Lesson plan:

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| **Phase** | **Contents** | **Material** |
| **1**  **45 min** | **Topic: Introduction to the context of AI and problematization**  **Purpose of the phase**   * Pupils are motivated to want to find out how an AI works. * Pupils gain initial insights into AI systems and machine learning:   + Classifiers are an example of AI systems: they can assign objects to a class.   + Training data is required for machine learning: These are examples with the appropriate label of a class.   **Core activity of the phase**   * The teacher briefly demonstrates Google Quick Draw [(](https://quickdraw.withgoogle.com/)https://quickdraw.withgoogle.com/), a ready-made AI system that can classify images.   + Work assignment: All pupils draw six objects that the AI is trying to recognize. The website is self-explanatory after opening the link. (20 min) * Important aspects for the subsequent discussion in plenary with presentation 1:   + Slide 2: Discuss how the AI works: The AI classifies objects correctly when they are drawn appropriately.   + Slides 3-4: The AI uses training data: After classification, an overview of what was or was not recognized was automatically displayed. In addition, some examples are shown that other people have painted the same object to illustrate the database on the basis of which the painted objects were classified. The technical term label is introduced here.   + Slide 5: Motivating the key questions of the lesson series: How can AI systems classify objects? What role do data and machine learning play in this? * For further background information, see document Information 1 on this phase.   Word memory: **AI, machine learning, object, class, label, feature** | Presentation 1  Information 1 |
| **2** | **Topic: Excursus on food and recommended nutrition**  If you would like a more in-depth introduction to the topic of food, you will find suggestions in the documents Information 2 and Nutri-Score.pdf. This is optional. Cooperation with biology lessons may also be an option. | Information 2  Nutri-Score.pdf |
| **3**  **45 min** | **Topic: Preparing the data: Providing data cards with labels**  **Purpose of the phase**   * A classification problem for food data is raised. A distinction should be made between "rather recommendable" and "rather not recommendable" foods. * The training data set for further use in the series of lessons is produced and agreed in plenary. * A link to the key question of the lesson series is established. The topic of these lessons is how an AI system can be created as a classifier based on data. This is worked out using the example of food data and the classification problem raised.   **Core activities of the phase**   * The teacher introduces the problem "Classifying food" and establishes a link to the previously explored classification problem. The aim is for the pupils to create a system of rules from the nutritional information, which can be used to decide whether a food is "rather recommendable" or "rather not recommendable". The following points are important here:   + Just as we saw with Quickdraw, we need a set of objects that already have suitable labels. In the example of food, these are not painted pictures, but food with data and with a label "rather recommended" or "rather not recommended". We call the collection of foods with labels: training data.   + Based on the training data, we then want to create a system ourselves that classifies these foods as accurately as possible.   + Later, we discuss how machines can produce such systems. * The teacher formulates the task for this phase: We create such examples with labels (=training data) together in order to train our AI system later.   + Pupils work in pairs on worksheet 1, on which pictures of the foods are shown. They assign labels based on their own experiences and decide which foods they think are more recommendable and which they think are less recommendable.   + When all pupils have completed AB 1, the decks of cards are distributed to the class. One deck of cards and 50 green and 50 red paper clips per pair are handed out.   + In a subsequent plenary discussion, a general consensus is reached on which foods should be given which labels. Only the blue cards in the deck are used, as these are intended for the training data. The yellow cards only become relevant later as test data.   + Each pair of pupils labels their cards accordingly with the colored paper clips.   **Didactic notes**  In several tests, a stringent procedure has proven to be sensible for consensing the card set in data with a label. Here is a suggestion:  All the cards are gone through one by one (teacher holds up card, all pupils take the same card) in order to attach the labels (paper clips) to the cards together. Procedure:   1. Each pair of pupils is given a deck of cards. The cards should always remain in the same order as they are in the box so that all pupils have the cards in the same order. 2. The plenary discusses and decides which label should be given to the first blue data card (hazelnut slices). Initially, a simple vote can be taken. If there is no clear majority, a discussion takes place. 3. If a consensus is reached, all pupils put a matching colored paper clip on the data card. If no agreement is reached after the discussion, the card can be put aside (it will be used as a new object in phase 6). 4. 2. and 3. are repeated for all blue cards.   