

Electronic Supplementary Material

Table S1. Competence statements and indicators for the Natural Sciences options modules assessment

| Competence statements | Indicators |
|---|---|
| Systems thinking and dealing with complexity | Application of interdisciplinary approach Stakeholders needs analysis and assessment Systems analysis and conceptual modelling Scenario, projection and vision development |
| Future thinking and dealing with uncertainty | Uncertainty evaluation Current and future states analysis Creative problem-solving |
| Critical thinking, reasoning and reflection | Evidence collection, analysis and assessment Reasoning and argumentation |
| Research competence | Qualitative and quantitative data analysis Use of digital tools for data analysis and presentation |
| Strategic Thinking | Application of assessment, decision-making and management tools Strategy development and application |
| Collaboration and effective communication | Assessment of barriers and adaptation to changing conditions |
| Decision-making | Working responsibly Resolving conflict and showing empathy Communicating effectively Assessing decision criteria and balancing trade-offs |
| Self-regulation, self-awareness and management skills | Reaching consensus decision Value, worldview and perspective analysis Leadership and role management Emotion management Self-reflection and motivation |
| Knowledge and understanding of water systems and Water management | Know the pathways and processes in water systems Know and apply the framework of contaminant behaviour within water systems Describe environmental, social, economic, technical and legislative pressures in water systems Know about different water management options |
| Knowledge and understanding of resource depletion and contamination assessment and management | Describe the fundamental causes of resource depletion and contamination in environmental systems Identify the interdisciplinary nature of these challenges. Know, apply and assess the relevant policy and legislative frameworks. |
| Knowledge and understanding of pollution problems and pollution assessment and management | Know about the scientific, technical and policy aspects of the most significant current UK pollution problems Analyse pollution problems |

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| | Identify and evaluate appropriate technical and policy responses Apply pollution modelling and assessment techniques |
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Table S2. Educator Assessment rubrics:

PERFORMANCE LEVEL RUBRICS FOR ASSESSING SUSTAINABILITY COMPETENCES

SYSTEMS THINKING AND DEALING WITH COMPLEXITY

| Level 1 Below basic 0-49% | Level 2 Basic 50-59% | Level 3 Intermediate 60-69% | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|--|--|--|---|---|
| Cannot produce a conceptual model of the system, show serious misconceptions or inability to think about factors influencing the problem (political, social, economic and environmental), do not identify different stakeholders' perspectives on the issue and are unable to select intervention points to take action. | Can produce only a fragmented conceptual model of the system without showing relationships between parts, show incomplete understanding of factors influencing the problem and include only some stakeholder views, while having difficulty in identifying intervention points to take action. | Can produce an adequate conceptual model of the system and provide information on important factors influencing it and basic explanations of relationships between parts, take into account most stakeholder perspectives and identify points to intervene in the system with occasional errors. | Can think holistically about the problem and provide an effective conceptual model with comprehensive consideration of factors influencing it (such as political, economic, social, environmental), include stakeholder influence and power on the issue as well as their perspectives and are successful in identifying ways to intervene in the system (leverage points) that will have positive outcome. | Can think creatively to develop an insightful and holistic representation of the system (parts, relationships, scales), interpret the factors that affect its behaviour, consider the perspectives of all involved stakeholders and develop innovative ways to intervene in the system that integrate the previous analyses . |

FUTURE THINKING AND DEALING WITH UNCERTAINTY

| Level 1 Below basic | Level 2 Basic 50-59% | Level 3 Intermediate | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|---------------------|-------------------------|----------------------|----------------------------|---------------------------|
|---------------------|-------------------------|----------------------|----------------------------|---------------------------|

