.30	1.50	1.50	1.60	1678
	5	0.11	0.14	0.25	0.40	0.80	1.20	1.20	1.40	1173
	Mean	**0.11**	**0.13**	**0.21**	**0.35**	**0.65**	**1.23**	**1.38**	**1.48**	**1290**
	Standard deviation	**0.01**	**0.02**	**0.05**	**0.13**	**0.24**	**0.21**	**0.21**	**0.15**	**±265**
	Standard error	**0.01**	**0.01**	**0.02**	**0.06**	**0.11**	**0.09**	**0.09**	**0.07**	**±133**
	Confidence interval (95%)									**±285**

***Shaded area = outlier, anomalous with respect to the rest of the data. Removed during data processing.**

Interpretation: The data shows the mean percentage biomass change of the control treatment was within the range of 616 ± 62.0% whilst the greywater treatment was 1290 ± 133%. The standard error has been used as a measure of the uncertainty associated with these averages (±SE). The larger standard error of the greywater treatment data may suggest low precision during data collection or high random biological variation in the samples.

Communication [2]

fluent and concise use of scientific language and representations

The response represents data in an appropriate format to ensure that the trends, patterns and relationships can be accurately interpreted.

Analysis of evidence [5–6]

thorough identification of relevant trends, patterns or relationships

The identification of trends, patterns or relationships is not superficial or partial. The trends, patterns or relationships are applicable to the research question.

Analysis of evidence [5–6]

thorough and appropriate identification of the uncertainty and limitations of evidence

The response suitably identifies uncertainty and limitations of the data in a way that is not superficial or partial. The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid.

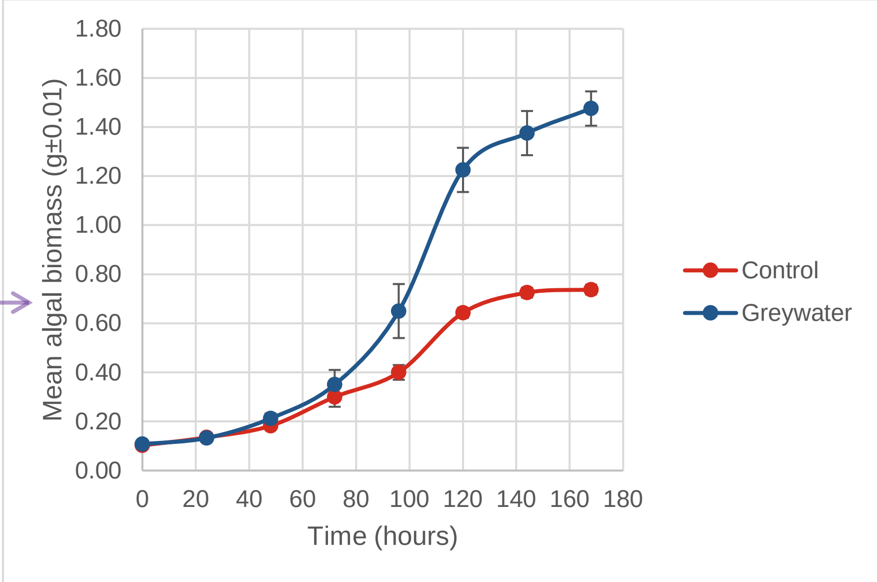
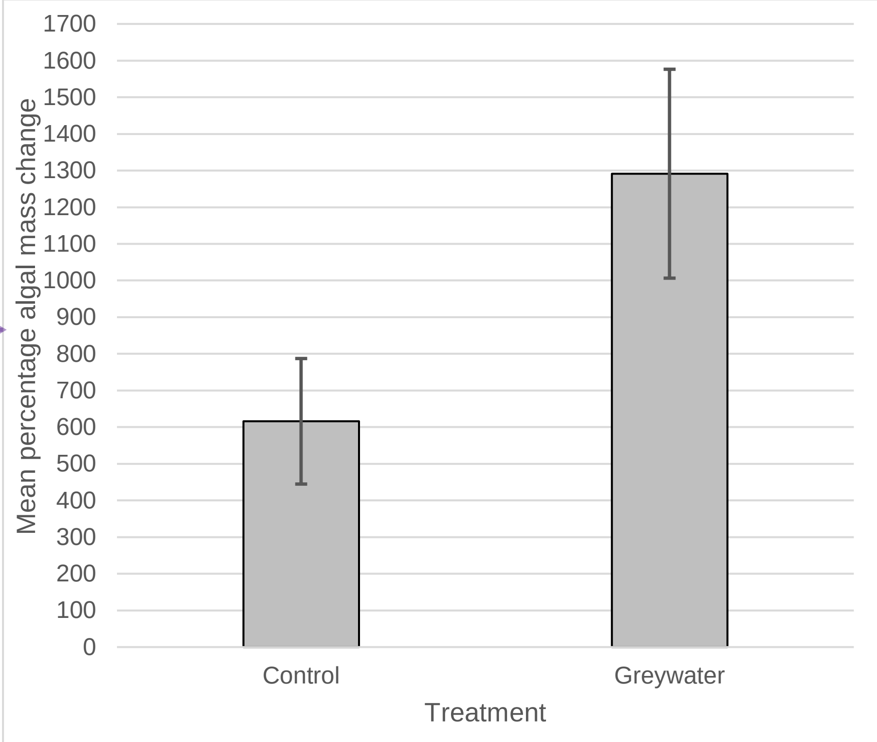