Leading the discussion: The teacher can moderate the discussions in plenary and, if necessary, intervene in the event of gross misjudgements (e.g. cucumber as "not recommended"). The file Rumpfdatensatz\_28.csv, in which the foods that are particularly easy to categorize can be found, provides orientation. However, individual deviations from this suggestion are not a problem, i.e. the discussion does not have to be strictly guided. Many classroom trials have shown that the majority of foods are assigned by majority vote as suggested by the pupils. For further work, we recommend labeling about 30 cards (about 10 cards can be set aside). The cards from Rumpfdatensatz\_28.csv should be included for the most part in order to achieve good results in further work.  AB 1 can be used later in the lesson as a reminder of which card was labeled in which color if labels have fallen off the cards between lessons.  For further background information, see document "Information2" on this phase.  A large envelope, a transparent envelope or a shoe box is suitable for storing the cards for each group. It is worth labeling them with the names of the pupils.  If the paper clips have fallen off the cards the next time the cards are taken out, AB1 can be used as a reference to reattach the correct paper clip to a card. Therefore, excess paper clips should be kept with the cards.  Word memory: **data, example, object, label, training data** | Worksheet 1 (print in color)  Data cards + 50 red & 50 green  Paper clips |
| **4**  **45 min** | **Topic: Introducing the concept of data and data-based decision rules**  **Purpose of the phase**   * A vocabulary for talking about data using food as an example is introduced. For this purpose, we understand nutritional values as characteristics of foods. Thus, a food can be represented by a list of data (numbers as nutritional information). * Establishing a decision rule based on data is introduced in order to classify food. The following important concepts are introduced: Data split, majority decision, misclassification, representation as decision tree(-diagram). (for background information on these concepts see [here](https://www.prodabi.de/materialien/entscheidungsbaeume/))   **Core activity of the phase**   * The teacher introduces that a common vocabulary is needed for joint work and explains the terms object, feature, characteristic and label using a data card. * Pupils work on worksheet 2 on the terms. * Discuss worksheet 2 * Subsequently, the establishment of decision rules is introduced by means of presentation 2   + The teacher gives the following impulse: "Maybe you can predict quite well with just one characteristic whether the food is recommendable or not. We try out a small data set and look for the energy characteristic. To get an overview, we sort the cards by energy   + To show this, the teacher uses presentation 2 . Presentation 2 shows a mini example with 6 foods. In the example shown, the optimal case is first shown in which all labels have the same color in both partial data sets.   + Discovery: From a certain "threshold value", all cards above the threshold value are not recommended. Based on the threshold value, a "data split" is carried out (division into two groups) and the obvious decision rule is formulated   + The teacher states that this perfect separation into recommendable and not recommendable is the *objective* for a data split, but that this is not achieved by every data split.   + An example is then shown with two additional foods, where a decision rule can only be set up in such a way that some foods are also classified incorrectly. This is the normal case. This example is used to introduce the majority decision and the term misclassification. The aim is to achieve as few misclassifications as possible with a decision rule. * What was previously seen in the presentation is now deepened through an activity. *Live statistics* are carried out in plenary to test the decision rule from presentation 2 with even more data. The concepts of *data split*, *threshold value, majority decision in the two partial data sets* and *misclassification* are deepened and consolidated. Each pupil represents a food card by holding it (.e. as many cards are used as there are pupils in the class). The data split from the previous presentation is considered (energy, threshold value 260 kcal). For the exact implementation of the living statistics, see **information 3**. The teacher notes the resulting one-step decision tree on the board. * The pupils return to their seats and the number of misclassifications is determined together in plenary using the documentation on the board for the decision tree * A subsequent discussion serves as a summary of the previous phase and as an outlook for further content of the lesson series. The following points should be included in the discussion: * A single decision rule is a small decision tree with only one level. * Important contents learned so far are the steps for setting up a decision rule:   + A *data split* is based on a specific characteristic and a value   + A majority decision is made in the partial data records   + Counting misclassified foods (= number of misclassifications) * The decision tree is already quite good, as it only makes a few errors. In the next phase, even more single-level decision trees will be checked to find the best one. * Further levels of decision rules will be added later. The trees will "grow". * Homework: * Exercises on the use of threshold values in the decision tree display (worksheet 3) * Optional additional homework: Mathematical repetition <, >, ≤, ≥ characters (e.g. https://anton.app/de/lernen/mathematik-5-klasse/thema-01-natuerliche-und-ganze-zahlen/uebungen-04-zahlen-ordnen-vergleichen/)   Word memory: **object, characteristic, characteristic attribute, label, classification, threshold value, data split, number of misclassifications** | Worksheet 2  Presentation 2  Information 3  Homework: Worksheet 3 |