| 0-49% | | 60-69% | | |
|--|--|---|--|--|
| Do not mention any past events that may influence the issue nor craft any scenarios/projections about the future. Suggest only one option for dealing with the problem and fail to deal with lack of data, contradictions and uncertainty. | Identify past events but fail to show how they relate to the issue, develop incomplete scenarios/projections about the future and overlook important details and implications of the problem. Can only produce limited alternatives to the problem, usually spontaneous without doing adequate research. | Adequately identify past events that have influenced the issue as well as provide plausible future projections/scenarios. Reference current and future states' demands, dealing with uncertainty and implications surrounding the problem and propose adequate alternative options. | Identify past influences and future developments (scenarios, projections) regarding the issue and inclusively take into account present and future generations' needs. Generate variety of effective options paying thoughtful attention to the problem, implications of actions and tackle misconceptions and uncertainties that are commonly overlooked. | Able to creatively produce a continuum regarding the issue integrating past, present and future in a way that brings to light hidden dimensions of the problem, take into holistic consideration implications of actions and emergent system properties and propose transformative solutions that address uncertainty and ambiguity. |

DECISION MAKING

| Level 1 Below basic 0-49% | Level 2 Basic 50-59% | Level 3 Intermediate 60-69% | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|---|---|---|---|--|
| Make a decision that is not reasonable, do not consider trade-offs nor take into consideration client and | Select alternative that is biased, consider limited trade-offs, take into account only economic | Select a reasonable alternative by considering various trade-offs, take into consideration client and | Select a decision that meets criteria towards numerous trade-offs, effectively map variety of | Select consensus decision that optimises trade-offs, making sure all perspectives/worldviews are respected. Comprehensively integrate environmental, |

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| stakeholder values and show inability to incorporate different worldviews and perspectives. Report does not convey professionalism. | values of client, and show difficulty understanding different worldviews and perspectives. Report fails to communicate important challenges, approaches and solutions. | different stakeholder economic and environmental values, and can understand different worldviews and perspectives. Report adequately addresses client's needs. | economic, environmental and social values related to the issue and appreciate different worldviews and perspectives. Report communicates challenges, approaches and solutions clearly. | social and economic values of client and stakeholders. Report is clear, of high quality and conveys professionalism to the client. |
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STRATEGIC THINKING

| Level 1 Below basic 0-49% | Level 2 Basic 50-59% | Level 3 Intermediate 60-69% | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|--|---|---|---|--|
| Do not suggest actions for addressing the problem and thus cannot initiate transformation, strategy is not present, so work fails its purpose. | Suggest limited actions that cannot produce significant results and so transformation cannot be achieved. Deploy incomplete strategy and the recommendation proposed does not cover crucial aspects of the issue. | Propose actions that show understanding of the issue, the strategy is effective for dealing with some aspects of the problem and the solution is adequate but does not address important obstacles. | Propose actions that show deep insight into the problem and bring to light strategic planning aspects that are commonly overlooked such as adaptability to change and overcoming crucial obstacles. | Suggest holistic action that shows novel insight to the problem, develop highly adaptive strategies for changing conditions, addressing obstacles and barriers and the solution provided establishes a model for creative/innovative work of high quality. |

CRITICAL THINKING, REASONING AND REFLECTION

| Level 1 Below basic 0-49% | Level 2 Basic 50-59% | Level 3 Intermediate 60-69% | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|---|---|--|--|--|
| Fail to provide evidence for the collection of data/information, significantly misinterpret the information, do not identify criteria for the decision task, are not aware of own assumptions, limitations and biases and do not reflect on their work, thus judgements are weak. | Provide some evidence for collecting data/information, interpretations show significant misunderstandings, selected decision criteria are irrelevant, assumptions, limitations and biases are not clearly identified, reflection on work is poor and thus judgements are limited. | Present valid evidence for collecting data/information, produce appropriate interpretations, the criteria used to assess alternatives are adequate as well as the descriptions of thinking/methodological barriers (assumptions, biases, limitations) and reflection on work, thus judgements give adequate results. | Present relevant and accurate information on which data and interpretations were based and convey deep insight into the problem. Identify valid criteria to reach decision and explain in detail thinking/methodological barriers and how they influenced results. Insightfully reflect on work and provide valid revisions. | Combine relevant/accurate information in innovative ways to produce robust and transparent judgements. By using valid criteria to assess alternatives and methods to overcome assumptions, limitations and other barriers, their results are of high quality. Reflection on work and adjustments inspire confidence on suggested approach. |