Figure 1: Mean algal biomass change over a 168-hour period for control and greywater treatment (error bars represented by standard error).

Interpretation: The literature suggests that the algal population growth should pass through four stages (lag, exponential, transitional and stationary). This data fits this model for both treatments, suggesting both samples grew in the expected pattern. The greywater data shows an increased exponential growth phase (48 – 120h) compared to the control treatment. The stationary growth phase (120 – 168h) occurs at a higher final mean biomass in the greywater data. This suggests that the greywater treatment has a positive effect on algal growth. Further statistical testing would need to be performed to confirm this relationship.

Analysis: The standard error of the data shown suggests that the data collected for the control treatment has a higher level of precision than that of the greywater treatment. Error bars are overlapping between 24 - 72 hours suggesting that the results fall within the same range for both conditions at these times. Consequently, as the error bars are not overlapping between 92 – 168 hours this suggests that the results for each treatment do not fall within the same range. This may suggest that there was no positive effect of the greywater treatment until after 92 hours.

Communication [2] **fluent and concise use of scientific language and representations** The response represents data in an appropriate format to ensure that the trends, patterns and relationships can be accurately interpreted.	 **Figure 2:** Mean percentage Chlorella sp. biomass change (over 168 hours) (error bars represented as confidence intervals).
Analysis of evidence [5–6] **thorough identification of relevant trends, patterns or relationships** The response identifies trends, patterns or relationships that are applicable to the research question.	**Interpretation:** The greywater treatment shows a 675% increase in percentage biomass compared to the control sample suggesting this treatment has a positive effect on algal growth.
Analysis of evidence [5–6] **thorough and appropriate identification of the uncertainty and limitations of evidence** The response suitably identifies uncertainty and limitations of the data in a way that is not superficial or partial. The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid.	**Analysis:** The data indicates, with 95% confidence, that the sample mean falls within the range of 616 ± 171% for the control treatment and 1290 ± 285% for the greywater. As there is no overlap in the errors bars (confidence intervals) it indicates that there is a statistical difference between the two means. Therefore, this suggests with confidence that the greywater treatment has a significant positive effect on algal biomass change. # Evaluation ## Limitations of the evidence Standard error, overlapping error bars and confidence intervals are all examples of the uncertainty and limitations observed from an analysis of the evidence. This can be explained by a lack of reliability and validity in the experimental process. The masses recorded for the algal biomasses were inconsistent (refer to Table 1, see standard deviation) hence the average percentage change is calculated from data that lacks some reliability, as indicated by the standard error. This suggests that not all variables were fully controlled. Also, the standard error of the greywater treatment data was higher than the control treatment (refer to Figure 2) which may suggest low precision in the measuring instrument or high random biological variation in the samples.

Analysis of evidence [5–6]

thorough and appropriate identification of the uncertainty and limitations of evidence

The response suitably identifies uncertainty and limitations of the data in a way that is not superficial or partial. The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid.

Interpretation and evaluation [5–6]

justified discussion of the reliability and validity of the experimental process

The response uses sound reasoning and evidence from the identification of uncertainties and limitations to support the consideration of the reliability and validity of the experimental process.

Interpretation and evaluation [5–6]

suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence

The response uses the analysis of the evidence to inform the suggested improvements and extensions to the experiment.

The response uses clear, sound reasoning to arrive at improvements and extensions that would improve the reliability and validity of the experimental process by reducing the impact of the identified random and systematic errors.