| **5**  **90 min** | **Topic: Creating good single-level trees**  **Purpose of the phase:**   * Setting up a decision rule with the help of data cards is practiced. The concepts of *data split*, *threshold value* and *majority decision* are explored in greater depth. * The comparison of decision rules is practiced. The concept of *misclassification* is explored in greater depth. * Pupils learn a heuristic on how to select a favorable *threshold value* for a given feature in order to set up a decision rule.   **Core activities of the phase**  Activity 1: Develop a procedure for finding good threshold values   * The first step is to introduce the sorting of data cards as an aid. By sorting in ascending order, different data splits can be tried out quickly without always having to form two piles of data cards (as in living statistics). The *ruler method* (see Information 4) can be used with sorted cards. * The ruler method is worked out in plenary based on presentation 3. In doing so, you can already give strategy tips on how to choose a *threshold value by eye* (see document Information 4). * Using worksheet 4, the ruler method is practiced in individual work in order to then apply the method in small groups with the data cards. * The results of AB4 are compared in plenary and corrected if necessary. Pupils can present and discuss their reasons. During the discussion, particular attention should be paid to the following aspects:   + What is a criterion for a "best" threshold? (number of incorrectly classified cards/misclassifications)   Activity 2: Find the best decision rule with data cards   * Pupils work in pairs, each with their own set of cards with labels. Each pair is assigned a feature by the teacher for which a decision rule is sought. Each feature should be assigned to at least one pair so that the decision rules can be compared afterwards based on all the different features.   + Task: Each pair sorts the cards according to the characteristic assigned to them, considers several threshold values (at least three) and justifies which is the best threshold value among those considered. At least three should be considered in order to practise the comparison. It is not required to consider all possible thresholds between every two cards, as this can be overwhelming for some pupils. Optionally, game plan 1 can be used to support the process. Documentation is provided on [worksheet 5](https://unterrichtsmaterial-ddi.cs.upb.de/images/4/4a/AB5_Entscheidungsregeln_Verlgeichen.docx). * Discussion: All pairs present the best decision rule they have found. The feature, threshold value and number of misclassifications are stated. The best decision rule overall is then determined in class from the features examined and noted on the board with the threshold value and the number of misclassifications   + Impulse for a joint discussion: What can a computer do faster and better than the pupils? Points are collected on the board. The following points are possible answers: A computer also looks for the best possible decision rule and takes **all** features into account.   + For each feature, the computer determines **all** meaningful threshold values (i.e. between two map values) based on the data and compares them using the number of misclassifications.   + A computer can typically perform these comparisons (and calculations) very **quickly**. * What did we (pupils) do compared to a computer?   + The class group almost completely simulated the approach of a computer because all characteristics were considered across all groups. Presumably not all possible, but many of the sensible threshold values were considered and compared.   + The computer can carry out these processes faster than a human. The class group, for , took half an hour.   **Didactic notes:**  Handling the data cards is central to this phase. In order to be able to argue with misclassifications and thus compare the quality of different threshold values, it is necessary to sort the cards in ascending order. It may be necessary for pairs to work at two tables pushed together in order to be able to sort the cards completely in ascending order according to one characteristic. This sorting work takes some time and can be challenging for some pupils, but provides a good opportunity to discuss what a computer can do faster (and more accurately) than a human.  Word memory: **data split, threshold value, majority decision, decision rule, misclassification, ruler method** | [Presentation 3](https://unterrichtsmaterial-ddi.cs.upb.de/images/6/63/Pr%C3%A4sentation3_Schwellenwert_suchen.pptx)  Information 4  Worksheet 4  Worksheet 5  Game plan (page 1 only) (optional) |