RESEARCH COMPETENCE (analytical tools for modelling and decision-making and digital tools presenting and preparing report)

| Level 1 Below basic 0-49% | Level 2 Basic 50-59% | Level 3 Intermediate 60-69% | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|--|---|--|---|---|
| Team members were not motivated to do the work, lacked ability to manage emotions, group processes and leadership were absent and this restrained the team's ability to deliver. | Roles and tasks were not clear or agreed, team members were easily derailed, occasional leadership and external support helped the team to manage the problems. | Had clear roles, became occasionally demotivated, showed ability to manage emotions most of the times without external support and overall had adequate outcomes | Actively encouraged and motivated each other, monitored personal emotions and kept feeling motivated by exchanging feedback and overcame problems on their own. | Engaged in collaborative approach with effective leadership from the start, had high level of ownership and accountability, learnt from each other and delivered high quality work. |

SELF-REGULATION, SELF-AWARENESS AND MANAGEMENT SKILLS

| Level 1 Below basic 0-49% | Level 2 Basic 50-59% | Level 3 Intermediate 60-69% | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|---|---|---|---|---|
| Lack quantitative analysis skills and ability to use decision making and digital tools to support research methodology and communicate the work and so do not deliver the project outcomes. | Have basic quantitative analysis skills and ability to use decision making and digital tools to support research methodology, communicate work and so produce limited outcomes. | Have sufficient quantitative analysis skills and ability to use decision making and digital tools to support research methodology and communication of the work and so make a significant contribution. | Have good quantitative analysis skills and ability to use decision making and digital tools to support research methodology and communication of the work and so add value to the work. | Have advanced quantitative analysis skills and ability to use decision making and digital tools to support research methodology and communication of the work and so the work is highly successful. |

COLLABORATION AND EFFECTIVE COMMUNICATION

| Level 1 Below basic 0-49% | Level 2 Basic 50-59% | Level 3 Intermediate 60-69% | Level 4 Advanced 70-79% | Level 5 Expert 80-100% |
|--|--|---|---|--|
| Did not show shared understanding, responsibility and commitment to the task, nor attempted to resolve conflict and establish group interactions, team members did the work individually. Limited or poor ability to communicate work orally and in writing. | Had difficulty working as a group, interactions between group members were present only after prompting and conflict did not allow consensus decision on how to do the work. Basic communication oral or written. Inability to convey some important messages. | Were committed to the task most of the times, had effective communication and showed empathy toward each other, so group interactions yielded positive outcomes. Good communication skills oral or written. Ability to convey important messages, with occasional shortcomings. | Group interactions were favoured from the beginning and negotiation allowed team members to resolve conflict and reach consensus decisions. Very good communication skills both oral and written. Conveying messages effectively. | Collaboration challenges were not perceived as barriers to doing work but as opportunities for synergies and conflict was managed to create added value for the project. Excellent communication skills both oral and written. Conveying messages effectively and efficiently. |

Table S3. The student self-assessment survey

Date:

Please provide the number of your team:

Option:

Module:

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| SYSTEMS THINKING AND DEALING WITH COMPLEXITY (time scale, client's perspective, stakeholders' needs, project objectives, interdisciplinarity) | Please tick one |
| Project complexity was overwhelming, and both myself and my team were unable to cope and produce what was required for the project. | |
| Project complexity was overwhelming and had negative influence on my team, as we could only produce parts of what was required for the project. | |
| Project complexity interfered with our ability to deliver but at the end we managed to produce most of what was required for the project. | |
| Project complexity was manageable, but we could have been more creative and effective in producing what was required for the project. | |
| Project complexity was appreciated by both me and the team, and we were able to address it creatively and effectively to produce what was required for the project. | |
| | |
| FUTURE THINKING AND DEALING WITH UNCERTAINTY | Please tick one |
| I was not able to cope with the lack of data, lack of support and uncertainties associated with the project. | |
| I had limited success in coping with the lack of data, lack of support and uncertainties, but by making assumptions, asking for help and developing scenarios/projections I managed to produce parts of what was required for the project. | |
| I was able to cope with the lack of data, lack of support and uncertainties associated with the project and managed to produce most of what was required for the project. | |
| My contribution was effective in dealing with the lack of data, lack of support and uncertainties, and we delivered what was required by the project. | |
| I saw the lack of data, lack of support and uncertainties associated with the project as opportunities and so we managed to produce an integrative, creative and transformative solution that was in line with client's expectations. | |
| | |
| DECISION MAKING | Please tick one |
| We had problems doing the work, did not deliver what was required and miscommunicated to the client our approach. | |
| We did the work, did not deliver what was required and miscommunicated to the client our approach. | |
| We did the work, delivered what was required but miscommunicated to the client our approach. | |
| We did the work, delivered what was required and communicated our findings to the client very well. | |
| We delivered added value to what clients expected and engaged effectively. | |
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| CRITICAL THINKING, REASONING AND REFLECTION | | Please tick one |
| The lack of evidence, reason and reflection in our work produced a weak result. | | |
| We provided some evidence, reason and reflection but overall limited results. | | |
| The evidence, reason and reflection provided was appropriate, and produced adequate results. | | |
| Our use of evidence, reason and reflection was effective in producing what was required for the project. | | |
| Evidence, reason and reflection was of high quality and inspired confidence to the client. | | |
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| COLLABORATION | | Please tick one |
| Working in a group was a real challenge, we argued most of the time and ended up doing most work individually. | | |
| Working as a group was difficult; interactions between members were present only after prompting and conflict prevented decision from being reached. | | |
| Most of the times team members were committed to the task, showed empathy to each other and so interactions yielded some positive outcomes. | | |
| Group interactions were effective, negotiation between team members helped overcome conflict and reach consensus decisions. | | |
| Our collaboration challenges were seen as opportunities for synergies and creative work, conflict was managed appropriately to create added value for the project. | | |
| | | |
| RESEACH COMPETENCE (quantitative skills and application of decision-making tools) | | Please tick one |
| My lack of skills in quantitative analysis and problems with the application of decision-making tools limited my ability to deliver what was needed for the project. | | |
| My ability for quantitative analysis, use of decision-making tools and overall research methodology was basic and produced limited outcomes. | | |
| My skills in quantitative analysis and competence in the use of decision-making tools enabled me to have a significant contribution towards important outcomes. | | |
| My ability for quantitative analysis, use of decision-making tools and overall research approach was very good and added value to our project. | | |
| My ability for quantitative analysis, use of decision making tools and overall research methodology enhanced the rigor of our approach and contributed to the overall success of the project. | | |
| | | |
| SELF-REGULATION, SELF-AWARENESS AND MANGEMENT SKILLS | | Please tick one |
| Lack of leadership, problematic group dynamics and lack of self-regulation have restrained our ability to deliver. | | |
| My role in the team was not clear or accepted, my team-mates were easily derailed and we needed plenty of external support to cope. | | |
| My role in the team was clear, group processes were monitored but lack of leadership and motivation limited our ability to deliver. | | |

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| I felt encouraged and motivated, received and gave constructive feedback and overall our team managed to overcome difficulties on its own. | |
| Our group's collaborative approach, ownership and accountability have enabled me to deliver high quality output and learn from other team-mates. | |
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| STRATEGIC THINKING | Please tick one |
| Our team lacked a coherent strategy and was unsuccessful in adapting to project conditions and overcoming barriers. | |
| Our team had difficulty devising a strategy for addressing project needs and failed to deal with some of the project's challenges. | |
| Our team strategy was adequate, we managed to adapt and lifted some obstacles, but with great effort and pain. | |
| Our team strategy was effective, gave new insight to the problem and helped us adapt to change and overcome obstacles for the majority of the work. | |
| Our team's strategy was flexible, highly adaptive to changing conditions and creatively overcoming barriers through a process that we all enjoyed. | |