The low sample size of this experiment is a major factor in determining the length of the confidence intervals (refer to Figure 2). Consequently, the evidence is limited in its ability to be used to extrapolate the findings of the experiment to the population of *Chlorella* spp.

An outlier (for the greywater treatment) was identified. However, this was not confirmed as a valid extreme value through experimentation; consequently, the mean reported may have altered the results of the data analysis.

Sources of error

Effecting reliability

- The electronic balance used to measure the mass of *Chlorella* spp.is imprecise (±0.01g). Therefore, the electronic balance contributes to the imprecision of the data. However, the variation in the data is greater than ±0.01g; therefore, there must be other sources of imprecision.
- The samples were not randomly selected and the strain of *Chlorella* spp. was not genetically screened. Random biological variation exists within the sample. This could explain some of the remaining imprecision in the data.
- The composition of the greywater was not determined prior to conducting the experiment. Therefore, it is not known which abiotic and biotic factors are affecting the growth of the *Chlorella* spp.

Effecting validity

- The sodium alginate leads to a wet rather than dry biomass reading. Therefore, the mass of the data is overestimated. In addition, the algal biomass is determined indirectly which could lead to greater variability in the data.
- The electronic balance does not count algae cells directly. The equipment used is not the most appropriate to collect data. Therefore, this could contribute to the data being inaccurate.

Suggested improvements and extensions

Suggested improvements

Reducing the random error in the experimental process would improve its reliability. In this experiment, the reliability of the data could be improved by increasing the number of repeat readings of each sample, increasing the number of samples and running the experiment (trial) more than once to decrease standard error.

To address the imprecision in the data a random sample selection technique should be used which would reduce selection bias. This could improve both the reliability of data and validity of the experimental process and allow the results to be generalised to the population. In addition, assessing the composition of the greywater prior to conducting the experiment or use water with a known nutrient concentration would allow

	the research parameters to be refined. Instead of using an electronic balance, the accuracy of the algal biomass data could be improved by using a colorimeter to quantify the density of cells, or a hemocytometer to count algal cells directly. To reduce the systematic error introduced from the mass of the sodium alginate balls a dry biomass reading would measure the algal biomass directly. This would improve the validity of the experiment. **Suggested extensions** • **Redirect** the experiment by choosing specific chemical treatments found within the composition of the greywater. • **Extend** the experiment by investigating an optimum concentration of greywater, varying the technique of applying the greywater or using different strains of Chlorella spp. or different microalgae.
Interpretation and evaluation [5–6] justified conclusion/s linked to the research question The response uses sound reasons and evidence to support a conclusion that directly responds to the research question.	**Conclusion** In conclusion, the evidence suggests that treatment with household greywater does increase the biomass of Chlorella spp. in a 168-hour fixed growth period. However, there are significant limitations to the experimental design and further statistical analysis would be required to support this conclusion. **Word count:** 1660
Communication [2] fluent and concise use of scientific language and representations The response is easily understood, avoids unnecessary repetition and meets the required length. **Communication [2]** acknowledgment of sources of information through appropriate use of referencing conventions. The use of a referencing system fits the purpose of a scientific report.	**Reference List** Chisti, Y. 2007. Biodiesel from microalgae. Biotechnology Advances 25:294-306 Dismukes GC, et al. 2008 Aquatic phototrophs: Efficient alternatives to land-based crops for biofuels. Curr Opin Biotechnol.19:235–40. IUPAC, Compendium of Chemical Terminology, 2nd ed. (the "Gold Book") (1997). Online corrected version: (2006–) "biomass". Lohman E. et al 2015. Optimized inorganic carbon regime for enhanced growth and lipid accumulation in Chlorella vulgaris. Biotechnology for biofuels vol 8 biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/s13068-015-0265-4 Mansouri, M. 2016. Predictive modeling of biomass production by Chlorella vulgaris in a draft-tube airlift photobioreactor. Advances in Environmental Technology. 3:119-126 Plant Biology, Algae to Energy, Teacher Manual 2015 btiscience.org/wp-content/uploads/2015/12/b.-Algae-to-Energy-Teacher-Manual-2015.pdf Science & plants for schools 2017. www.saps.org.uk/secondary/teaching-resources/1354-a-level-set-practicals-factors-affecting-rates-of-photosynthesis Queensland government, Department of housing and public works. 2016. 'Greywater' www.hpw.qld.gov.au/construction/BuildingPlumbing/Plumbing/Greywater/Pages/default.aspx Wen, Z. 2014. Algae for biofuel production. www.articles.extension.org/pages/26600/algae-for-biofuel-production