| **6**  **90** | **Topic: Creating multi-level decision trees**  **Purpose of the phase**   * It is motivated to look at multi-level decision trees, not just single-level ones, as all single-level decision trees still make mistakes. In addition, good nutrition is multifactorial, so it makes sense to use several characteristics. * The procedure for creating the second stage is explained and practiced: The procedure for the second stage is essentially the same as for the first stage, with two differences. In the second stage, only the partial data records that were created in the first stage are worked on further, and different characteristics are used than in the first stage.   **Core activity of the phase**   * The teacher motivates looking at multi-level decision trees as follows. The previous phase showed that not all foods can be correctly classified with single-level decision trees. Therefore, in this phase, based on the first rule, additional features are included to create decision rules in the second level of the decision tree, which improves the decision tree in terms of the number of misclassified foods. * As an important addition to the one-step decision tree, it is introduced that in the second step only the cards of a partial data set are worked on (either the cards in the left or right branch are worked on). This can either be discussed in plenary with the support of [presentation 4](https://unterrichtsmaterial-ddi.cs.upb.de/images/b/bd/Pr%C3%A4sentation4_Zweiter_Datensplit.pptx) or optionally illustrated by another activity in the living statistics (see **information 5** on this phase). * Using [presentation 4](https://unterrichtsmaterial-ddi.cs.upb.de/images/b/bd/Pr%C3%A4sentation4_Zweiter_Datensplit.pptx), the teacher explains the documentation of a multi-level decision tree according to [worksheet 6](https://unterrichtsmaterial-ddi.cs.upb.de/images/5/5f/AB6_Zweiter_Datensplit.docx). * Again working in pairs, the pupils work with their set of cards and create further levels of their decision tree. Each pair can choose whether to continue working with their own decision tree from the last phase or to use the one selected as the best one-step decision tree. * Next task for the pairs: Improve the tree by growing more steps. Select suitable features. Documentation is provided on worksheet 6. Game board part 2 can be used to organize the data cards, e.g. to store unused cards of a partial data set in a suitable place. See **Information 5 for** the exact use of the game plan.   + For differentiation for fast groups: Further improvements by changing the tree     - Differentiation 1: A third level of the decision tree is added. Game plan part 2 can be used for this by creating "individual data splits" by cutting up game plan part 2. A third level of the decision tree can be drawn on AB6 itself.     - Differentiation 2: Different features are tried out by pupils in the second split.   + All pairs of pupils create at least one two-stage decision tree and document it on AB6. * In the plenary session, the multi-level trees created are presented with reference to the features used, threshold values and total number of misclassifications. The decision rules are also formulated verbally. * The trees created are compared with each other based on the criterion of the number of misclassifications. All trees are scored and the best three trees (those with the lowest number of misclassifications) are highlighted. * For the next lesson, the decision trees created in this phase (AB6) are hung up in the classroom (or collected by the teacher). These will be needed again in the next lesson to apply test data to them. * Homework: All pupils fill in a blank card (AB8) for a new food at home. These new foods are classified in the next lesson using the trees created.   **Didactic notes**  It is known from several tests that pupils work at very different speeds in this phase. The aim should be for all pairs of pupils to create a two-stage decision tree and document it on AB6 with the number of misclassifications.  A typical mistake made by pupils is to continue working with all the cards in a branch, even though they are only allowed to work with the subset of cards in that branch.  Word memory: **Stages of a decision tree** | Presentation 4  Information 5  Worksheet 6  Game plan (all pages)  Homework: Worksheet 8 |
| **7**  **45 min** | **Topic: Using different decision trees to classify a new food map**  **Purpose of the phase**   * For the first time, pupils explicitly use a multi-level decision tree to classify a food. In doing so, they learn how to use the decision tree as a classifier. * Pupils apply different decision trees to the same food in order to determine that different decision trees as classifiers can make different decisions for the same food. * It is motivated to check which decision tree classifies a particularly large number of new foods correctly. Test data is introduced for this in the next phase.   **Core activity of the phase**   * Preparation: The teacher lays out (or hangs up) the trees created (as a completed sheet 6 from the previous phase) as stations together with red and green paper clips in the classroom. * In plenary, Presentation5\_Tree\_Apply is used to introduce how a decision tree can be used to classify a food item using a food map. This prepares the pupils for the next activity. * Each pupil goes from station to station with the new food (the blank card from AB 8 filled in at home). At each station, the pupils go through the respective decision tree with the card and attach the appropriate colored paper clip to the card at the end (depending on whether the decision tree classifies the food as rather recommendable or rather not recommendable). Each new food is thus given a variety of classifications. * Important aspects for the joint discussion:   + Observation: A food item may have been classified differently by different trees, which can be recognized by the different coloured paper clips on individual cards.   + Conclusion: Different decision trees can classify the same food differently.   + New goal: We want to find out which decision tree classifies food most reliably and correctly.   + Procedure: This can be found out by using test data.   Word memory: **test data, classifier** | Worksheets 6  Presentation 5 |