The reliability and validity of the self-assessment questionnaires has been determined in a separate study (Vasiliki Kioupi Doctoral thesis Imperial College London SPIRAL) and measures to further reduce bias have been applied. Some measures taken to reduce bias in the questionnaires were the provision of strict performance criteria through rubrics and the fact that multiple surveys were recorded for each group so every member acted as assessor of team performance (Vleuten van der, Sluijsmans, & Joosten-ten Brinke, 2017). Self-assessment questionnaires have some shortcomings, the most important being positive response bias and leniency effect (Lipnevich, MacCann, & Roberts, 2013). The results of this study show that students self-assess lower than the educators assess them, thus limiting the possibility of positive response bias or leniency. Educator rubrics have drawbacks too, some of these being that in some cases they are difficult and time consuming to use, educators may find it hard to assign a specific level to a student or coursework and they may be subject to user biases. These potential problems were addressed by testing the rubrics with the educators and improving their clarity and usability based on the comments, and by asking three independent assessors to use them to assess each piece of coursework and subsequently calculating interrater reliability using Fleiss kappa and Kendall's tau correlation coefficients. The results showed statistically significant moderate agreement among the three (~0.41).

Table S4. Feedback example given to a group of students of the WM option based on the formal assessment criteria and the educator rubrics and personalised feedback given to student regarding their presentation skills.

“A good contextual introduction of the project. Thoroughly mentions the current situation in the area and the environmental, social, economic and political systems that interact to produce it (systems thinking), but misses background/historical information on the region (future thinking). Consideration of the balance between “social, environmental and economic” aspects, values and views to develop a successful strategy (strategic thinking and decision-making) – is aligned with wider context and sustainability principles.

The use of the DPSIR analysis is a clear and informative method to display identified drivers, pressures, states, impacts and responses for the strategy (research and decision making skills). Very effective mass balance diagram with added suggestions for addressing needs that clearly conveys the complexity of the system and where solutions could be implemented (research skills and systems thinking). A good inclusion of the stakeholder analysis matrix, clearly displaying who the stakeholders are, however this is missing from the stakeholder analysis tables in the appendix. In addition, the stakeholder analysis is not integrated in the recommendations sections and thus not linked to the solutions proposed (critical thinking). An in depth Interventions section. It is clear that each intervention has been well researched with evidence of wider reading coupled with a critically analysis of each intervention based on literature (research and critical thinking skills). This ties in nicely with the recommended and viable options from leakage, smart meters to constructed wetlands and biosolids management. All strategies include phasing which is important (strategic thinking).

The MCA could have been be more targeted to the mass balance diagram and thus would have yielded more appropriate options (decision-making and critical thinking). Currently, it is targeted to stakeholders, which is a good idea, but it misses other important parameters such as financial and social barriers and environmental regulations (critical thinking). Sustainable development of the area although mentioned in the introduction should have been incorporated more in the approach you took to address the problem in terms of calculating future scenarios and their implications and clearly stating the assumptions you made to construct them (future thinking).

The report has an excellent format. The clarity of writing, which is regularly cited from a variety of references, really adds to the report. There is excellent use of figures and diagrams, which are correctly labelled (effective communication). On a very few occasions there are references missing, on p 2, (16.5.1) and p 6 (2.1.1.)”.

Personalised feedback given to a student of the same team through the report on the individual presentation: A “Very clear and confident delivery to the room, well done! Very good posture, volume and pacing, kept eye contact, tried to help team mates with difficult questions and managed to tackle the tricky ones, had a very good overview of the whole project and presentation and conveyed messages effectively (collaboration and effective communication)”.