| **8**  **45 min** | **Topic: Systematic testing of decision trees using multiple test cards**  **Purpose of the phase**   * Pupils apply test data to their own decision tree to find out how many of the 15 test foods are misclassified. * Pupils compare different decision trees based on the number of incorrectly classified test foods. * In class, the decision tree with the lowest number of incorrectly classified foods is selected on the basis of the test data.   **Core activity of the phase**   * The yellow test cards are introduced in plenary and labeled with the help of worksheet 9 (as in phase 1 for the blue training data). * Each pair of pupils uses the test data to test their own decision tree (result from the previous lesson on AB6). To do this, each test card is taken and classified by the decision tree. For each card, note whether the classification by the decision tree corresponds to the label chosen on the card in the plenary session. * At the end, the following sentence can be added to AB6: "Using our group's decision tree, \_\_\_ foods were correctly classified from the test data and \_\_\_\_ foods were incorrectly classified." * The plenary session compares how well each tree performs with test data. The comparison criterion is the number of incorrect classifications by the decision tree. * Finally, the following aspects are discussed in plenary:   + Which are the three best decision trees in terms of the number of incorrectly classified test foods?   + The top 3 best decision trees based on the training data are compared with the top 3 best decision trees based on the test data.     - Aspect for the discussion: A decision tree is created with training data and optimized for it. If this decision tree is used for new data, it may no longer provide the best result. It is therefore important to always additionally check decision trees created based on data with test data.   **Didactic notes**  To compare the performance of a decision tree on training and test data, the proportion of incorrect classifications in the training data is normally compared with the proportion in the test data. We have simplified this here to the absolute number of incorrect classifications in order to avoid potential difficulties for students when comparing decimal numbers. | Test cards  Worksheet 9  Worksheet 6 (completed from previous lesson) |
| **9**  **90 min** | **Topic: Automatic creation of decision trees with the computer and reflection on possible applications and limitations**  **Purpose of the phase**   * Pupils work out how a computer proceeds systematically when selecting threshold values. To do this, they draw on their own experience in creating decision trees. * Pupils create a decision tree, in the true sense of machine learning, automatically with the help of a computer and a digital learning environment. * Pupils reflect on the possible uses and limitations of their own decision trees.   **Core activity of the phase**   * In the plenary session, the group revisits what was noted in an earlier phase (end of phase 4) about how a computer can automatically create a decision tree. The following points are important for this:   + A computer first searches for the best one-step decision rule, taking all features into account.   + For each feature, the computer determines all meaningful threshold values (i.e. between two map values) based on the data and compares them using the number of misclassifications.   + The same procedure is then repeated in the second (third, fourth, ...) stage so that the tree gradually builds up.   + A computer can typically perform these comparisons (and calculations) very quickly, so that we are shown a multi-level decision tree within seconds. A human would take much longer. * It also briefly discusses what a person has to contribute to this process:   + Objects must be given a suitable label by a human before the computer can work with them.   + The human must give the algorithm a few "instructions", such the maximum depth of the tree (= number of levels of the tree). * After this rough repetition, the pupils work out in detail how a computer tests all sensible threshold values for a characteristic and given data and makes a decision based on this. This is done on [worksheet 10](https://unterrichtsmaterial-ddi.cs.upb.de/images/d/dd/AB10_Systematik.docx) and discussed in plenary. * After learning how a computer works, the pupils work in a digital learning environment to have decision trees created automatically by a computer. In preparation, they go through various steps that they had previously carried out manually with the data cards (selecting labels, sorting, creating decision rules manually). Further information on using the learning environment can be found in the document **Information 8.1.** * In the plenary, two important aspects are discussed in turn (more detailed suggestions in **Information 8.2**)   + Comparison of the decision tree creation process manually with data cards and automatically with the computer   + Reflection on the limits and possible applications of the self-created decision trees with regard to a healthy diet | Worksheet 10  Information 8.1  Learning environment  <https://go.upb.de/auto-baum>  Computer  Information 8.2 |
| **Evaluation**  (1/2 hour) | **Request for evaluation**  At the end of the lesson series, please give the students the evaluation (feedback) with the note that this is an anonymous feedback to the "inventors" of the lesson series. The "inventors" are very interested in finding out how the students liked the series.  A survey on the evaluation can be found digitized on a server of the University of Paderborn: [https:](https://go.upb.de/ev-lebensmittel)  Thank you very much for this! | Online survey  <https://go.upb.de/ev-lebensmittel> |